Objects, boundaries and joint work

The role of geographic information systems in the formulation and enforcement of deforestation control policies in Amazonia

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List of Acronyms

APP	Permanent Protection Areas are the riparian forests and other delicate areas that must be preserved for hydrological or geological reasons in line with the Forestry Code.
DETER	The Deforestation Detection in Real Time is the GIS-based monitoring system developed by INPE in 2004 that detects new deforestation every 15 days.
IBAMA	The Brazilian Institute of the Environment and Renewable Natural Resources is the federal environmental agency that executes the national policy set by the Ministry of the Environment.
INPE	The National Institute for Space Research is responsible for developing most GIS-based monitoring systems in the Amazon.
PRODES	The Program to Calculate Deforestation in the Amazon is a GIS-based monitoring system developed by INPE in 1989 that detects deforestation on a yearly basis.
RL	Legal Reserve is the percentage of private properties which must be preserved in order to comply with the Forestry Code.
SEMA	The State Secretary of the Environment of Mato Grosso is the state-level environmental agency responsible for enforcing the law in that state.
SLAPR	The Environmental Licensing System for Rural Properties is a GIS-based monitoring and registry system developed by SEMA in 1999.
SAD	The System of Deforestation Alerts is a GIS-based monitoring system created in 2006 by IMAZON, an environmental non-governmental organization.

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Abstract

Over the last decade, the use of geographic information system (GIS) technology has been increasingly depicted by scholars and policy-makers as being able to reduce or even stop deforestation in the Brazilian Amazon. Simultaneously, this technology was introduced into a growing number of governmental and non-governmental organizations as a policy-making and law enforcement tool. However, despite the growing importance of GIS the literature lacks studies that empirically examine the actual role of this technology in the region. In the light of the above omissions, the aim of this thesis is to explore the role of GIS in facilitating or hindering the joint work practices of the different groups which are involved in the formulation and enforcement of the deforestation control policy in the Amazon.

This study was conducted through a yearlong fieldwork in Brazil during which time historical documents were collected, and interviews as well as work observations with scientists, politicians, senior officials, local managers, bureaucrats and forest rangers (among other groups) were made. The empirical material was mainly analyzed through the concepts of objectification and boundary objects. Specifically, GIS has been conceptualized as a boundary object which, in particular circumstances, is able to offer common ground to facilitate different forms of joint work (i.e. coordination, cooperation and collaboration) across occupational, spatial and political boundaries. From this analysis, three major conclusions emerged. Firstly, the establishment of GIS as a boundary object over the last decades can be explained by considering three interrelated dynamics: a) the political flexibility that enabled GIS to be tailored to suit political and work needs - which varied across historical and organizational contexts; b) the process of negotiation surrounding GIS that allowed different groups to reach compromises and build trust in the technology; and c) the epistemological affinity between the modernist values embedded in GIS and the historical roots of the Brazilian government.

Secondly, the use of GIS as a boundary object has been central for the emergence of new forms of joint work across boundaries. Specifically, the process of objectification related to the functioning of GIS as a boundary object facilitated coordination and

cooperation in three ways: a) the creation of objectifications on different scales (e.g. from broad policy documents to specific fines) while keeping a single identity allowed different groups to overcome occupational boundaries when coordinating each other's work; b) the objectification of location references into absolute geographic coordinates enabled the outcome of the work of different groups to travel long distances while still being decipherable, thereby overcoming the spatial boundaries involved in coordination and cooperation; and c) the objectification promoted by GIS allowed rangers and bureaucrats to erase the traces of the subjectivity of their own work and thereby to create legal documents that are deemed sufficiently trustworthy to transcend political boundaries.

Thirdly, the over-reliance of GIS and the process of objectification also had long-term negative effects and contributed to 'boundary-blinding', namely, the inability of certain groups to understand the social reality and the work done across boundaries. In particular, GIS contributed to: a) the blinding of practices by preventing senior officials and scientists from appreciating the complex challenges involved in enforcing the law on the ground; b) the blinding of the outcomes of the practices and policies relating to the environmental protection of the Amazon, so that senior officials cannot understand the implications of abstract indicators and deforestation rates; and c) the blinding of the motives behind the use of GIS so that the introduction of this technology is believed to always reduce deforestation regardless of the political agenda of those using this technology. As a result of this, boundary-blinding is creating tensions and contradictions within the government that could ultimately undermine the very environmental protection practices that GIS was supposed to support.

These three points taken together suggest that the Brazilian government should embrace more engaged forms of joint work. In particular, the government should attempt to move from instrumental forms of coordination and cooperation to forms of collaboration involving knowledge sharing and learning. In this way, the government would be able to deal with the boundary-blinding related to the use of GIS while benefiting from the ability of this technology to overcome spatial, occupational and political boundaries.

Declaration

I declare that the work presented in this thesis is my own and has not been submitted in this or any other form for a research degree at this or any other institution of higher education. Aspects of the present work have been published during the course of its completion. The full references are as follows:

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Chapter 1: Introduction

1.1 Introduction

The Amazon rainforest, also known as the Amazon jungle and Amazonia, is a global symbol spanning cultural and geographical boundaries. Since the first Europeans set foot in the region in the 16th century, the region has been known as the 'El Dorado', 'Green Hell', and even as the 'Paradise on Earth' where 'noble savages' and miraculous plants capable of curing all illnesses can be found among its lush vegetation (Gondim, 2007; Slater, 2002). With the emergence of modern environmentalism over the last few decades, the image of the Amazon has gained yet another layer. Biologists have recognized that human action in the region may lead to the extinction of some species, generating in turn a domino effect that could interfere with the ecological balance of the planet (Lovejoy, 1980; Paine, 1969). A growing number of studies have also linked the process of deforestation in the Amazon to greenhouse gas emissions and climate changes on a global level (Matthews et al., 1971; Schroeder et al., 1995). According to different estimates the greenhouse emissions from deforestation in the Brazilian Amazon is responsible for up to 5% of man-made greenhouse emissions at global level, this being twice the amount generated by air transportation (Fearnside, 1997; IPCC, 2007; Schroeder et al., 1995). As a result, the environmental preservation of the Amazon rainforest is widely regarded as one of the main challenges facing our generation (Hecht et al., 1989; Kintisch, 2007; Stern, 2007; Wallace, 2007).

Over the last decade, a growing body of literature has proposed that geographic information systems (GIS) would be useful not only as research tools but also as the basis for more effective deforestation control policies in the Amazon (Câmara et al., 2009; Fearnside, 2003: 343). In the meantime, GIS technology has been rapidly diffused across the Brazilian government, and today it is used not only in policy-making but also in law enforcement practices at the heart of the rainforest. However, despite the growing enthusiasm surrounding GIS, the current literature offers very little empirical evidence of the actual role of GIS in the environmental protection of

the Amazon and the implications stemming from the current emphasis on this technology.

On the basis of these omissions, the aim of this thesis is to explore the role of GIS from the point of view of how the different groups work together in the formulation and enforcement of the deforestation control policy in the Amazon. To this end, fieldwork was carried out in Brazil for the period of one year during which time historical documents were collected and interviews and work observations were conducted with scientists, politicians, senior officials, local managers, bureaucrats, forest rangers, among other groups. The empirical material was mainly analyzed through the concepts of objectification (i.e. the transformation of complex entities into abstract representations) and boundary objects (i.e. artifacts and concepts that have at the same time a tailored and a shared use across groups). Through these and other concepts the study specifically explores the historical process that led to the establishment of GIS over the last four decades and the ways in which GIS currently facilitate or hinder multi-disciplinary and geographically distributed joint work practices in the region. From this analysis, the thesis also makes concrete suggestions for the Brazilian government concerning how it could improve its current deforestation control policies and practices in the Amazon.

The remainder of the chapter is organized as follows. The next section provides the background of the case study by briefly introducing the content of the Brazilian environmental policy in the Amazon and the role of GIS in it. Based on this explanation, Section 1.3 lays out and justifies the focus of this thesis and exposes the limitations of the current literature concerning the Amazon. In particular, Subsection 1.3.1 outlines the theoretical concepts and methodological stance that inform the thesis. Following this, Subsection 1.3.2 defines the time periods, geographical areas, organizational contexts, practices and technologies that form the focus of this study. Finally, Section 1.4 outlines the structure of the remainder of the thesis.

1.2 The Brazilian environmental policy in the Amazon

The Brazilian portion of the Amazon basin is contained within the ‘Legal Amazon’, a geopolitical region that covers about half the country’s territory. This region is composed of 9 states: two in the center-west portion of the country, one in the north-east and the remaining six in the north. In addition to the rainforest biome, the region

also contains portions of *cerrado* (i.e. wooded savannah) and *pantanal* (i.e. wetlands) in the south. Prior to the 1970s, the region was largely inhabited and pristine. Over the last four decades, however, a process of large-scale deforestation in the eastern and southern portions of the Amazon was initiated which since then has been advancing towards the still preserved north-western portion of the rainforest. The line that indicates this deforestation frontier is commonly known as the 'deforestation arc' due to its curved shape (see Figure 1).

Figure 1 Political map of Brazil highlighting the legal Amazon and the deforestation arc

The Brazilian government is a very complex organization. Breaking with a long centralization tradition that dates back to the colonial period the national constitution of 1988 aimed to distribute the government's responsibilities equally at three levels: the municipalities, the states and the federal government. Here, each sphere has the independence to create its own laws and to manage its own resources as long as it does not go against a disposition from a higher sphere. Today the country has 5,564 municipalities, 26 states and one federal district which hosts the capital city, Brasília.

In line with the current constitution, the national policy for the environment is organized in three levels. At the federal level, the Ministry of the Environment (MMA) is responsible for formulating norms and coordinating the environmental policy nationally. Moreover, following the creation of the Brazilian Institute for the

Environment and Renewable Resources (IBAMA) in 1989, this agency has been responsible for enforcing the environmental policy set by the ministry and the national congress. At a lower level, the state-level agencies for the environment are responsible for the control of activities capable of provoking environmental degradation at state-level. Finally, at the municipal level, the local environmental agencies are responsible for the law enforcement and control of low impact activities within their jurisdiction (IBAMA, 2006). While the environmental policy prescribes that all environmental issues should be solved by the most local agency (i.e. at state or municipal levels), in practice IBAMA is still very active agency throughout most of the country.

The Brazilian environmental policy is very extensive. It regulates issues ranging from fishing to the disposal of chemicals, and demand environmental agencies to carry out activities ranging from education to the licensing of roads and industrial plants. The most relevant legislation for the environmental protection of the Amazon is the Forestry Code of 1965 with later changes and addenda. The current environmental law considers that land conversion from forest to agricultural land (i.e. deforestation) is a source of environmental damage, and therefore landowners must obtain authorization to work upon their own land. In order to control the extension of damage to the native vegetation, the Forestry Code institutes strict limits to deforestation. This code states, among other points, that all rural properties in the different types of biome in Brazil must preserve the areas near the springs and the margin of the rivers as areas of permanent reserve (APA) and create legal reserves (RL) with a size that varies according to the type of the original vegetation. In the Amazon rainforest the legal reserves must cover at least 80% of the total area, leaving less than 20% to productive activities such as ranching and growing crops. One of the main duties of IBAMA and the state-level environmental agencies in the Amazon is to check the compliance of local farmers with this law, and when necessary, to issue fines and other forms of punishment. This is a very complex activity involving a long chain of command starting with the creation of broad policies at national level, down to the coordination missions and the issuing of individual fines and licenses.

In addition, the Brazilian Institute for Space Research (INPE) located in São José dos Campos (near São Paulo), play an important role in policy-making and law enforcement in the Amazon. Even though INPE is a research institute under the

Ministry of Science and Technology with no explicit environmental duties, the different GIS-based monitoring systems which it developed have provided the main data sources about deforestation in the last decades. In short, GIS can be defined as computer-based information systems specializing in the detection, storage, analysis and diffusion of data concerning spatial phenomena (Maguire, 1991). In the case of the Amazon, the main attribute being detected and analyzed is the conversion of forest to other land-uses (i.e. pasture, crops, timber production) through clearings, fires and selective logging. This is detected according to the images from sensors on board the various orbital satellites of NASA (the North American civil space agency) and INPE. After receiving the satellite images, teams of scientists interpret and transform them into georeferenced data about the Amazon (see Figure 2).

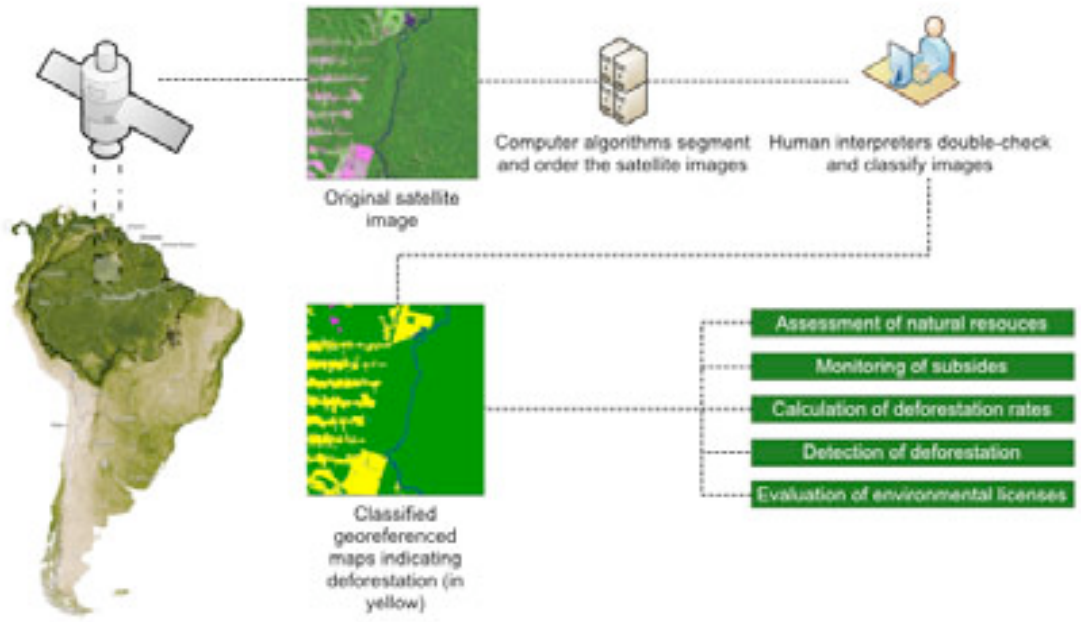

Figure 2 Workflow of the GIS in the Amazon and the past and current role of these systems within the Brazilian government

As will be described more in detail in the following chapters, the Brazilian government has been using GIS for a wide variety of roles. In particular, PRODES (the program for the calculation of deforestation) has provided yearly deforestation rates which have guided the policies towards the region since 1989, while DETER (deforestation detection in real-time), which was created in 2004, has been extensively used by IBAMA and state-level environmental agencies to enforce the Forestry Code. GIS technology has also been considered increasingly important for the state-level agencies of the Amazon. In particular, SEMA, the agency from Mato

Grosso, has invested considerable resources in the development of SLAPR (Environmental Licensing System for Rural Properties) and other proprietary GIS for the licensing of local farms. In this way, the use of GIS has become diffused not only in policy-making but also in law enforcement practices in the region.

1.3 Research focus

Many studies in the literature have shed light on the role of non-governmental organizations (NGOs) (Price, 1994; Viola, 1987; Zhouri, 2004), multi-lateral banks (Gwin, 1994; Keck et al., 1998), grass-roots' movements (Gonçalves, 2005; Hecht, 1989; Hecht et al., 1989; Moran, 1996) and diplomats, politicians, and technocrats (Guimarães, 1991; Kolk, 1998; Viola, 1998) in shaping governmental policies towards the Amazon. However, the role of the Brazilian environmental agencies, one of the most active governmental organizations in the Amazon, is treated only superficially, and often with a derogatory tone. For example, a special report about the Brazilian Amazon published in the National Geographic depicts the region as a 'Wild West frontier of guns, chain saws, and bulldozers' and affirmed that 'government agents are often corrupt and ineffective' (Wallace, 2007). Following the lead of journalist accounts, the current literature tends to either ignore these agencies or depict them as inherently corrupt and inefficient (e.g. Brito et al., 2006; Chomitz, 2007; de Moura, 2006).

Some academic studies go a little further, providing descriptions of the historical trajectory and the broad political struggles faced by the environmental agencies in the Amazon (Azevedo, 2009; Guimarães, 1991; Mello, 2006). But even these more attentive descriptions have the tendency to make a distinction between the environmental policy (i.e. the law and other legal texts) and the way these agencies operate, dealing only superficially with the later. In particular, the academic literature often describes the environmental policy as 'one of the most advanced in the world' on the one hand, placing the blame of environmental issues such as deforestation on the lack of capability of the environmental agencies to keep up with their obligations (Drummond, 1999: 145). In addition to this, many studies emphasize that the environmental agencies are old-fashioned and stubborn for insisting on command-and-control strategies rather than market-based (e.g. carbon credits) or institutional (e.g. with improved definitions of land rights) mechanisms for deforestation control

(Alencar et al., 2004; Campari, 2005; de Oliveira, 2008; Fearnside, 2008; Laurance et al., 2001). Finally, some studies blame the government as a whole and the environmental agencies specifically for not having the 'political will' to enforce environmental policy as they should (Chomitz et al., 2005; Keck, 2001; Nepstad et al., 2009).

However, while many authors are keen to criticize the work of the Brazilian environmental agencies, to the best of my knowledge no study has attempted to observe their work practices in detail or to identify the challenges involved in protecting the rainforest. That is to say, the literature on the Amazon has not so far explored how senior officials and scientists in Brasília and São José dos Campos, and forest rangers, bureaucrats and other lower ranking officials in the Amazon, actually work together in order to enforce the environmental policy. This neglect is even more pronounced in relation to the role of GIS technology in the environmental protection of the Amazon. As the following chapters will show, many scientists and senior officials use deterministic arguments in relation to the role of GIS in the public sector. For instance, GIS is often depicted as a 'solution' that invariably contributes to reduce deforestation and promote sustainable development in the region (Fearnside, 2003; Fonseca et al., 2009; Fuller, 2006). Moreover, different governmental officials have suggested that the reduction of 72% in yearly deforestation between 2004 and 2009 was mainly due to the efficiency of GIS technology in detecting deforestation in real-time and allowing the control at a distance of farmers in the region (Brasil, 2009a, 2009b; SEMA, 2009).

While the notion that technology can bring determinate effects has been heavily criticized in other empirical contexts (e.g. Brown et al., 2000; Pinch et al., 1984; Walsham, 1993) very few studies have considered this in relation to the Amazon. Furthermore, the studies that scrutinize the environmental claims of GIS tend to rely almost exclusively on quantitative GIS-based data, and largely ignore the reality on the ground. These studies include, for instance, the suggestion that the use of GIS in Mato Grosso is losing its efficiency for reducing deforestation (Lima et al., 2005a), the insinuation of a link between the ineffectiveness of GIS in Mato Grosso and its political context (Azevedo, 2009), and the argument that the reductions in deforestation were caused mainly by the downturn in the global economy and the creation of new environmental protection areas, and not by the role of GIS in the

region (Aggege et al., 2009; Soares-Filho et al., 2010). However, while these and other authors often make strong assertions about how the government should work in order to ensure the preservation of the Amazon, so far very few studies have attempted to make a more in-depth examination and base their suggestions on observations about the work practices of the groups working in the region.

The neglect mentioned above constitutes more than a gap in the academic literature. Even though the reductions in deforestation in recent years have eased concerns about the Amazon, the increase of 180% in the deforestation detected between November and December 2010 (in relation to 2009) suggests the existence of a growing trend in the coming years (INPE, 2011). However, the lack of understanding as regards the practices involved in controlling deforestation in the Amazon makes it all the more difficult for researchers from different areas to make sensible suggestions on how the government could tackle this emerging issue. This suggests that a better understanding of the role of GIS in the Amazon is not only desirable from an academic point of view but also important in order to ensure the long-term preservation of the rainforest and to tackle climate change.

1.3.1 Research approach

Bearing in mind the omissions in the current literature, this thesis aims to explore the historical and current role of GIS as regards the way in which different groups work together in order to control deforestation in the Amazon. For this purpose, the thesis draws upon three partially overlapping bodies of literature in the social sciences. The first body concerns the study of GIS implementations. In particular, this line of research explores the relationship between organizational and cultural dynamics and the establishment of GIS technology in different social contexts (e.g. Barrett et al., 2001; Georgiadou et al., 2005; Walsham et al., 1999). Based on this literature the study sets out to obtain a grasp on the peculiarities of GIS technology and establish what is involved in its diffusion in developing contexts such as Brazil.

The second body concerns the study of the process of objectification in terms of the use of information technology in general and GIS specifically. In brief, objectification refers to the transformation of living subjects and complex social phenomena into static and simplified objects, such as GIS data, legal documents and job descriptions (e.g. Brown et al., 1991; Kallinikos, 1995; Pickles, 2004; Star et al., 1999). The

intention is therefore that the literature should provide a starting point from which to understand how the objectification promoted by GIS pertains to the ways different groups in the Amazon relate to each other and how they engage with their work.

The third body of literature that informs this study focuses on the dynamics of joint work practices and the role of artifacts in them. This literature provides concepts that differentiate between different forms of joint work (i.e. coercion, coordination, cooperation and collaboration) which are useful to understand the types of social interaction taking place in the Amazon (e.g. Adler et al., 2006; Collins et al., 2007; Engestrom et al., 1997; Heckscher, 2007; Powell, 1990). Furthermore, the literature also explores the challenges involved in working together in the private and public organizations and provides some indication of how these challenges may be overcome (e.g. Lipsky, 1980; Spinuzzi, 2008; Tsoukas, 1996). Within this literature, the notion of boundary objects initially proposed by Star and Griesemer (1989) is particularly important for this research. In brief, boundary object are artifacts (including concepts) that are flexible enough to have at the same time a well-structured (i.e. tailored) use within a certain group and an ill-structured (i.e. shared) use across groups. By drawing upon the notion of boundary objects this study intends to explore the ways in which GIS helps or hinders joint work in the Amazon and the social dynamics involved in this process.

The research methodology adopted by this thesis is closely related to its theoretical focus. In particular, the thesis adopts a constructivist approach aimed at producing an in-depth case study of the past and present use of GIS in the control of deforestation in the Amazon (Walsham, 1993). In order to provide a case study that gives particular emphasis to the historical context and current social practices, this study has drawn inspiration from ethnography (Neyland, 2008), practice studies (Czarniawska, 2007) and historiography (Thompson, 2000). In total, hundreds of documents were collected (many of which were for internal use only), 85 interviews were carried out and notes were made about 48 episodes these ranging from a few hours to a full day in duration.

1.3.2 Research questions

In order to attain the aims outlined above, this study endeavors to answer three research questions:

1. Why and how did GIS technology become established as common ground for the formulation of territorial policies in the Amazon between the 1960s and 2000s?

This first research question explores the historical aspect of the use of GIS within the Brazilian government, with particular focus on the systems developed by INPE. By emphasizing the role of GIS in the formulation of 'territorial policies' rather than only 'environmental policies' this research question also includes the role of GIS in the large-scale colonization and economic integration of the Amazon in the 1970s, and considers how it evolved into an environmental protection system. In this way this research is aimed at understanding how the role of GIS has changed over the last four decades and examines how historical events are reflected in current practices.

In addition to this, it is also the aim of this thesis to shed light on how GIS is used in policy-making. Given the temporal span and the difficulty of obtaining detailed empirical data, this thesis is limited to the formulation of the formal aspect of policies (i.e. policy blueprints, laws, norms, plans), discussing in less detail the ways in which they were enacted over the last decades. Moreover, the thesis aims to explain the process of the establishment of GIS as common ground for policy-making. Bearing this in mind, this research places particular emphasis on the social dynamics behind the diffusion of GIS, as well as how it became accepted by different groups (i.e. environmentalists, politicians, scientists) as a trusted boundary object. In this context, the empirical research is focused on the conflicts, negotiation processes and cultural expectations related to GIS and the way this technology changed in order to suit the needs of different groups.

2. How is GIS used in joint deforestation control practices in Mato Grosso?

While the first empirical question focuses on the establishment of GIS and broad policy changes over time, the second question is aimed at producing a fine-grained description of the current use of GIS in the enforcement of the environmental policy. This research question defines the empirical focus of this thesis in different ways. While the first research question has a wide (and less detailed) scope, this question is limited to the understanding of the work practices of the environmental agencies responsible for enforcing the environmental policy. The question above also indicates a geographical focus on the state of Mato Grosso (for more details on this choice see Chapter 3). As mentioned above, IBAMA is active in all the states of Brazil. Similarly, every state in the country has its own environmental agency, making a total

of 9 state-level agencies and IBAMA regional offices in the Legal Amazon. By placing the focus on Mato Grosso, this research narrows its focus to IBAMA headquarters and its local offices in Mato Grosso, as well as SEMA, the state-level Secretary of the Environment. In this way it becomes more feasible to explore in detail their work practices rather than holding a bird's-eye view of all the agencies operating in the Amazon.

Additionally, this research question restricts the scope of the research to a specific set of practices. As mentioned above, IBAMA and SEMA are responsible for enforcing the entire environmental policy, making it infeasible for a doctoral research to cover all the practices carried out by these agencies in detail. For this reason, this research focuses on the role of GIS in the enforcement of the deforestation control policy, that is, the set of laws and regulations that restrict the ability of local farmers to clear their own farms. Within this, the research question gives priority to three sets of practices. At a higher level, the study aims to understand how GIS is used to plan and coordinate the execution of law enforcement operations. At a lower level, the study focuses on two legal mechanisms: at IBAMA it to shows how forest rangers use GIS to identify the location of clearings and write-up fines for illegal deforestation, while at SEMA this research pays particular attention to how bureaucrats analyze environmental license applications for SLAPR, the agency's GIS. Since the enactment of the practices described above not only involve forest rangers and bureaucrats but also attorneys, lawyers, senior officials and managers working in other locations, this research pays particular attention to how practices are done locally and also how they are interconnected to other practices conducted across spatial, occupational and political boundaries. In particular, in line with the research approach outlined above, the study draws upon the notion of boundary objects in order to establish how GIS helps and hinders joint work and the role of objectification in this process.

It is important to note that, by setting this specific focus, the thesis intentionally leaves outside its scope some important components of the environmental policy towards the Amazon. These include, for instance, territorial planning (Ab'saber, 1989; Mahar et al., 1999; Mello, 2006), the promotion of sustainable economic activities (Castro, 1995; Lima et al., 2005b) and the payment for environmental services (Borner et al., 2010; Fearnside, 1997; Moutinho et al., 2005a). In addition to this, by

giving preference to the groups that formulate and enforce the environmental policy, and (indirectly) the groups that tend to deforest illegally this research pay less attention to some important social groups. These include, for instance, native Indians, land-reform settlers, rubber tappers and fisherman – namely the populations that tend to be at the center of most social studies about the Amazon (Conklin et al., 1995; Garfield, 2004; Gonçalves, 2005; Hecht, 1989; Lima et al., 2005b; Meggers, 1971; Price, 1989; Ramos, 1994).

3. What could the Brazilian government do in order to improve the ability to control deforestation in the Amazon?

The last question is aimed at exploring the organizational and policy implications of this research. As such, it draws together the findings of the other two research questions in order to reflect, in a balanced way, on the benefits and drawbacks of this technology and how to improve the current situation. The answer to this question therefore involves making concrete suggestions to the Brazilian government on how it could improve its environmental protection practices in the Amazon. As reported in detail in Chapters 3 and 8, I had the opportunity to voice these suggestions to the government through one-to-one feedback with officials at different levels, at seminars held at IBAMA, INPE and the United Nations headquarters in Brazil and via formal and informal consultations with deputies from the National Congress.

Given the time limitations imposed on this research, it is impossible to provide evidence of whether these suggestions yielded the desired outcomes. However, by discussing the actions already taken by the government in the particular areas suggested and the issues the government faced, this research intends to anticipate some of the challenges that may lie ahead. In this way the thesis is intended to contribute to some extent to the development of better policies and technologies to protect the Amazon.

1.4 Structure of the thesis

The thesis is organized as follows. Chapter 2 provides a review of the bodies of literature that informed this study. Firstly, it provides an account of the widespread perspective within the mainstream literature concerning the potential of GIS. Particular emphasis is given to the assumptions behind the studies that describe GIS as the basis for the emergence of better environmental policies in the Amazon.

Following this, the chapter reviews the critical literature on the implementation of GIS, the process of objectification, joint work and the role of GIS and other technologies as boundary objects. A brief conclusion is given by defining the specific set of theoretical sensibilities adopted by this thesis.

Chapter 3 presents the research methodology adopted by this study. It starts by pointing out the philosophical underpinning of this research, then describes the trajectory of the research and the issues it had to face in order to obtain access to different agencies and practices. After this, the chapter sets out the methods adopted to collect and analyze the empirical data behind the case study as well as the limitations of this study.

Chapters 4, 5 and 6 present an account of the past and present role of GIS in the Amazon. In particular, Chapter 4 presents a historical account of the introduction and establishment of GIS in the Brazilian Amazon in the last four decades. It starts with a history of the Amazon following the military coup in 1964 and the role of GIS technology within the vision of the new regime. The chapter then reports on the involvement of NGOs in environmental policy-making in the 1990s and 2000s. In describing these events, the chapter emphasizes how GIS became a trusted common ground where different groups have worked together in the formulation of the environmental policy in the region.

Chapter 5 discusses how IBAMA forest rangers enforce the deforestation control policy in the Amazon and the role of GIS in it. The chapter opens by providing the historical background of IBAMA. It then describes how IBAMA managers, attorneys and forest rangers in Mato Grosso work together in order to plan missions, carry out the fieldwork and write-up the fines for illegal deforestation. In this section the expectations of senior officials in Brasília and scientists from INPE are compared to how GIS is actually utilized by IBAMA rangers and managers. The chapter closes with a discussion about emerging tensions within IBAMA, as well as the relationship between these tensions and the shortcomings in the current deforestation control practices of the region.

Chapter 6 examines the practices of SEMA from a similar perspective. It opens with a discussion about the historical origins of the state of Mato Grosso and SEMA, and emphasizes the central role of farmers in the political context of the state. The chapter

then discusses how SEMA uses GIS to enforce the environmental law in the state. As in the previous chapter, it explains how SEMA rangers use GIS to plan missions and write-up fines for illegal deforestation. Following this, the chapter explains how low ranking bureaucrats from SEMA use GIS to analyze and issue environmental licenses. In addition to this, the chapter highlights how SEMA's practices differ from those of IBAMA and the role of local politics in this.

Chapter 7 draws upon the previous chapters in order to answer the research questions set out above. Specifically, the chapter discusses the establishment of GIS as a boundary object by analyzing the relationship between this technology and its social context. It then highlights the manner in which GIS, by acting as a boundary object, has helped and hindered collaboration. The discussion gives particular emphasis to the process of objectification behind the functioning of boundary objects in practice and its relation to different forms of joint work. Finally, the chapter makes particular suggestions to the Brazilian government. Chapter 8 concludes the thesis by highlighting the areas the research has contributed to and indicating topics for further research.

Chapter 2: GIS, objectification, joint work and boundary objects: a review

2.1 Introduction

This chapter offers a review of the literature and provides insights into the role of GIS in the public sector, and the relation between artifacts and joint work in general. Since GIS is closely related to geography, many of the studies reviewed here can be located within this discipline. However, in addition this, it is also possible to identify relevant studies from information systems (IS), science technology and studies (STS) and organizational and management studies (OMS) which provide insights about the concerns that are at the focus of this thesis. Even though some of these studies are not specific to GIS technology, the debates in these fields are relevant for this research for two reasons. Firstly, as will be seen below, the body of literature specifically dealing with GIS from a critical perspective is still young and underdeveloped. For this reason, it is often useful to draw upon fields with more substantial research. Secondly and most importantly, GIS are computer-based information systems, and hence, the theories and concepts developed to deal with information technology in general are also likely to be relevant to the study of this technology.

This chapter is organized as follows. The next section provides an account of the 'mainstream' GIS literature with a particular focus on the application of GIS for deforestation control policies. Section 2.3 turns its attention to the studies within the social sciences that analyze the challenges and social dynamics relating to the implementation of GIS technology in different contexts. Section 2.4 explores the social implications of GIS, with particular emphasis on the process of objectification and its consequences. Section 2.5 reviews the studies that describe the challenges involved in joint work and that qualify the different levels of engagement that this may entail. Section 2.6 then continues the argument started in the previous section by reviewing the literature describing how GIS and other artifacts may act as boundary objects and how they are implicated in joint work. Finally, Section 2.7 concludes the chapter by providing a summary and outlining the set of theoretical sensibilities derived from the literature that were adopted in this thesis.

2.2 GIS in the mainstream literature

This section provides a review of the mainstream GIS literature, namely the studies (which are largely) from a positivist perspective that tend to dominate the specialist journals and shape the vision of decision-makers in relation to this technology. The next subsection provides a definition of GIS, briefly touching on its historical roots and disciplinary affiliations. The second subsection aims at exposing the assumptions behind most of this literature. The third and final subsection reviews the studies that highlight how GIS should be used to guide policy-making in the Amazon.

2.2.1 A definition of GIS

Generally speaking, a geographic information system (GIS) is 'a computing application capable of creating, storing, manipulating, visualizing, and analyzing geographic information' mostly represented in numeric form (Goodchild, 2000: 6). As its name suggests, the origins of GIS are closely related to the theoretical and practical development geography, and in particular the use of quantitative methods for spatial analysis. Quantitative data has been widely used by geographers for centuries. For instance, around 200 BC, Eratosthenes used mathematics to calculate the Earth's circumference, which he did with remarkable precision when compared to contemporary measurements. Even though elements of GIS can be found in techniques and artifacts dating many centuries back, this technology started to emerge as a stable set of research tools for academic research and public governance only after the Second World War (Goodchild, 2000). In particular, it was only with the development of computers that the application of quantitative methods for spatial analysis led to the 'quantitative revolution' at the basis of GIS (Barnes, 2001; Harvey, 1969).

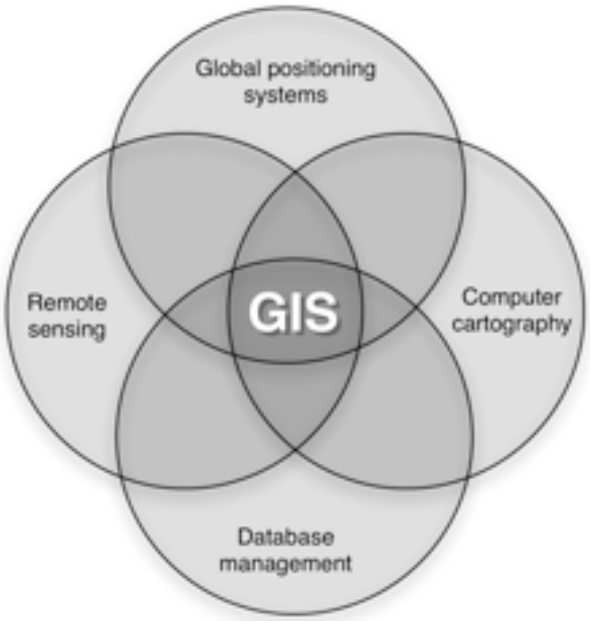

Figure 3 Components of modern GIS technology: computer cartography, database management, remote sensing and global positioning systems (Adapted from Maguire, 1991)

Modern GIS can be understood as the overlap of four technologies (see Figure 3). Computer cartography and data base management technology are the elements that enable GIS to store and analyze vast amounts of data systematically. In contrast to old paper-based technologies, the ability of computer cartography to represent spatial phenomena as standard data symbols stored in databases meant that repetitive activities, such as the aggregation of census data, could be completed in a few hours instead of many months (Goodchild, 2000). The diffusion of satellite-based remote sensing technology from the 1970s also contributed significantly to the development of GIS. Until this point, data on spatial phenomena had to be collected through lengthy fieldtrips or aerial photography. Even though remote sensing satellites demand substantial investments, once they are in orbit they are able to provide a regular stream of data on natural resources (e.g. forests, geological features) and related phenomena (e.g. deforestation, pollution) at a low cost per square kilometer (Biache, 1983). More recently, global position systems (GPS) became an important addition to GIS technology. GPS are global navigation satellite systems from which devices on the ground are able to determine their exact position in terms of latitude/longitude. This made it possible for the first time to link the data provided by digital cartography and remote sensing with specific locations on the planet, and in this way to make more precise interventions (Abler, 1993).

Most of the academic research on GIS technology has a technical and promotional character (for an early example see Dobson, 1983). Hence, these studies are largely aimed at developing methodologies to improve GIS as a research tool and at encouraging its widespread use in policy-making by highlighting its technical features (Abler, 1993; Campbell, 2006; Goodchild, 2000; Leimgruber et al., 2005; Martin, 1996; Navratil, 2009). In particular, most studies within the GIS literature focus on the detection of physical and social phenomena (e.g. deforestation, carbon emissions) using satellite images (Kintisch, 2007; Schroeder et al., 1995; Valeriano et al., 2004), analysis and the prediction of spatial phenomena (Aguiar et al., 2007; Soares-Filho et al., 2006), spatial data integration (Fonseca et al., 2002; Navratil, 2009) and proposals for new data collection regimes (Craglia et al., 2008; Fonseca et al., 2009; Fuller, 2006; Moutinho et al., 2005b).

2.2.2 The rationale of GIS for policy-making

Even though it is rare for the mainstream GIS literature to explicitly discuss its own assumptions, with greater scrutiny it is possible to observe a close affiliation between them and the current mainstream approach to environmental policy-making. Modern environmentalism only emerged during the second half of the 20th century. In contrast to the aesthetic or strictly economic concerns of the earlier phases of the environmentalist movement, modern environmentalism distinguishes itself by a strong worry with the survival of the planet as a whole (Guha, 2000; Nail, 2008; Pepper, 1996; Scott, 1998). Therefore, rather than campaigning for the preservation of particularly beautiful landscapes or important natural resources, modern environmentalism attempts to deal with the risks created by industrialization and modern science at a global level (Beck, 1992; Berger et al., 1974). As the environmentalist movement entered in mainstream politics in the 1980s, the anti-technological ethos of the movement was largely abandoned in favor of the idea that science and technology are part of the solution of environmental problems rather than being only their causes. In particular, scholars and practitioners have increasingly defended the idea that environmental policy should be strictly guided by scientific principles and that valid scientific data is crucial for a proper decision-making process (Cohen, 2000; Esty, 2001, 2004; Hajer, 1995; Heinonen et al., 2001; Mol et al., 2000; Pullin et al., 2010; Speth et al., 2006). The director of the Yale Center for

Environmental Law and Policy, Daniel Esty and the director of the Harvard Institute for Strategy and Competitiveness, Michael Porter, illustrated this perspective well:

> Our analysis strongly supports the notion that the uncertainties that plague environmental policy-making can be reduced. We believe that a robust, statistically serious, and data-driven approach to understanding environmental problems and evaluating policy options could move the environmental field toward decision making based on objective evidence rather than letting strongly held beliefs and emotions create divides that are hard to bridge. (Esty et al., 2005: 425)

This excerpt suggests for the supporters of this perspective it is crucial to extirpate the green ideology that has plagued earlier attempts to conciliate economic growth and environmental protection. Moreover, for them the only way to separate ideology and policy is to base the decision-making process on comprehensive scientific evidence about the phenomena being regulated. Even though this particular form of policy-making has been criticized by different studies, it has been behind a number of important policies in the UK (Barry et al., 2004), the Netherlands (Cohen, 2000) and the USA (Mol et al., 2000) among other countries.

GIS is one of the most frequently mentioned technologies in the context of debates concerning the need of fostering data-driven environmental policy-making (Esty, 2004; Leeuw et al., 2010; Wise et al., 2008). This should not be a surprise. In a more detailed examination of the literature it is possible to see that GIS scholars are closely related to the expectations and assumptions of this approach. Specifically, because of the close relation between GIS, quantitative geography and positivism, the data produced and manipulated by GIS is usually considered a neutral and rigorous reflection of the world (Pickles, 2004; Roberts et al., 1995; Taylor et al., 1995). A good example of the perspective illustrated above can be found in an influential research article (in terms of number of citations in Google scholar) written by a group that includes some scientists from INPE, the Brazilian institute for space research (Fonseca et al., 2002). In order to deal with the integration between different GIS data-sources they propose an ontology, namely a formal representation of reality that explicitly makes the link between GIS-based representations and their referents. The proposed GIS ontology is based on a cascade of 'universes', each one in direct relation to each other; it starts with the *physical universe* (or the 'real world') being mapped onto a *logic universe* where geographical phenomena are represented as both sets of points (e.g. houses, landmarks), lines (i.e. road, political boundaries), polygons (e.g. plots of farmed land, forests), or distributions such as rain fall or the percentage

of forest cover in a specific region. Then the representations from the logic universe enter the *implementation universe* becoming data structures in a geographic information system. Even though Fonseca et al. (2002) intended to solve a specific technical problem related to data sharing, their description of how the real world can be translated into the implementation universe in a direct way reflects the widespread belief within the mainstream literature that GIS is able to present 'a representation of earth space that is simply and unproblematically a reflection of what is really "out there"' (Pickles, 1995a; Roberts et al., 1995: 179).

GIS has also been repeatedly depicted in the mainstream literature as having the capability (or at least the ambition) to provide comprehensive representations of the world (Craglia et al., 2008; Gore, 1998; ISDE, 2009; Navratil, 2009). With this purpose, in recent years different projects, such as Digital Earth, have been attempting to realize the vision of a GIS that is not only able to provide scientifically valid data, but also comprehensive representations of all the relevant aspects of the world, 'from state boundaries to 3-D models of grocery stores' (Keating, 1992: 32). This point resonates closely with the current approach to environmental policy-making. Since policy decisions are expected to be based on almost complete information, it is important to use technologies such as GIS which are able to 'place the world at one's fingertips […] and position the viewer high-above the earth to claim a view that is total' (Roberts et al., 1995: 174). In the launching speech of the Digital Earth initiative, the former Vice President of the USA, Al Gore (1998), illustrated this perspective:

> We have an unparalleled opportunity to turn a flood of raw data into understandable information about our society and our planet. This data will include not only high-resolution satellite imagery of the planet, digital maps, and economic, social, and demographic information. If we are successful, it will have broad societal and commercial benefits in areas such as education, decision-making for a sustainable future, land-use planning, agricultural, and crisis management (*ibid*: 1998)

The speech from Al Gore (1998) quoted above as well as many studies within the mainstream GIS literature also indicate the belief of a deterministic relationship between the use of GIS and the creation of more effective environmental policies (Brown et al., 1998; Campbell, 2006; Fonseca et al., 2009; Fuller, 2006; Martin, 1996; Rocheleau, 1992). For instance, Abler (1993) argued that the combination of detailed spatial data about all physical aspects of the planet (from the fertility of soil to the age of telephone cables) will allow human kind to put 'everything in its place'

leading in this way to the optimal management of agriculture, urban traffic and all other relevant aspects of society. In Abler's (1993: 133) words, 'when everything is in its place in a GPS-based decision and management support system, the place for everything else becomes obvious'.

2.2.3 GIS for deforestation control policies

The control of deforestation in the Amazon has been one of the main areas where scientists and policy-makers have highlighted the potential of GIS technology. In line with the more general arguments made regarding GIS in the public sector, many authors have suggested a direct link between the introduction of this technology and improvements in the ability of the government to protect the Amazon rainforest. For instance, some influential researchers have proposed the idea of a 'Global Forest Information System, […] a combination of [GIS] tools that allow *reasoning about change*, provide *semantic information about the rain fo*rests, and support cognitive navigation over the world's tropical belt' (Câmara et al., 2009: 212, italics in the original). From the creation of this global GIS the authors intend to 'allow researchers and policy makers to find ways of making the forest worth more alive than dead' (Davis et al., 2009: 158; Fonseca et al., 2009). Fuller (2006) makes a similar point by examining the case of INPE's GIS in Brazil. In particular, he concluded that 'if [GIS-based] forest monitoring is promoted explicitly as part of regional and global cooperation, it can help defuse regional conflicts and tensions by enhancing transparency and promoting common interests in sustainable environmental management and economic wellbeing' (Fuller, 2006: 26). This suggests that for many scholars the introduction of GIS in the Amazon has a specific pre-determined outcome: the formulation of governmental policies that are inherently superior due to their scientific basis.

In addition to policy-making, an increasing number of scholars have proposed that GIS should be considered as the basis for a 'new model' for the enforcement of the law in the Amazon (Fearnside, 2003: 343; Kintisch, 2007; Valeriano et al., 2005). These studies tend to be based mainly on two premises. In a much quoted article, Hardin (1968) proposed that the lack of clear land rights and the related shared ownership of resources may give rise to the 'tragedy of the commons', namely a situation where individuals ultimately cause the depletion of a shared resource by

simply following their own self-interest. Even though since the late 1960s this notion has come under heavy criticism, many authors still argue that the lack of a clear definition for land-use rights and titles is one of the main factors behind the rampant deforestation of the Amazon and other tropical forests (Campari, 2005; de Oliveira, 2008; Peters et al., 1989). Based on the premise that GIS can offer an unambiguous definition of land ownership and environmental responsibilities, some authors have argued that GIS-based environmental license initiatives, such as the one carried out by SEMA in Mato Grosso, will lead to reductions in deforestation (Chomitz, 2007; Fearnside, 2003; Wertz-Kanounnikoff, 2005).

The second premise for the promotion of GIS in the environmental protection of the Amazon is based on the idea that environmental agencies operating in the Amazon are ineffective because they lack timely data about the Amazon. Here, different authors propose that by providing more precise and timely GIS-based deforestation data will help environmental agencies to stop ongoing deforestation (Anderson et al., 2005; Souza Jr et al., 2009; Valeriano et al., 2005). Google Earth Engine Manager, Rebecca Moore, apparently ignoring the existence of INPE's GIS, provided a good illustration of this perspective:

> Today if you want to monitor deforestation in the Amazon it takes weeks to run the analysis. By the time you have done that, the illegal activities are long gone. With Google Earth Engine you can build a real-time alerting system based on images that are taken that show what the state of the forest was last week and what it is this week. […] Anyone around the world [will be able] to see what is happening and support law enforcement. (Google, 2010)

It is important to note that this vision has not remained only on paper. Governmental organizations such as INPE, SEMA as well as non-governmental organizations such as IMAZON and Google.org (the chartable arm of Google) have been investing large amounts of resources into the development of GIS with the aim of representing the Amazon as holistically and as close to real-time as possible. However, despite the prevalence of this view, current studies offer very little evidence to show the link between the use of GIS and changes in governmental practices. For instance, most studies analyzing the role of SLAPR, a GIS developed by the Secretary of the Environment of Mato Grosso (SEMA), are largely limited to the correlation between deforestation rates (as detected by GIS) and the diffusion of the system in the region (Chomitz, 2007; Fearnside, 2003; Wertz-Kanounnikoff, 2005). Although they are

useful, these studies largely leave unchartered the practices behind the use of these systems and other social factors behind deforestation.

From the mainstream GIS literature a strong and common theme emerges; it is possible to observe a tendency to present GIS as a system that reflects the reality 'out there' in a neutral and comprehensive way. Furthermore, there is an inclination to consider that the introduction of GIS and the availability of increasing amounts of data in 'real-time' directly contribute to the creation of better policies and a sustainable future for the Amazon rainforest. Even though this perspective is prevalent within the GIS literature, some social studies dealing with GIS and technology in general challenged the mainstream orthodoxy in different ways. The remainder of this chapter will therefore review this literature, beginning with the studies that highlight the importance of the social context in understanding the implementation of GIS technology.

2.3 GIS implementation and the social context

One of the first critical perspectives to emerge on GIS focused on a particular practical concern. As seen in the previous section, the mainstream GIS literature implies that this technology is an infallible solution for the public sector (Abler, 1993; Rocheleau, 1992). From this point of view - often referred as technological determinism - the implications of technology, such as increases in productivity, are considered to be independent of the particular social context in which the technology is implemented (Brown et al., 2000; Grint et al., 1997; Nardi et al., 1999). In spite of the prevalence of this view, the reality of the implementation of GIS and other technologies is very different. Many authors have noticed that new technologies frequently fail to become established in the organizations in which they are introduced and in some cases bring more havoc than gains (Bostrom et al., 1977; Trist, 1983). This is particularly the case in relation to GIS in developing countries where different authors reported that despite the promises of GIS, the implementation of new systems is prone to failure and the few that are eventually implemented tend to be used in unsatisfactory ways (Campbell et al., 1995; Walsham et al., 1999). In particular, different authors pointed out that this issue can be explained by conceptualizing the organizations' socio-technical systems, where the outcome of the implementation of GIS depends not only on its technical aspects (i.e. the

technological features of GIS applications) but also on how they fit with the human factors found in each social context (Campbell et al., 1992; Nedovic-Budic et al., 1996; Ventura, 1995).

The development and adoption of socio-technical systems theory was an important first step in challenging the view that the introduction of new technology leads to deterministic outcomes. By indicating that technology depends on social considerations, and vice versa, this strand of the literature revealed the importance of understanding the specific social context in which these technologies are enacted. More recently, this field also embraced more sophisticated theories from organizational studies, sociology and science and technology studies (Avgerou et al., 2001; Bloomfield et al., 1992; Currie et al., 2007; Hayes, 2001; Walsham, 1993, 1997). The different approaches adopted to analyze the establishment of GIS include: the actor-network theory (Martin, 2000; Walsham et al., 1999); the structuration theory (Barrett et al., 2001), the social construction of technology (Sahay, 1997; Sahay et al., 1996) and boundary objects (Harvey et al., 1998). Within this body of literature, it is possible to identify three partially overlapping themes (see Table 1).

Concept	Description	Key references
Negotiation and politics	The implementation of new GIS often involves politics and negotiation between different groups.	Martin, 2000; Lance et al., 2009; Harvey, 1998
Cultural values and conflicts	GIS embeds certain values and epistemological positions that may be at odds with the local context of its implementation.	Walsham and Sahay, 1999; Homburg and Georgiadou, 2009
Interpretive flexibility	The outcome of GIS is shaped by the perception of the groups implementing and using it.	Sahay and Robey, 1996; Pinch and Bijker, 1983

Table 1 Key themes emerging from the literature on GIS implementations

2.3.1 Politics and negotiation

One of the key points that emerged from the literature on the implementation of GIS and other technologies in organizations was the importance of attending to the political dynamics and negotiations they entail (Barley, 1986; Elwood, 2008; Georgiadou et al., 2005; Richter et al., 2010; Schuurman, 2005). Specifically, different studies showed that the functioning of organizations is embedded in a complex web of power relations. In this context, the presence of project allies such as

champions (i.e. high ranking individuals who provide continuity to a project) is crucial for the successful establishment of GIS (Borges et al., 2000; Richter et al., 2010). For instance, Lance et al. (2009) drew upon the notion of networks to discuss the relation between GIS and political support. Based on Powell's forms of coordination, the authors analyzed the relation between the actions of central budget agencies and the success of voluntary GIS networks in Canada and USA. Here, they found that even though the support and control of central agencies for GIS networks went against the supposedly voluntary and non-hierarchical ethos of these networks, they also conferred legitimacy to GIS. In this way, the case studies revealed a contradictory situation whereby the greater central control and legitimacy conferred by power actors led to a more vigorous use of GIS across agencies.

Other studies have also highlighted the political dimension of new technologies, emphasizing that artifacts should be seen as active allies themselves rather than passive elements. In particular, by drawing upon the actor-network theory (ANT), different authors have conceptualized social life as networks composed of human (e.g. developers, users, politicians) and non-human (e.g. GIS, roads, desk) actors. These the studies paid particular attention to the role of alliances (i.e. alignment between heterogeneous actors) and the obligatory points of passage in the formation of powerful and successful (i.e. stable) networks (Câmara et al., 2006; Harvey, 2001; Walsham, 1997). Martin (2000) presented a case study of the implementation of GIS in conservation areas in Ecuador (including a portion of the Amazon rainforest) that draws upon this perspective. Based on ANT, the author pointed out that the establishment of GIS involved not only scientists, politicians and members of NGOs, but also non-human actors such as money, scientific studies and satellites. He therefore concluded that the success of GIS in the region lay not only in the technical expertise and political support provided to this technology, but also in the ability of certain actors to use to their advantage key resources and artifacts.

Other studies went further and also shed light on the complex negotiation process involved in the implementation of GIS (Carton, 2007; Chrisman, 2005; Jarosz, 1996; Zubrow, 2003). Harvey and Chrisman (1998) provided a good example of this issue in a case study about the construction of a spatial data standard in Germany and a wetland classification map in the USA. In particular, the authors showed that policy-makers, scientists and other groups of different affiliations often have disagreements

in relation to the specifics of GIS. For this reason, the creation of shared GIS definitions often involves lengthy negotiations and the acceptance of ambiguous standards. Based on this finding the authors concluded that 'GIS technology and technoscience are not monolithic autonomous edifices but the localized results of processes of negotiation that involve the construction of artifacts to fit various social perspectives' (Harvey and Chrisman, 1998: 2693).

2.3.2 Cultural values and technology

The role of culture in GIS implementations was another important finding that emerged from the literature (Barrett et al., 2001; Georgiadou et al., 2005; Homburg et al., 2009; Madon et al., 1997; Puri, 2006; Sahay, 1998; Sahay et al., 1997). As seen in the previous section, GIS technology is often viewed in the mainstream literature as a neutral technology able to provide a universally valid standard for the representation of spatial phenomena. However, despite the prevalence of this view, many critical studies have demonstrated that GIS (like any specific technology and body of knowledge) should be understood as being part of the cultural context from which it emerged (Lefebvre, 1991; Pickles, 2004; Taylor, 1990).

In bringing this insight to GIS, some authors argued that the success or failure of the system depends on the extent to which the values embedded in it are compatible with those of the social context in which it is being implemented (Barrett et al., 2001; Walsham et al., 1999). Drawing upon a case study of GIS in India, Walsham and Sahay (1999) noticed that GIS contains the values of its developers working in North America and Europe. In particular, GIS was inscribed with a particular type of rationality (i.e. scientific) and representation of space (i.e. 2-D maps) that are widespread in the west but much less familiar to the average Indian. From a similar case study, Barrett et al. (2001) pointed out that the introduction of GIS in the Indian forestry sector has led to tensions at institutional and individual levels. The authors argued that with the introduction of GIS, officials and remote-sensing scientist as well as forestry officers working on the field would have to increasingly deal with each other in a condition of absence (see also Sahay, 1998). However, in their view this tendency of disembedding between time and space goes against the Indian preference for face-to-face relations, which by definition occurs in a condition of presence. Based on this and other findings, both studies concluded that the initial failure of GIS

in India should be understood as the outcome of the tension between the western/scientific assumptions embedded in the GIS and the resilience of traditional local work practices.

2.3.3 Interpretive flexibility

Finally, different studies have stressed that interpretive flexibility helps to explain why certain technologies succeeded and others fail to become established. Much of this line of research emerged from the Social Construction of Technology (SCOT), a theory proposed by Pinch and Bijker (1984) to explain the establishment of new technologies and scientific theories. The authors pointed out that the traditional model for understanding science and technology conceptualized the relationship between research, production and the use of technology in a linear and deterministic manner. In other words, the relationship between the intentions of designers and how the technology is actually used tended to be seen as being unproblematic, while the reasons why certain kinds of technology succeed and others fail was generally understood as being restricted to the technical aspects of the artifact. Based on the case study of the development of the bicycle and solar physics, Pinch and Bijker (1984) argued that traditional theoretical approaches fail because they do not take into account how technology is socially constructed by its users. Specifically, the authors argued that technological artifacts have an 'interpretative flexibility', and therefore, depending on the social context in which it is introduced, may be understood and used in different ways. For this reason, new technologies initially have considerable flexibility and may be interpreted in ways that may even contradict the original intentions of its designers. Following this, however, the social groups dealing with the technology may reach a consensus over its meaning and use, which leads to a process of closure and reduces its degree of flexibility.

The notion of interpretive flexibility was very influential in the study of GIS implementations. (Homburg et al., 2009; Puri, 2006; Sahay et al., 1996). Sahay and Robey (1996) provided one of the first accounts of this issue in relation to the implementation of GIS in two local government agencies in the USA. The authors showed that the differences in the social context and practices of the two agencies led to opposing outcomes. In the southern agency, GIS technology was seen as an empowering device and consequently was widely accepted by the staff. In the

northern agency, in contrast, GIS was interpreted as a control mechanism with very limited usage. By drawing upon SCOT the authors criticized technological determinism and concluded that GIS should be understood as being 'interpretively flexible' for having the 'the capacity […] to sustain divergent opinions', local uses and configurations (ibid: 260).

Some studies have linked the failed establishment of GIS to its ability to be interpretive flexible. Puri (2006), for instance, provided a case study of the implementation of GIS in India which builds upon Sahay and Robey's analysis. The authors indicated that different interpretations of GIS are organized around technological frames, namely, differing perceptions and conceptualizations around a particular technology. In particular he showed that the perceptions of the designers, political supporters and users of GIS were often at odds with each other, so generating tensions and frustration. From this the author concluded that the ability of GIS to support multiple interpretations helps to explain why its introduction in India was deemed to be largely unsuccessful.

More recently, however, Williams and Pollock (2009) and Homburg and Georgiadou (2009) arrived at an opposite conclusion. In a study of the diffusion of enterprise resource planning (ERP) software packages, Williams and Pollock (2009) showed how the complex interplay between the generic aspect of software and its adaptation to specific organizational context explain its successful establishment across different contexts. More specifically to GIS, Homburg and Georgiadou (2009) showed how the concept of 'spatial data infrastructure' (SDI) (i.e. shared GIS) successfully travelled between North America and Africa. The author highlighted how it was possible to identify a set of myths that inspired actors to implement SDI in their own contexts. However, they also noted that these myths not only evolved over time, adapting to emerging concerns, but also changed radically across social contexts. Hence, for example, while the myths behind the diffusion of SDI in North America highlighted the potential of this technology in terms of maintaining economic competitiveness, in Africa such technology was interpreted mainly as a way to alleviate poverty and manage natural resources. Both studies suggested that the ability of technological artifacts to be reshaped according to their social context was crucial for their diffusion. Furthermore, it was highlighted the importance of attending to the historical

trajectory of these artifacts (or their biography) in order to understand this reframing process.

The literature reviewed above provided interesting insights about the significance of the social context in shaping the outcome of GIS implementations. It also showed how the outcome of GIS should be understood as emerging from the interaction between the social and technical aspects of this technology. Furthermore, the literature also pointed out that GIS should be understood as a technology embedded with certain cultural values and epistemological positions, which may be at odds with the social context in which it is being implemented. Finally, it revealed that GIS is a flexible technology that can have different or even contradictory outcomes depending on the perspective of the groups implementing it. However, the data provided by these studies tended to focus mostly on the interpretations and events that preceded the implementation of GIS, rather than the social implications that emerged following the establishment of this technology. The remainder of this chapter reviews the studies providing insights on what happens following the establishment of GIS and other technologies in a given social context, with particular emphasis on the issue of objectification and joint work.

2.4 Social implications of objectification

The rapid growth of GIS as an area of research in the 1980s and 1990s led many scholars to make ambitious claims about the potential of this technology in solving societal problems (e.g. Abler, 1993; Dobson, 1983). These claims did not pass unnoticed by geographers and other scholars studying the relation between government, space and technology from a critical perspective. By drawing mainly upon a broad historic analysis and philosophical arguments, a small but active group of geographers created a field that would later be known as critical GIS (Aitken et al., 1995; Pickles, 2004; Taylor, 1990). Specifically, in contrast to the strongly promotional character of the mainstream GIS literature, critical GIS scholars tended to provide a bleak image of the social implications of GIS, suggesting for instance, that the introduction of this technology furthers the digital divide (Pickles, 1995a), provides opportunities for surveillance (Rose-Redwood, 2006), and leads to the neglect of non-Western/scientific epistemologies (Sheppard, 2005).

In spite of the broad range of topics and theories adopted by critical scholars to discuss the social implications of GIS, the notion of 'objectification' underlies much of this literature. Broadly speaking, objectification (or reification and representation) refers to a process whereby something that is alive, dynamic and multifaceted is treated or becomes for all practical purposes a static thing or a physical object. While the process of objectification may occur in different contexts, two aspects are particularly important (Nussbaum, 1995). Firstly, objectification transforms subjects with feelings, agency and so on, into objects that serve some instrumental purpose (Haraway, 1991; Kwan, 2002; Suchman, 1994). The root of many debates concerning this aspect of objectification can be traced to the work of Karl Marx. Here, Marx argued that in the capitalist mode of production, social relations are objectified into money, which in turn transforms labor and workers into objects. As a result of this, money becomes an instrument of domination and alienation between men (Frederico, 1995; Marx, 1844/1974; Reale et al., 1990). The second meaning of objectification refers to the transformation of subjective concepts (e.g. personal ideas, opinions, accounts) into objective facts (e.g. hard data, widely accepted documents) that are considered to be independent of any particular person. This type of objectification is particularly important in the legal and scientific practices which on principle can only accept objective forms of evidence (Daston, 1992; Daston et al., 1992; Golan, 2004). This section therefore provides a review of the studies analyzing the relation between these two understandings of objectification and technology, with particular emphasis on GIS. The review is organized around three interrelated themes: selective objectification, the (in)visibility of work outcomes and practices and the illusion of transparency (see Table 2).

Concept	Description	Key references
Selective objectification	Objectification is inherently partial and selective.	Taylor and Johnston, 1995; Kallinikos 1995
(In)visibility of work outcomes and practices	Objectification leads to the increasing visibility (and surveillance) of some work outcomes and practices and the invisibility (and neglect) of others.	Brown and Duguid, 1991; Star and Strauss, 1999; Pickles, 2004
Illusion of transparency	Even though objectification is partial and politically ridden, it is perceived as holistic and neutral.	Lefebvre, 1991; Golan, 2004

Table 2 Key themes emerging from the literature on objectification and technology

2.4.1 Selective objectification

While objectification has long historical roots, the emergence of modern bureaucracy, computers and related information systems have greatly increased the scope and speed of this process (Brown et al., 2000; Kallinikos, 2006; Lilley et al., 2004). Different studies have pointed that an important implication of the introduction of information technology (IT) is the selective character of the objectification it promotes (Cooper, 1992; Kallinikos, 2006; Lilley et al., 2004). For example, Kallinikos (1995) gave an explanation of this process in the following excerpt:

> IT is not simply concerned with the duplication or symbolic coding of the world in all its detail and diversity, but rather with the selective objectification of things, states and processes. Representation is selective in the sense of objectifying properties or facets of the world: for instance, when human beings are considered as labouring bodies, consumers or role incumbents, nature as raw material, objects and actions as products or services, etc. (Kallinikos, 1995: 118)

Different studies suggest that the selective nature of objectification leads to contradictory outcomes. On the one hand, selectivity is described as a necessity for management. As initially pointed out by Herbert Simon, organizations depend on information in order to function properly. Since managers (like all human beings) have limits in relation to the amount of information they can cope with, organizations need to devise ways to abbreviate the world or to reduce it selectively in order to fulfill specific aims (Cooper, 1992; Kallinikos, 2006; Lilley et al., 2004). Similarly Spinuzzi (2008) argued that complex organizations often have to create 'black boxes', with formal and information functional unities which depend on specific inputs and produce particular outputs and whose internal functioning is deliberately ignored by outsiders. From this it emerges that the objectification promoted by technology plays an important role in enabling the emergence of complex organizations. On the other hand, it is argued in many studies that the selective character of objectification leads to more losses than gains depending on the circumstances (Bowker et al., 1999; Petrakaki et al., 2009; Star et al., 1999; Suchman, 1995). Specifically in relation to GIS and other representations of space geographers, such as Lefebvre (1991), Harvey (1984) and Soja (1989), dedicated much of their work to criticizing the growing focus of geography on positivist methods. In particular, they pointed out that the positivist epistemology embedded in quantitative geography objectifies a complex social reality into an impoverished abstract space of numbers and symbols. According to Levebvre (1991: 7) the selective objectification of space produces:

> [E]ither mere descriptions which never achieve analytical, much less theoretical, status, or else fragments and cross-sections of space. There are plenty of reasons for thinking that descriptions and cross-sections of this kind, […] may well supply inventories of what *exists in space*, or even generate a *discourse on space*, [but] cannot ever give rise to a *knowledge of space*.

This line of criticism was very influential among critical GIS scholars (Asdal, 2008; Bibby, 2005; Pickles, 2004; Roberts et al., 1995; Rose-Redwood, 2006; Sletto, 2002; Taylor, 1990). Many of these studies have highlighted that the use of GIS objectifies selectively complex social phenomena into points, polygons and lines - the basic data elements of GIS. In this way, the objectifications provided by GIS are epistemologically limited to showing the spatial correlation between discrete elements (e.g. roads and deforestation), leaving largely unchartered the underlying social causes of the phenomena being represented (Barnes, 2001; Boonstra et al., 2009; Harwell, 2000; Liverman et al., 1998). Or, as Taylor and Johnston (1995: 57) put it, 'knowing that the impact of an axe on wood will split [...] does not tell you why the axe is being directed at the wood in the first place'.

2.4.2 The (in)visibility of work outcomes and practices

An important consequence of selective objectification is how it changes the relation between what is visible and what is invisible within organizations and societies. A key theme in the IT and GIS literature has been the relation between the introduction of technology and the possibility of surveillance. By drawing upon the writings of Foucault (1977) as regards the birth of the prison and other topics, many authors have pointed out that the ability of technology to objectify, store and manipulate traces of human behavior make it a powerful disciplinary tool (Cooper, 1992; Introna, 1997; Lilley et al., 2004; Petrakaki et al., 2009). In relation to IT in organizations, Zuboff (1988) proposed the notion of an 'Information Panopticon', namely a mechanism able to 'transmit the presence of the omniscient observer and so induce compliance without the messy conflict-prone exertions of reciprocal relations' (323). Specifically, in relation to GIS, many authors have pointed out that the capability of this and related technologies objectifying people and territories greatly increase the ability of governments to control citizens (Harley, 1989; Pickles, 1995a; Rose-Redwood, 2006; Scott, 1998). For instance, it was highlighted that the visibility offered by GIS and other modern objectifications of space, such as maps and ordnance surveys, have been crucial for the slow extermination of many native Indian tribes in North America

(Hannah, 2000), the exploitation of natural resources in India (Edney, 1997) and the emergence of modern warfare in Iraq (Harris, 2006).

Notwithstanding this, other studies have also pointed out that the selective character of objectification can also generate an opposing effect and render certain groups and their work practices invisible. Different authors have indicated that the objectification of the outcome of work into abstract indicators which are carried out by bureaucratic technologies can create adverse effects (Blackler, 2006; Chapman, 2004; Miller, 2003). Lipsky (1980) provided some interesting insights in this regard. Referring to examples within areas as diverse as job placements and legal cases handling, he argued that performance indicators contain very little information about the work they are intended to represent. So for instance, a figure showing that a high success rate of a job placement scheme may hide the fact that bureaucrats were only allowing into the scheme the workers more likely to find a job, leaving aside groups that are considered to be problematic. Blackler (2006) expanded on Lipsky's work in order to the criticize the overemphasis of the British National Health Service (NHS) on abstract indicators. In line with Lipsky (1980) he discovered that hospital managers tend to be more focused on achieving the targets set by the central government than attempting to improve health services. In addition to this he suggested that the indicators were not only blinding central government from understanding the needs of local hospitals but also prevented local managers from taking up their role as effective leaders in their organizations.

Some studies also highlighted the fact that the process of objectification transforms the understanding of what is involved in enacting work practices (Bowker et al., 1999; Star et al., 1999; Suchman, 1994). Based on Julian Orr's (1996) detailed study of Xerox repairmen (see below), Brown and Duguid (1991) proposed the notions of canonical and non-canonical practices in organizations. They defined as canonical practice the simplistic understanding of work practices usually objectified in training manuals, job descriptions and standard operating procedures. Non-canonical practices, in contrast, are the practices that play a key role in the successful accomplishment of tasks even though they are largely invisible to managers. Based on this distinction, Brown and Duguid (1991) highlighted that:

> Through a reliance on canonical descriptions (to the extent of overlooking even their own non-canonical improvisations), managers develop a conceptual outlook that cannot

> comprehend the importance of non-canonical practices. People are typically viewed as performing their jobs according to formal job descriptions, despite the fact that daily evidence points to the contrary (Suchman 1987b). They are held accountable to the map, not to road conditions. (*ibid*: 42)

The relation between objectification and invisible work has also been discussed by particular studies dealing with computer-supported cooperative work and IT in general (Hughes et al., 1994; Orlikowski, 1994; Winograd, 1994; Zuboff, 1988). In particular, Suchman (1994, 1995) and Star & Strauss (1999) provided interesting discussions on how information technology renders particular work (and workers) visible and others invisible. Echoing much of the literature mentioned above, they pointed out that selective objectification is the basic principle behind the functioning of most information technologies. Consequently, they are due to exchange complex sentient engagements and face-to-face relations with simplified abstract symbols. According to this observation they argued that the designers of IT artifacts should be more attentive to the actual work practices and how they should be objectified (or not) by technology. Star and Strauss (1999:23) also warned that '[w]hen the relationship between visible and invisible work is solely traded in abstract indicators, both silence and suffering result, to say nothing of inefficiency and obfuscation', suggesting that organizations should avoid adopting IT as their only channel for joint work and self-understanding.

Even though so far no study dealing specifically with GIS has indicated the invisibility of work, an important branch of the critical GIS literature has come to similar conclusions in relation to the invisibility of social reality. Specifically, different studies suggested that the overreliance on GIS might lead to the distancing of government officials from the local communities and also lead to a selective image of their social reality whereby what is not represented in the system is not 'real' to decision-makers, and as such, not addressed by their policies (Aitken et al., 1995; Pickles, 1995a; Roberts et al., 1995; Taylor et al., 1995). For example, Haque (2001) pointed out that some city councils in the USA are so poor that they are not able to hire GIS experts to collect data and represent themselves in country's welfare statistics system. Since the USA federal government distributes financial resources based mainly on the data found in this GIS, many of the poorest parts of the country are unfairly left out of poverty reduction programs.

2.4.3 Illusion of transparency

While the processes of selective objectification and (in)visible work have been explored in detail by the literature as regards IT in organizations, the notion that technology may create an illusion of transparency has mainly been developed by critical geographers and STS scholars. Specifically, in relation to GIS technology and other representations of space, some researchers have pointed out that the process of objectification is not only selective (and thus partial) but also deeply political (Harley, 1989; Lefebvre, 1991). Hence, GIS and other representations of space such as traditional maps, land titles and city zoning are not only powerful disciplinary tools, but can also be shaped by powerful groups in order to represent reality in ways that reinforce their dominant position (Black, 1997; Harley, 1989; Harvey, 1984; Monmonier, 1991; Scott, 1998; Soderstrom, 1996). Studies here have shown, for instance, that GIS and other representations have been explicitly designed to establish colonial powers (Harvey, 1984), wartime propaganda (Black, 1997), and more recently, the manipulation of public opinion in relation to natural resources and environmental disasters (Harwell, 2000; Jarosz, 1996; Sletto, 2002). At the same time, however, GIS is still widely believed to be able to mirror the world in a holistic and neutral way: 'a view of space as innocent, as free of traps or secret places' (Lefebvre, 1991: 28). It is from this paradox that the illusion of transparency emerges, namely, the idea that GIS is a transparent window to the world despite its political and selective character.

Harwell (2000) provided a good example of the illusion of transparency in relation to a case study close to role of GIS in the Indonesian rainforest. In particular, she compared how environmental activists, international donors and the government used GIS to support their own political stance in relation to a series of fires that devastated the country in 1998. She noticed, for instance, that the Indonesian government used GIS to develop an analysis that blamed the fires on El Niño (a natural weather occurrence) and local farmers, relieving in this way the owners of palm tree plantations who have close ties with senior officials. However, by using similar GIS-based data, environmental activists were able to show that the presence of fires was closely related to the conversion of native rainforest to commercial palm tree crops. Nevertheless, despite the stark differences between these GIS objectifications and the clear role of politics in shaping them, she noticed that GIS was still seen as being

inherently superior to the oral accounts of the native inhabitants of those forests. This and other studies about the relation between scientific objectification and oral accounts suggest that GIS and other advanced technologies incite an unshakable trust in the neutrality of technology despite overwhelming evidence to the contrary (see also Klepeis, 2006; Roberts et al., 1995; Sletto, 2002; Taylor et al., 1995).

Other studies within the social sciences also point to the performative dimension of the process of objectification and, even if only indirectly, to how it contributes to the illusion of transparency mentioned above (Goodwin, 1994; Heritage, 1984; Johnson, 2008; Latour, 1999; Neyland, 2006). Garfinkel (1967) and Sacks (1972) provided one of the first studies that examined how objective facts emerge in practice. By looking closely at the practices of forensic doctors and policemen, respectively, Garfinkel (1967) and Sacks (1972) revealed that the process of objectification behind the establishment of legal facts (i.e. objective statements deemed trustworthy) is a practical accomplishments of competent professionals. They also emphasized that it would be wrong to attribute a direct relation between an external reality, independent of any observer and the existence of those facts. Instead a person can only become a suspect and a body the outcome of a homicide as a consequence of series of practical actions (i.e. filling up forms, talking to colleagues, doing a full body search). Furthermore, the authors argue that these actions do not create an absolute truth, but rather a 'rational-adequacy-for-all-practical-purposes' in relation to the task at hand (Garfinkel, 1967: 8).

More recently, these insights also contributed to the study of how scientific and organizational objectivity is accomplished in practice (Fuchs et al., 1994; Jasanoff, 1998; Lynch et al., 2003; Roth et al., 1999). An important outcome of this literature is that the trustworthiness of objectifications depends on the ability of their creators to erase the traces of their own agencies from the outcomes of their work. Golan (2004), for instance, highlighted that in order for X-rays to become a trustworthy 'silent witness' it was crucial to marginalize the role of photographers in their use so that the statements produced by them appear as objective facts devoid of any subjective interference. More recently, Neyland (2007) made a similar argument in relation to 'transparency reviews' (i.e. documents providing the objective evidence of an organization's environmental record, financial situation, etc…). He argued that instead of opening up organizations for scrutiny the reviews present a specific version

of the organization aimed at answering the expectations of the external reviewers. Moreover, he also provides further evidence of the performative nature of objectivity by showing the practices behind the construction of these normative versions of the organization for external audiences. In this way, these studies suggest that the illusion of transparency should be understood as the outcome of specific practices rather than merely a cultural phenomena related to the superiority of positivist epistemology.

Many studies mentioned above suggest that the process of objectification promoted by GIS and other technologies tends to bring more negative consequences than benefits for the general population. In particular, the process of objectification fostered by GIS should be understood as being selective, that is, as only being able to represent a portion of the elements it aims at reflecting. The selectivity of objectivity, in turn, renders some aspects of work more visible and other invisible. Furthermore, even though objectifications are inherently selective and political, they are often seen as holistic and neutral; a phenomenon that renders the selective character of objectifications even more damaging since it prevents the search for alternative forms of engagement and understanding. This body of literature, however, frequently fails to provide an adequate indication of how to tackle the negative outcomes of objectification. Further to this, many studies exploring objectification tend to do so from a bird's-eye view largely neglecting in this way the particularities of the social context in which an event takes place. This is particularly evident within the GIS literature. From this many literature reviews in this field have concluded that there is an urgent need to study GIS in practice, rather than in theory or historically (Chrisman, 2005; Georgiadou et al., 2009; Leeuw et al., 2010; Richter et al., 2010). The next sections provide a review of the literature on joint work and boundary objects. By combining ideas stemming from the literature reviewed so far with these more detailed accounts of the role of technology in joint work this thesis aims to obtain a better starting point to analyze the role of GIS in the Amazon.

2.5 Joint work across boundaries

This chapter continues the review of the literature by highlighting how GIS and other technologies may be implicated in joint work across boundaries. However, before dealing explicitly with the relation between artifacts and joint work it is important to

define what a 'boundary' is, and to determine how it is implicated in our understanding of the challenges of joint work.

2.5.1 Boundaries and practices

In everyday language, the term 'boundary' is mainly used to denote the physical lines dividing space, such as the boundaries between two countries. Within the social sciences, however, this term has acquired a much broader meaning. Starting from notions such as 'forms of life' (Wittgenstein, 1958/1986: 88), 'thought collectives' (Fleck, 1979), 'webs of significance' (Geertz, 1973) and 'social worlds' (Strauss, 1978), the social sciences expanded the understanding of boundaries to any sort of division that divides and identifies different social groups. From this, studies emerged where boundaries can be found in a wide variety of dimensions. These include, for instance, the division between the proletariat and capitalists (Marx, 1867/1990), Protestants and Catholics (Weber, 1905/1992), scientists and laymen (Evans, 2005), men and women (Lamont et al., 2002), the users and developers of technology (Suchman, 1994) and competing political groups within an organization (Hayes et al., 2000). Therefore, boundaries can be not only geographical but also epistemological, religious, political, cultural to cite some possibilities. Furthermore, even though boundaries are usually discussed separately for analytical purposes, in practice people live at the intersection of many boundaries which often conflict (Espinosa et al., 2003; Lamont et al., 2002). Thus, a person can simultaneously be Brazilian, Portuguese, a computer scientist, a social scientist, a baroque singer, a student, a member of the family Rajão and so forth.

The study of occupational boundaries (i.e. divisions relating to the presence of a specific set of practices) has dominated much of the literature within management and organization studies as well as the related research about information systems. A common feature of these studies is the idea that occupational communities tend to develop complex social practices which are only fully understood by those working in the same function. Therefore, social practices should be understood as situated, complex, fuzzy and irreducible (Blackler et al., 2000; Boland et al., 1995; Engestrom et al., 1995; Schatzki, 2002). One of the most illuminating empirical accounts of the situated aspect of practice and the difficulties related to crossing occupational boundaries are the studies elaborated by a group of researchers connected to Xerox

PARC in California (Brown et al., 1991; Lave et al., 1991; Orr, 1996; Suchman, 1987). The detailed ethnography of Julian Orr (1996) about a group of repairmen showed that the social practices involved in fixing photocopiers are much more complex than managers, training programs and manuals assumed. Orr (1996) indicated that technicians have to skillfully draw on their own and the groups' work experience in order to make sense of a series of clues coming from both the machine and customers so that they can do their jobs. Furthermore, a crucial but invisible aspect of the technicians' work were 'war stories' told and retold amongst the technicians in order to share experiences and maintain and expand the highly complex knowledge-base behind their practices. He also found that despite the importance of on-the-job experience, skills and storytelling for repair practices, these aspects tended to be overlooked by managers, with serious consequences.

The notion of a 'community of practice' has been one of the most influential ways to conceptualize the relation between practices and the emergence and maintenance of the sort of occupational boundaries described in Orr's (1996) ethnography. Based on detailed studies of communities ranging from meat cutters to naval quartermasters, Lave and Wenger (1991) pointed out that the process of socialization into a new community takes time and effort. Specifically, it involves a 'legitimate peripheral participation' through which newcomers are able to observe and slowly acquire the vocabulary, practices and skills necessary to engage in the core set of activities that characterize that specific community (Boland et al., 1995; Brown et al., 1991; Wenger, 2000). However, despite the insulated nature of occupational boundaries, modern organizations often have to work across such boundaries in order to accomplish their aims (Boland et al., 1995; Tsoukas, 1996). Thus, for instance, the delivery of health services is likely to involve not only doctors but also nurses, administrators, politicians and policy makers, with each one operating within his or her own community of practice.

The recognition that social practices are situated within a given set of boundaries has important consequences for understanding joint work practices across boundaries. Here, the crossing of boundaries is seen not only as a movement between functions within an organization, but also constitutes an engagement with different social worlds, containing local languages and practices that are often exotic to outsiders (Engestrom et al., 1995; Gherardi, 2000). Hence, 'crossing boundaries involves

encountering difference, entering onto territory in which we are unfamiliar and, to some significant extent therefore, unqualified to act' (Suchman, 1994: 25). The next section provides a detailed definition of joint work and a review of the studies that discuss how it could be managed.

2.5.2 Joint work and levels of engagement

Broadly speaking joint work refers to processes whereby a certain outcome depends directly on the input of different people. It may range from officials obeying orders from a distant centre of power (Cooper, 1992) up to two team members cooperating closely in the judging of a legal process (Engestrom et al., 1997). Joint work may also vary in time, lasting from only few minutes, as in the case of a buyer and seller negotiating a price or a temporary team in an emergency, to many centuries, as in the case of the relationship between governments and citizens in many modern states (Engestrom, 2006; Lanzara, 1983; Powell, 1990). Even though terms such as 'collaboration', 'cooperation' and 'coordination' are often used as synonyms for joint work, some authors point out that it is useful to differentiate between their meanings in order to describe the different levels of engagement for the parties involved (Collins et al., 2007; Engestrom et al., 1997; Heckscher, 2007; Powell, 1990). In particular, it is possible to identify four types of joint work (see Table 3).

Coercion	Imposed joint work involving an alignment of interests and forced compliance (e.g. slavery, imperialism)
Coordination	Vertical joint work involving delegation and control at a distance (e.g. hierarchical relations, lines of command)
Cooperation	Horizontal joint work that maintains the independence of the groups involved (e.g. inter-departmental work, networks)
Collaboration	Transformative joint work involving negotiation and learning (e.g. participatory software development, knowledge sharing)

Table 3 Levels of engagement of joint work across boundaries

Coercion

This type of joint work indicates situations in which one group compels the participation of another group, usually through the use of force. Slavery is the most extreme example of coercive joint work. Here, as in any type of joint work, it is necessary to establish a certain level of mutual understanding. But this mutual understanding does involve any form of deep engagement between the two groups.

Thus, the line of communication is often reduced to the bare minimum necessary for the immediate accomplishment of the interests of one of the groups. For instance, a slave in a Roman galley did not need to speak Latin, let alone share the practices and culture of his masters in order to contribute to the functioning of the ship. Instead, the beating of a drum was in most cases sufficient for the emergence of a mutual understanding whereby the slave knew how often he needed to row in order to receive his meal and avoid being punished (Collins et al., 2007).

This type of joint work has been particularly preeminent in the accounts from actor-network theorists of how different actors came together to form stable scientific theories and technologies (Harman, 2009; Miettinen, 1999; Star et al., 1989). The 1980s was a period of intense theoretical debate in the field of science and technology studies (STS). By drawing upon Merton, Kuhn and other pioneers in the field, different authors in variety of ways challenged the positivist notion that science is a mere reflection of nature, and that consensus around new 'discoveries' emerges smoothly as more rigorous experiments and new instruments are created. The actor-network theory (ANT) was one of the approaches developed to oppose this view that attracted more attention and criticism. As mentioned above, ANT conceptualizes social reality as emerging from the networks composed by heterogeneous humans (scientists, politicians, tax-payers…) and non-humans (bacteria, instruments, money). Specifically in relation to scientific work, the proponents of ANT suggest that strong scientific statements emerge from the ability of some actors to create aligned heterogeneous networks. For this purpose, actors may force other actors to join their networks (e.g. a colleague from another field) by inscribing in them their own interests (e.g. presenting the data of his/her work in certain ways), so that this actor start acting on the behalf of the former (e.g. providing evidence for his/her own scientific theory) (Callon, 1986; Latour, 1987; Latour et al., 1979).

Coordination

This type of joint work indicates a situation where the social interaction between actors involves delegation and control at a distance, usually within a formal line of command. This is the most common form of joint work, and features in all organizations that contains some form of hierarchy (Powell, 1990). Coordination is often related to the needs of managers in organizations with increasing complexity and size to maintain control over their employees via bureaucratic mechanisms

(Donaldson, 2001; Heckscher et al., 2006). As with coercion, coordination has a vertical relation, whereby there is necessarily an actor coordinating and another being coordinated. This often entails the monitoring of the activities of those being coordinated, which in some cases may be done at a distance. Furthermore, in line with coercive joint work, coordination does not require the creation of deep forms of mutual understanding, since in many cases the interaction between coordinators and coordinated is limited to objectifications of work such as performance indicators and internal reports (Adler et al., 2006; Cooper, 1992).

Nevertheless, in contrast to coercion, the forces propelling compliance are subtler and allow the possibility of subversion since the coordinators often rely on their subordinates to get the work done, and the coordinated may chose to disobey or even quit the organization. Moreover, it is particularly the case in modern organizations that there is always the possibility that an actor who is being coordinated today may have a promotion and become a coordinator tomorrow. Therefore, in contrast to coercion, coordination maintains the possibility of mobility or learning between groups, even if it is not a prerogative of this type of joint work (Collins et al., 2007).

The Taylorist industrial plant is where the archetypical coordination takes place. On the one hand, there are managers who plan the functioning of the plant; these enforce specific work scripts onto the workers and monitor their practices (Adler et al., 2006; Taylor, 1911/2005). On the other hand there are the plant workers who may obey the orders from the manager, or choose to subvert their orders by decreasing their productivity or by not going to work. Similarly, in the public sector this type of joint work is referred to as a command-and-control culture where 'those further down the hierarchy are treated instrumentally and experience a lack of choice and freedom' (Chapman, 2004: 55). Less extreme forms of coordination may also involve situations where workers have the freedom to decide how they carry out their work, and are accountable only to its final output. In both cases, however, both groups rarely attempt to engage with each other's work in order to find common solutions. Engestrom (1997: 372) defines this aspect of coordination as the 'normal scripted flow of interaction coordination [whereby] the various actors are following their scripted roles, each concentrating on the successful performance of the assigned actions'.

Cooperation

This type of joint work contemplates a wide variety of situations. It ranges from stable relations between agencies in the public sector (Engestrom, 2001) to more transient and volatile inter-departmental projects in large organizations (Blackler et al., 2000) as well as research and development agreements between competing companies (Powell, 1990). In some cases, cooperation may take place in exceptional or one-off situations where temporary joint work has to take place in order to deal with a natural disaster (Lanzara, 1983) and solve a technical problem with a client (Spinuzzi, 2008). Despite the different contexts described, in all the instances mentioned above the different groups are able to maintain their independence while working together and are not linked by direct hierarchical relations. As in coordination and coercion, in most cases cooperation does not involve the emergence of shared practices or deep mutual understanding. Instead, the different parties involved are usually more interested in the final outcome of their side of the joint work, than the concerns and practices across boundaries. Thus, even though partners in cooperation may respond to a specific request, they rarely challenge their own practices in this process[1] (Engestrom et al., 1997).

Therefore, the main difference between coordination and cooperation lie in the horizontal character of the latter. While in coordination there is a clear power relation between the parties involved, participation in cooperation is optional and depends on the willingness of both parties. In any case, cooperation rarely takes place in a pure form. The reasons for this are that the individuals involved in cooperation are usually also being coordinated by their own organizations, and in some instances, participation may even be indirectly discouraged due to particular circumstances (Heckscher et al., 2006). This suggests that coordination may force the parties involved to confront particular dilemmas: at one extreme, an actor may refuse to cooperate to give an advantage to his or her own organization and undermine the joint work, while at the other extreme, he or she may be seen as a traitor within the actor's own hierarchy by giving too much to other groups (Pettigrew et al., 2000). For this reason, different authors point out that communication needs to be more intensive in cooperation than in coordination (Sullivan et al., 2002) and that it is crucial to build

[1] For Engestrom et al. (1997), coordination also involves the joint search for solutions and a process of negotiation of shared aims. In this thesis these aspects of joint work are attributed only to collaboration.

trust across boundaries in order to foster successful cooperative relations (Alter et al., 1993; Heckscher et al., 2006).

Collaboration

An important issue in the literature reviewed above is how to foster effective joint work across boundaries. A sizable portion of the management literature (in particular the studies based on a positivist perspective) give the impression that increasing levels of centralization, control and social engineering lead to a more effective relationship between the different parts of the organization. This tendency can be seen in Frederick Taylor's (1911/2005) scientific management and more recently in attempts to improve joint work through initiatives such as business process reengineering (Hammer et al., 1993), total quality management (Boje et al., 1993) and target-driven approaches in the public sector (Chapman, 2004; Miller, 2003).

A growing body of literature on the challenges of joint work, however, suggests a different direction. By pointing to broad social phenomena, such as the emergence of the knowledge economy and globalization, these studies have argued that organizations in the private sector should become more dynamic and adaptable (Alter et al., 1993; Heckscher, 2007; Powell, 1990). In this context, these studies have suggested that traditional forms of coercion, coordination and cooperation are no longer sufficient (Blackler, 1995; Boland et al., 1995; Tsoukas, 1996). For instance, Adler and Heckscher (2006: 30) defined the limits of traditional coordination and cooperation (here understood as hierarchies and markets) in the context of this new social context as follows:

> *For this* markets and bureaucracies are not the answer. Markets involve an exchange of the products of knowledge: individuals get the output of specific expertise but not the ability to interact with it and improve it. Bureaucracies, similarly, structure interactions so that each person performs in a box and 'throws' the output 'over the wall' to the next; the only combination occurs by moving up the hierarchy, where the superiors are supposed to know everything their subordinates know. This system crumbles when superiors no longer can grasp the full scope of the problems on which their subordinates are working. (*ibid*: 30, italics in the original)

Other authors have also highlighted similar transformations in the public sector. Due to budget cuts, decentralization and the push towards the integration of services, the reliance on traditional top-down forms of joint work are becoming problematic (Blackler, 2006; Lipsky, 1980). For instance, when referring to the consequences of the prevalence of target-driven approaches in the British public sector, Chapman

(2004: 55) concluded that civil servants tend to be 'focused on meeting the latest target or directive passed down from above instead of [being] focused on the actual needs of their clientele'. From this, different studies have suggested that organizations should attempt to adopt more engaged forms of joint work (Boland et al., 1995; Engestrom, 2001; Spinuzzi, 2008). However, this does not imply that hierarchies and power relations will disappear or be replaced by egalitarianism and brotherhood. Rather, this perspective recognizes that increasingly complex organizational contexts require greater efforts from managers and workers in order to manage the many boundaries and functions effectively (Adler et al., 2006).

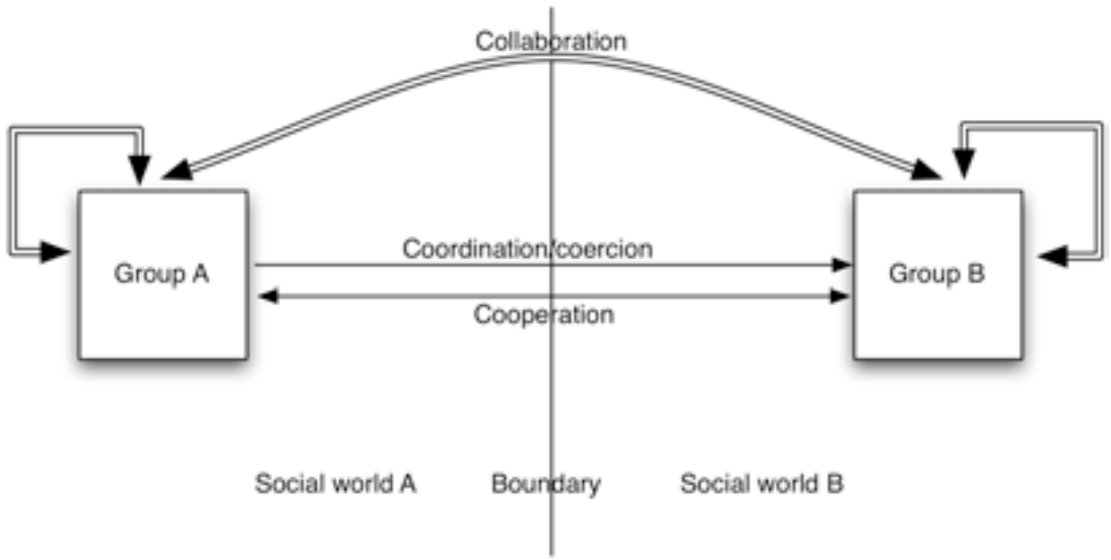

Figure 4 Types of joint work: coercion, coordination, cooperation and collaboration

Reduced to its root definition in Latin, collaboration means *cum laborare*, or working together. In this broad sense, collaboration is close to the meaning of coordination, meaning 'order things together' and cooperation meaning 'operate together'. However, within the social sciences this term came to develop a much more specific meaning, making it qualitatively different from the other types of joint work (Adler et al., 2006; Engestrom, 2008; Gray, 1989). Figure 4 illustrates this difference. As the unidirectional arrows connecting two different groups across boundaries suggest, coercion and coordination involve the imposition of the will of one group onto another. With cooperation, in contrast, this relation is bidirectional, meaning that there is no hierarchical relationship between the groups involved and the information and work outcomes flow either way. Nonetheless, as suggested by the single line both coercion, coordination and cooperation require the emergence of a relatively

superficial level of common understanding only. In this way, these forms of joint work keep the different practices largely intact while engaging occupational groups across boundaries.

In collaboration, in contrast, the relationship is not only bidirectional but also transformative. As the self-referential arrows suggest, collaboration is 'an interactive process having a shared transmutational purpose' (Roberts et al., 1991: 209). Hence, collaborating individuals engage in 'a process through which parties [that] see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible' (Gray, 1989: 5). This process may take place between organizations and departments (as in the cooperation between groups) and also within the line of command of an organization (as in coordination). Thus, what distinguishes collaboration from other types of joint work is not its particular organizational form (i.e. vertical/horizontal, hierarchical/networked) but the willingness of its participants to immerse themselves in the foreign territory and, based on this experience, to reflect on their own practices (Engestrom et al., 1997). For this reason, as the double stroke line suggests, the level of common understanding required for collaboration is much deeper than with other forms of joint work.

Different studies have discussed collaborative joint work and how it is opposed to the prevalent instrumental and positivist views on the matter (Chapman, 2004; Gray, 1989; Levina et al., 2008; Lipsky, 1980; Sullivan et al., 2002). In particular, it is possible to identify three main ways in which this issue has been understood: communicative action, knowledge sharing and learning across boundaries. An important starting point for the debate on the importance of collaboration can be found in the theory of communicative action by the philosopher Jürgen Habermas (1984). Even though this philosopher was mainly interested in dynamics at a societal level such as with democracy and the rule of law, his distinction between strategic and communicative social action lies at the heart of the debate concerning collaboration at organizational level. Specifically, by drawing on the work of Max Weber and Karl Marx, Habermas (1984: 286) argued that strategic action involves 'egocentric calculations of success' whereby the people involved are seen as mere instruments or mediums for reaching a specific goal. Moreover, even if this type of social action is the most common in contemporary society, Habermas (1984) pointed out that its

overuse is leading to alienation and preventing social groups from discussing their concerns and reaching mutual agreements. In this context he proposed that society should foster a form of rationality based on communicative rather than strategic action, whereby:

> [The] participants are not primarily oriented to their own individual successes; they pursue their individual goals under the condition that they can harmonize their plans of action on the basis of common situation definitions. In this respect the negotiation of definitions of the situation is an essential element of the interpretive accomplishments required for communicative action (Habermas, 1984: 286).

From the definition above, it is possible to see that the strategic or instrumental action described by Habermas (1984) is closely related to coercion, coordination and cooperation as defined above. In both cases, the coercing or coordinating side of the joint work sees the other side as a mere instrument of its aims: a passive actor whose interests can be translated and aligned to a powerful network in a Machiavellian manner. Furthermore, even though with cooperation no side has direct powers over the other, their relationship is often restricted to the instrumental outcome of each other's work. On the other hand, in communicative action both parties collaborate and negotiate in an open and constructive manner with joint solutions, even if this involves changing their own plans (and practices). It is this vision that is particularly evident in studies that highlight the importance of adopting participatory approaches where different groups are able to voice their concerns and shape the outcomes of the policies and technological artifacts that are directly relevant to them. Studies inspired by these ideas include the use of participatory GIS in policy-making (Harris et al., 1995; Jankowski et al., 2001; Sieber, 2006) as well as participatory software development methodologies (Bodker, 1996; Schuler et al., 1993).

The notion of knowledge sharing (and the management of this process) initially emerged as a way to describe how organizations could foster innovation and avoid losing a competitive advantage (Choo, 1996; Nonaka et al., 1995). By expanding (and quite often criticizing this work) different authors proposed that knowledge management was relevant not only for fostering innovation but also as a way of increasing collaboration between different parts of the organization. Specifically, these authors deny the view of knowledge as a static entity that can be encoded and transferred at will. Instead, by drawing on the practice literature they suggested that engaged forms of collaboration involve the view of knowledge as an entity that is

enacted on an everyday basis and situated within the many communities that compose modern organizations. Consequently, knowledge sharing is seen as a difficult but necessary process involving the recognition of differences between perspectives and the willingness to engage in new territories (Blackler, 1995; Boland et al., 1995; Brown et al., 1991; Gherardi, 2000; Orlikowski, 2002; Tsoukas, 1996; Wenger, 2000). Tsoukas (1996) proposed one of the most influential accounts of how collaboration and knowledge sharing are closely related. Firstly, the author conceptualized organizations as 'decentred knowledge systems', but due to the situated character of knowledge, these cannot be known by a single person or surveyed and controlled by managers from 'the cognitive equivalent of a "control room"', as implied by Taylorist approaches (ibid: 22). Hence, even though managers may attempt to coordinate their employees and regulate the way in which they cooperate with others (e.g. by imposing certain rules) people will necessarily interpret those rules according to their own body of knowledge in the face of the 'inescapably contingent-cum-local matter' where they are operating (*ibid*: 22). In the light of this, Tsoukas (1996) suggested that instead of attempting to micro-manage people's actions, managers should try to create the conditions for knowledge sharing.

Finally, other studies have highlighted the importance of collaboration by conceptualizing organizations as learning systems (Brown et al., 1991; Gherardi, 2000; Wenger, 2000). In both cases it is possible to see an emphasis on joint work as a transformative endeavor involving reciprocity and the creation of deep forms of mutual understanding as opposed to the more superficial forms of top-down coercion, coordination and cooperation. Argyris and Schön (1978) provided one of the first studies proposing the notion that organizations must be dynamic learning systems rather than static entities. Drawing upon the Bateson's concepts of first and second order learning, the authors pointed out that organizations tend to adopt a single-loop learning, namely a process similar to the process of cooperation defined above whereby individuals, groups and organizations modify their actions by comparing the expected and obtained outcomes. They argue, however, that organizations should also attempt to engage in second-order learning, that is, they should be able to question the values and assumptions leading to their actions in the first place.

Based on Bateson works but also on the Marxist and Russian psychological tradition, other authors have conceptualized organizations as activity systems which should

engage in ‘expansive learning’ in order to improve their joint working practices (Blackler, 2009; Engestrom, 2001: 151; Nardi, 1996). From this perspective, activity systems (and the joint working relations taking place within them) continually generate contradictions and tensions between the participating groups. However, even though these contradictions clearly create problems and hinder the effectiveness of joint work, they are not necessarily negative: the acknowledgment of these contradictions may lead to a process of change. In some circumstances this change process prompts individuals to engage into ‘expansive learning’, namely, the collaborative effort ‘to embrace a radically wider horizon of possibilities than in the previous mode of the activity (Engestrom, 2001: 137).

More recently, Spinuzzi (2008) also pointed out the importance of recognizing organizational issues in dynamic, geographically dispersed and multi-disciplinary organizations. Referring to a case of a telecommunication company, the author emphasized that networked organizations require a set of (often invisible) practices in order to ensure effective cooperation between independent groups. In particular, he indicated that breakdowns and misunderstandings should be seen as inherent to joint work in complex organizations. These organizations should not try to avoid issues at all costs, but rather learn how to deal with them constructively. In this way, Spinuzzi (2008) suggested that learning should take place not only in the context of major turning points, as sometimes implied by the notion of ‘expansive learning’, but also in the context of small breakdowns that emerge on a daily basis. Spinuzzi (2008) also made a series of pragmatic recommendations on how to foster collaborative relations that are able to continually mend breakdowns. For example, he argued that managers should learn how to trace regular information flows to make sure they are working well and correct them if necessary. In other words, managers should be able to open the many black-boxes that compose the organization and actively mend their breakdowns when necessary. In addition to corrective measures, Sipinuzzi (2008) encouraged managers to think strategically, that is, to anticipate issues and act preventively. In this regard, managers should train workers formally as well as informally to allow them to learn with their colleagues from other occupational groups and look for, cultivate and support liaisons, these being workers who are able to circulate between groups and bring information and knowledge back and forth (see also Wenger, 2000). He also pointed out that workers should act more like managers

by learning how to manage their time and holding a broader view of how their specific work fits into the overall scheme of the organization. Finally he argued that workers needed to become more adaptable in order to learn quickly, develop arguments, build trust and negotiate shared solutions across boundaries.

From the review above, it is possible to see how practices (i.e. bureaucratic control, learning, knowledge sharing) and people (i.e. liaisons, managers, workers) are key elements in understanding joint work and how to achieve collaboration. Following from this, the next section continues the review by presenting the literature on the role of artifacts in joint work, with particular focus on the notion of boundary objects.

2.6 Boundary objects and joint work

In the last two decades, a growing body of literature has highlighted the role of objects in joint work across boundaries (Boland et al., 1995; Goodwin, 1995; Hayes, 2001; Latour, 1999; Levina et al., 2008; Orlikowski, 1994; Spinuzzi, 2008; Star et al., 1999; Winograd, 1994). Among the different theoretical approaches in the literature developed to conceptualize this issue, the notion of a 'boundary object' has undoubtedly been one of the most influential (Trompette et al., 2009; Zeiss et al., 2009). This section presents a review of the origins and varying uses of this notion, with particular emphasis on the way it has been used to study information technology and GIS in organizations.

2.6.1 The origins of a concept

The notion of boundary objects was initially proposed by Susan Leigh Star and James Griesemer (1989) in the context of a study of the creation of the Museum of Vertebrate Zoology at the University of California in Berkley. Here, the authors proposed a conceptual framework to study scientific cooperation (i.e. non-hierarchical joint work) and the emergence of common representations across 'diverse intersecting social worlds'. Even though the notion of boundary objects has been expanded in different directions since the publication of the initial article, it is important to understand the early concerns that motivated the authors to propose this notion and its specific original meaning.

As mentioned above, ANT tends to present scientific joint work as a 'Machiavellian' process: an endeavor whereby an actor or group of actors manipulate and coerce other

actors in order to form stable and aligned networks under their control (as gate-keepers) so that they can perpetuate their interests (Fujimura, 1992; Miettinen, 1999). The joint work process described by ANT is clearly useful in explaining the emergence of the scientific consensus around particular scientific theories, such as the paradigms shifts described by Kuhn (1962) between Newton's mechanics and Einstein's quantum theory. Star and Griesemer (1989) pointed out, however, that not all forms of joint work presuppose the presence of a consensus among the different parties. In particular, the authors highlighted that the creation of the museum in California between 1907 and 1939 involved neither the strict alignment of interests presupposed by ANT nor the presence of a single gatekeeper able to translate the interests of several actors into a narrower passage point. Instead, by analyzing the interactions between the professional scientists, the amateur scientists and other groups, they observed a situation whereby the translation of interests and the creation of passage points occurred as a 'many-to-many' relationship without the prevalence of a specific actor or the emergence of a strongly aligned network. Furthermore, the authors found that some artifacts and concepts (i.e. standard forms, repositories, general models, maps) and shared practices (i.e. specimen preservation procedures, note keeping practices) were crucial for the success of the joint work between the multiple groups.

Star and Griesemer (1989: 393) defined these practices as 'standard methods' and the artifacts as 'boundary objects', that is to say as objects at the margins between these groups which allowed 'different groups to work together without consensus' (Star, 2010: 602). As a result, Star and Griesemer (1989) set out to describe forms of joint work that were different from the coercion implied by ANT. This distinction is clear in the conclusion of the paper where the authors explained that 'the production of boundary objects is one means of satisfying these potentially conflicting sets of concerns. Other means include the imperialist imposition of representations, coercion, silencing and fragmentation' (*ibid*: 413). In this way, the authors explicitly excluded the relationship between boundary objects and coercion, and focused instead on the role of artifacts, concepts and practices in cooperation. In their view, the cooperation in scientific work created 'common understandings [which would] ensure reliability across domains and […] gather information [that would retain] its integrity across time, space and local contingencies' (*ibid:* 387); from this it would obtain a 'mutual

modus operandi' (388). However, the examples provided by authors suggested that these 'common understandings' and 'mutual modus operandi' may range from a simple exchange of specimens for money between scientists and trappers, to more intense cooperation between scientists and amateur collectors with the use of maps and structured field notes. This suggests that the original notion of boundary objects indicated more superficial forms of joint work (with the exception of coercion), even if it did not preclude the possibility of collaboration as defined in the previous section.

In a frequently quoted passage, Star and Griesemer (1989: 393) defined boundary object as artifacts and concepts that:

> [B]oth inhabit several intersecting worlds […] and satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. (Star and Griesemer, 1989: 393)

The excerpt above as well as Star's (2010) recent clarification suggest that boundary objects should be understood as having three partially overlapping aspects, namely interpretive flexibility, the dynamic between ill-structured and more tailored uses of objects and an informatic structure and work processes. It is to these three aspects that we now turn our attention in attempting to elucidate the meaning and mechanisms behind the notion of boundary objects (see Table 4).

Interpretive flexibility	The possibility of shaping an object to tailor local informational and work needs.
Dynamic between ill and well structured uses	The transition between local and general uses while maintaining a single identity.
Informatic structure and work processes	The structure of the content being shared through the boundary object and related common coding/decoding practices.

Table 4 Aspects of the notion of boundary objects (based on Star, 2010)

Interpretive flexibility

By far the most studied aspect of boundary objects is the ability of certain artifacts and concepts to 'be both plastic enough to adapt to local needs and the constraints of the several parties employing them' (Star et al., 1989: 393). As mentioned in Subsection 2.3.3, the notion of plasticity or 'interpretive flexibility' is one of the cornerstones of the constructivist approach to the study of technology (Star, 2010: 602), and, as seen above, has already been explored in detail in the context of GIS

implementations (e.g. Sahay et al., 1996). An important novelty developed by Star and Griesemer (1989), however, was the idea that this flexibility facilitates joint work across boundaries.

Star and Griesemer (1989) recognized that the work involved in the establishment of the museum 'encompassed a range of very different visions stemming form the intersection of participating social worlds' (*ibid*: 396). Consequently, the different groups involved in this effort had varying needs and interests that needed to be catered for. For instance, while amateur collectors wanted to collect and conserve the local fauna and flora, trappers wanted meat, skins and furs to earn money and eat, Joseph Grinnell wanted data to demonstrate his theory and Annie Alexander was interested in conservation and educational philanthropy. Thus, Star and Griesemer (1989) suggested that for an object to be accepted within a given social world and have a local use it needed to be sufficiently flexible to meet the needs and contingencies of these different groups or run the risk of being irrelevant.

Dynamic between ill and well-structured uses

More recently Star (2010: 602) reinstated the importance of interpretive flexibility when referring to the maps of the state of California:

> [A] road map may point the way to a campground for one group, a place for recreation. For another group, this ''same'' map may follow a series of geological sites of importance, or animal habitats, for scientists. Such maps may resemble each other, overlap, and even seem indistinguishable to an outsider's eye. Their difference depends on the use and interpretation of the object.

The excerpt above not only draws attention to the interpretive flexibility of maps but also suggests that boundary objects have a double identity. On the one hand, these boundary objects need to be local, strongly structured and tailored to the needs of a specific social world (i.e. a map showing animal habitats); on the other hand, these local uses are linked to general, weakly structured versions that have common uses across boundaries and are 'robust enough to maintain a common identity across sites' (Star and Griesemer, 1989: 393). This dynamic between ill and well-structured uses of objects is one of the key mechanisms of boundary objects in enabling joint work (Star, 2010). To return to the example of the map, while pointing to locations in a map, amateurs and the professional scientists had different well-structured uses for this object; amateurs used their tailored version of the map to find particular beauty spots where they could camp and take pictures. The scientists, in contrast, used their

map in a well-structured way to identify and classify the habitat of specific animal and plant species. However, despite these differences, the two groups were able to collaborate because they shared an ill-structured practice that sees these objects as maps of California that are comparable to each other. In this way, even though these maps had different contents and were used use differently, they offered a basis for the emergence of a common understanding (e.g. the information of where a specimens was collected), even if this understanding was only transient and superficial.

Informatic structures and work processes

The discussion regarding the ability of boundary objects to metamorphose from ill to well-structured uses and back is also related to the ability of some objects to be used across different locations. In order to discuss this aspect of boundary objects, Star and Griesemer (1989) drew upon the notion of 'immutable mobiles', namely 'objects which can be transported over a long distance and convey unchanging information' (Star et al., 1989: 411). The notion of immutable mobile has its origins in the discussions by Bruno Latour (1987) and John Law (1987) (two actor-network theorists) regarding the role of artifacts, such as official documents, ships and maps, in enabling coordination at a distance (see also Cooper, 1992; Kallinikos, 2006; Lilley et al., 2004). One of the main examples used by these authors is the role of maps as immutable mobiles in the European maritime expansion. Specifically, the authors explained that maps were important because they allowed distant actors to understand the physical environment in similar ways, even if they never met face-to-face or had been to the places represented by the map. In the following excerpt, Latour (1987: 224) explained this point:

> There is no way to bring the lands themselves to Europe, nor is it possible to gather in Lisbon or at Versailles thousands of native pilots telling navigators where to go and what to do in their many languages, […but] [b]y coding every sighting of any land in longitude and latitude (two figures) and by sending this code back, the shape of the sighted lands may be redrawn by those who have not sighted them.

The excerpt above suggests that the way in which navigators codified information in their maps (i.e. in longitude and latitude) was an important element that enabled an object to function as a boundary object and travel long distances through time and space. In the original paper of Star and Griesemer (1989) the authors referred to this as 'standardized information' and the related 'methods of standardization', but more recently Star (2010) used the term the 'structure of informatic' or informatic structure.

Specifically, the authors suggest that the structure of a boundary object is not arbitrary but emerges from the information and work needs of the different groups using it. For instance, Star and Griesemer (1989) explained that the fieldwork notebooks were organized in a format that amateur naturalists would be able to record the habitat and time of capture in a standard way. This informatic structure was crucial for facilitating effective cooperation between amateurs and professionals in scientific research; it was thanks to it that scientists were able to analyze individual specimens and include this data in their research even though they were at a distance of hundreds of kilometers and many months from the place and moment of collection. Similarly, because of this standard, scientists were able to compare the data collected by amateurs over the years and develop scientific theories describing large-scale phenomena.

2.6.2 The development of a concept

Since the publication of the original article, the notion of boundary objects has enjoyed a vigorous academic life (Barrett et al., 2010; Trompette et al., 2009; Zeiss et al., 2009). In science and technology studies (STS), this notion has been used to study the cooperation between scientists within and between disciplines (Collins et al., 2007), and the relation between scientists and the broader society (Guston, 2001). The topics explored by these studies include: the uncertainty in environmental policy-making (Shackley et al., 1996); multiple interpretations of the meaning of 'cancer' in joint research activities (Fujimura, 1992); public understanding of the science of genetic databases (Ratto, 2006); the role of drawings in the design of turbine engines (Henderson, 1991); the role of institutions, such as the European Environment Agency in mediating cooperation (Guston, 2001); and the contestation of scientific expertise in courts (Edmond, 2002).

After a few years' delay, the notion of boundary objects was also embraced by organization and management studies (OMS), and within it, by information systems research. Here, it is possible to find this concept for the study of joint work in many areas including: new product development (Carlile, 2002); project management (Yakura, 2002); knowledge management (Boland et al., 1995; Hayes, 2001); and cross-cultural software development (Barrett et al., 2010). The studies from these two fields also indicated that a wide variety of entities could act as a boundary object, including: scientific discourses (Shackley et al., 1996); ideal types of diseases

(Fujimura, 1992); Gantt charts (Yakura, 2002); legal texts (Edmond, 2002); classification schemes (Bowker et al., 1999); software development methodologies (Barrett et al., 2010); groupware applications (Boland et al., 1995); individuals acting as 'boundary spanners' (Levina and Vaast, 2005); and even entire organizations (Guston, 2001).

The notion of boundary objects has also been influential in critical geography and other disciplines studying the social aspects of GIS technology. As mentioned in the previous sections, much of literature on GIS technology and other representations of space (including traditional maps) tend to either depart from a positivist stance (Fearnside, 2003; Fonseca et al., 2002) or focus on the implications of this technology at societal level (Lefebvre, 1991; Pickles, 1995b). More recently, however, different authors have stressed the importance of attending to social practices and the related implications of GIS at organizational level (Chrisman, 2005; Georgiadou et al., 2009; Leeuw et al., 2010; Richter et al., 2010). From this a small number of researchers have adopted the notion of boundary objects, among other theories, to study: the implementation of new GIS systems and standards (Chrisman, 2005; Harvey, 2009); the relation between GIS data and a shared understanding of geographic phenomena (Ahlqvist, 2005; MacEachren, 2001); the role of GIS in planning practices (Carton, 2007); and participative approaches to policy-making (Puri, 2007).

In these studies it is possible to observe that while some aspects of the original paper of Star and Griesemer (1989) were wholeheartedly embraced, others were largely ignored. In particular, the notion of 'interpretive flexibility' and the role of boundary objects in creating a common understanding can be found in almost all the articles cited above. However, 'standard methods' (i.e. the practices relating to boundary objects), the 'structure of informatics' and the 'dynamic between ill and well structured uses' were largely neglected by the literature (Star, 2010; Trompette et al., 2009; Zeiss et al., 2009). In addition to this, the literature that followed challenged, reinterpreted and complemented the notion of boundary objects in different ways. For instance, in expanding on the original notion of boundary objects, different authors have proposed notions such as 'border-ordering devices' (Shackley et al., 1996), 'boundary infrastructures' (Bowker et al., 1999), 'boundary brokers' (Wenger, 2000), the 'boundlessness' of technology (Hayes, 2001), 'boundary organizations' (Guston, 2001), 'boundary work' (Evans, 2005), 'boundary spanning' (Levina et al., 2005),

'boundary object-in-use' (Levina et al., 2005) and 'boundary negotiating artifacts' (Lee, 2007). Specifically, it is possible to identify four main directions in which this notion was taken forward: the description of other forms of joint work, the study of the emergence of boundary objects, the ability of objects to re-configure boundaries and the contradictory implications of objects (see Table 5).

Concept	Description	Key references
Objects, coordination and collaboration	Boundary objects describe not only cooperation but also coordination and collaboration, including knowledge sharing and learning.	Boland and Tenkasi, 1995; Bowker and Star, 1999
Boundary objects as transformative	Objects not only travel through space and time but also change the configuration of boundaries and the entities being represented.	Lee, 2007; Bowker and Star, 1999
The establishment of boundary objects	Boundary objects are established through complex (and often lengthy) processes that involve negotiation, concessions and the emergence of new practices.	Levina and Vaast, 2005; Bowker and Star, 1999
Boundary objects as contradictory	Boundary objects may help as well as hinder joint work depending on the circumstances of use.	Barrett and Oborn, 2010; Carton and Thissen, 2009

Table 5 Key themes emerging from the literature developing the notion of boundary objects

Objects, coordination and collaboration

As mentioned above, the notion of boundary objects was initially conceived as a way to describe scientific cooperation, this being in stark contrast to the sort of coercion implied by ANT. Some authors also used the notion of boundary objects as 'an alternative to traditional hierarchical coordination' (Sapsed et al., 2004: 1519). More recently, however, some studies have expanded this notion in order to also describe cases of joint work that featured coordination and collaboration. An important study in this direction was provided by Star in collaboration with Geofrey Bowker (1999). Here, the authors argued that classification schemes, such as the international classification of diseases could be understood as 'a boundary object between communities of practice, with a delicate cooperative structure' and depending on their extent, they could also be 'boundary infrastructures', spanning multiple communities of practice and serving as a (frequently invisible) basis for wide-scale coordination across geographically dispersed groups. (Bowker et al., 1999: 152). In their analysis, the authors highlighted that information infrastructures may act not only as a basis of cooperation but also as a 'coordinating mechanisms' between groups. In one of the

examples, the authors emphasized how the introduction of a nursing interventions' classification (and the computer-based information system in which it was embedded) allowed managers to control the work carried out by nurses more tightly and facilitated the coordination of planned change. In the same way, other authors have used the notion of boundary objects to describe joint work taking place in hierarchical contexts. These studies describe, for instance, how specifications allowed the coordination of cross-cultural software development (Barrett et al., 2010), how GIS data standards facilitated administrative coordination in the public sector (Harvey et al., 1998) and how sketches brought about the coordination of design intentions and manufacturing processes (Henderson, 1991).

At the other extreme, some studies promoted a view of boundary objects as the basis for more engaged forms of social interaction in line with the definition of collaboration provided above[2]. In the original paper, Star and Griesemer (1989) indicated their interest in the 'creation of new scientific knowledge'. However, it was only in the OMS literature that the notion of boundary objects was developed as a way of describing instances in which artifacts and concepts become 'important means of achieving collaboration, promoting the sharing of knowledge between diverse groups' (Barrett et al., 2010: 1200; Zeiss et al., 2009). This substantial strand of the literature adopted the notion of boundary objects to highlight, for instance, the challenges involved in fostering expansive learning via artifacts and concepts (Engestrom et al., 1995), the limits of information technology in knowledge sharing (Hayes, 2001), the importance of negotiation in the promotion of IT-based knowledge sharing initiatives (Levina et al., 2005) and how boundary objects transform perspectives and provide opportunities for deeper understanding across boundaries (Bechky, 2003).

Many studies putting forward this point of view can be traced to a work by Boland and Tekansi (1995) on the potential of groupware technology for knowledge sharing. In accordance with the theory of communicative action of Habermas (1984) and the calls in the critical GIS literature for participatory approaches (Harris et al., 1995),

[2] Zeiss and Groenewegen (2009) argued that by relating boundary objects with knowledge sharing and other forms of engaged collaboration some studies within OMS literature were going against certain STS sensibilities. This thesis adopts a different position and considers these studies useful contributions to the original notion.

Boland and Tenkasi (1995) invited members across boundaries to engage in a process of perspective-making and perspective-taking. In particular, the authors argued that communities of practice should attempt to use groupware technology to discuss and solidifying their local knowledge. In this way, these groups would be able to create a stronger and more coherent set of practices. Then, in a second stage, the groups could use groupware technology as a boundary object and embark on perspective-taking, that is, 'a process of mutual perspective-taking where distinctive individual knowledge is exchanged, integrated and evaluated with that of others in the organization' (*ibid*: 358).

Expanding on Boland and Tenkasi (1995), Puri (2007) indicated how GIS was involved in the collaboration between policy-makers, scientists and the local population. He reported how in contrast to previous attempts to introduce GIS in India which preclude any form of collaboration, the local populations were encouraged to draw on the ground (not to scale) their own perceptions of the territory and provide inputs on where to build new watersheds, among other decisions. These small-scale inputs were then incorporated into the GIS database, serving in this way as a basis for an analysis on a larger scale. From this, Puri (2007) concluded that with the introduction of participatory mapping practices the local populations would be able to tailor some aspects of GIS (i.e. data input) for their own needs and epistemological perspectives. In this way, GIS became an effective bridge allowing collaboration and knowledge sharing between the local population and policy-makers.

Even if rarely acknowledged, the encounter between a boundary object and collaboration (and in a particular way, the notion of knowledge sharing) is one of the most significant transformations of the original notion of boundary objects. From this novel perspective, the idea of boundary objects can be used to describe not only the superficial cooperation and coordination keeping intact the social worlds involved, but also the collaborative joint work that approximates disparate perspectives and facilitates the emergence of deeper forms of mutual understanding.

Boundary objects as transformative

As it was originally conceived, the notion of boundary objects described the role of artifacts and concepts in facilitating boundary crossings, without necessarily changing the shape of those boundaries or transforming the object being represented and

transported (Star and Griesemer, 1989). More recently, however, some studies have expanded on the original notion in order to describe the role of objects in the reshaping of boundaries and entities. Lee (2007), for instance, described how the engagement of a temporary cross-disciplinary team in the creation of a museum exhibition involved a series of negotiations that changed the disciplinary boundaries that were initially present (Shackley et al., 1996). Barrett et al. (2007) arrived at a similar finding in relation to more established cross-disciplinary teams in the context of a hospital ward. The authors found that by taking the role of a boundary object, a medicine-dispensing robot reconfigured the relationship between pharmacists, technicians and assistants. Specifically, the robot in some cases brought about 'boundary cooperation' between some groups, making their mutual relationship more supportive and beneficial. In other cases this boundary reconfiguration exposed situations of 'boundary neglect' in which the work that up until then had been invisible became apparent. However, in certain instances the introduction of this boundary object also caused 'boundary strain', namely, the transfer of some competencies from one group to another, so generating tensions and conflicts.

Another important and still barely explored extension of the notion of boundary objects concerns its transformative nature. The traditional view of classification systems sees them as merely reflecting an external reality, which is very much in line with the notion of the illusion of transparency presented above. In contrast to this view, Bowker and Star (1999) indicated that classification systems not only record and move representations of objects and people in time and space, but also transform these entities. In line with the literature on the process of objectification reviewed above, the authors maintain the use of classification systems involve 'the ongoing destruction of selective traces in the present' (*ibid*: 257). In the case of the classifications of nursing interventions, for example, only the aspects of a nurses' work deemed relevant for scientific or financial purposes were codified by the classification systems and recorded in the hospital information systems; the remaining aspects, in contrast, lasted only for the few moments they were being enacted. This omission also has consequences for how the work of a nurse is understood. On the one hand, it opens up the possibility of surveillance and control, and still prevents distant actors from understanding what is involved in being a nurse. On the other hand, however, classification systems are able to confer an aspect of rigor and

legitimacy to the entities being transformed that would not be recognized as such otherwise. For instance, by superimposing a classification system on their work, the nurses, were able to make claims about the scientific relevance of their profession and obtain more financial gains. This suggests that the use of boundary objects could be understood not only as being flexible and mobile, but also leads to the qualitative transformation of the status of entities being represented.

The establishment of boundary objects

Another area where studies have expanded and clarified the notion of boundary objects concerns the process that leads to the establishment of artifacts and the concepts taking this role, this being an issue that was largely ignored in the original paper. As in the other dimensions mentioned above, an important starting point of this extension is the book by Bowker and Star (1999) on classification. Referring to the international classification of diseases and the nursing interventions' classification, the authors pointed out that beneath the scheme's claims of scientific rigor and universality lie a myriad of local adaptations and cultural reframings. These local adaptations included, for instance, limiting the number of possible diseases to the size of a sheet of paper for pragmatic reasons, and the tendency of Japanese doctors to classify heart attacks as strokes due to the social stigma relating to heart diseases in that country. Similarly, the authors also indicated that every time the nurses used their classification system they had to draw upon their tacit knowledge and make local adaptations for the specific purpose at hand. In both cases, it emerged that in order for classification schemes to be accepted across boundaries (e.g. by the nurses as well as the administrators and doctors) they have to undergo local adaptations and concessions. This in turn suggests, that interpretive flexibility is involved not only in the functioning of a boundary object but also during its establishment. It further indicates that the establishment of boundary objects is closely linked to the social context from which it has evolved, a point that was highlighted by other studies (Bechky, 2003; Henderson, 1991; Lee, 2007; Subrahmanian et al., 2003).

Some authors within information systems literature have also explored the establishment of boundary objects (Barrett et al., 2007; Carlile, 2002; Levina et al., 2005: 354; 2006; Orlikowski, 2002). While the diffusion of the notion of boundary objects certainly contributed to an understanding of the role of artifacts in joint work, many studies adopting this notion convey a view of boundary objects as relatively

stable entities with essentialist properties (Trompette et al., 2009; Zeiss et al., 2009). In contrast to this, other authors have proposed the notion of 'boundary objects-in-use' to highlight that objects 'acquir[e] both a local usefulness and a common identity in practice' (Levina, 2005: 354). Specifically, Levina and Vaast (2005) emphasized that the functioning of an artifact as a boundary object both in theory (i.e. designated by the organization) and in practice requires the emergence of a joint field of practice. They also indicate that this is not an easy process: the emergence of boundary objects-in-use requires, among other things, that some members of the organization become legitimate participants of different communities of practice and use their own social capital to negotiate their involvement of these fields. In this way this strand of the literature suggests that the establishment of boundary objects should be understood as a challenging process involving negotiation and learning.

Boundary objects as contradictory

Finally, more recently particular studies have highlighted how the outcomes of boundary objects may change dramatically depending on the circumstances in which they are enacted (Briers et al., 2001; Levina, 2005; Levina et al., 2006). Barrett and Oborn (2010: 1215) provided a good example of this aspect of boundary objects in their study about the role of software development methodologies in the work of a cross-cultural team. The authors reported that initially software specifications acted as a boundary object, so facilitating collaboration across cultural boundaries by allowing Jamaican and Indian programmers to share their knowledge about the local context and technologies, respectively. Following this, however, some Indian managers started to use software specifications to impose their authority over the Jamaican programmers in order to speed up the development process. As a result of these events the authors noticed that:

> This led to changes in interaction and a shift in the use of the spec as a source of collaboration and in facilitating knowledge exchange. Instead, the lack of knowledge sharing around the spec was now perceived to reinforce differences between them. The strict timeframes served to privilege the readily specifiable technical knowledge held by programmers, a cultural resource that reinforced their [Indian] dominant position on the team. (*ibid*: 1214)

Writing in relation to GIS technology, Carton and Thissen (2009) arrived at a similar conclusion. In a study of spatial policy-making in the Netherlands, the authors observed that 'different actors have their own worldview or "frame" as starting points to analyze, assess and plan for spatial problems' (ibid: 1992). These frames include,

for instance, the analytical view of GIS experts that tends to see maps largely as the realization of a scientific research which should be 'correct', unambiguous and precise. At the other extreme and based on a negotiation frame, experienced decision-makers tend to see GIS-based maps as a realization of policy agendas. Despite these differences, however, the authors showed that GIS approaches may develop into '"boundary objects" between different professionals or disciplinary groups' and related frames (*ibid*: 1992). In some instances, however, the difference between these frames may reach a point where the use of GIS becomes more a source of conflict than common ground for reaching agreements. This suggests that GIS may have a contradictory role in policy-making, facilitating or hindering joint work depending on the circumstances of its use.

Even though this particular extension of the notion of boundary objects is still in its infancy, these and other findings challenge the notion implied by different authors that boundary objects emerge in a purely democratic way, without the interference of pre-existing power/hierarchical relations and other social dynamics (Cooke et al., 2001; Stone, 1989). Instead, these studies show that the outcomes of collaboration are also shaped by politics and practices, and as such will change as these elements change. Hence, boundary objects should be conceptualized as 'both pluralist, recognizing the potential for collaboration and conflict, as well as interactional' (Barrett and Oborn, 2010: 1215).

2.7 Conclusion

This section provides a summary of the main themes found in the literature and concludes by indicating the specific theoretical stance adopted by this thesis. It was possible to see in this chapter that the studies from the social sciences dealing with GIS and other technologies challenge the mainstream GIS literature in different ways. We have seen in Section 2.2 that the mainstream GIS literature suggests that this technology is able to represent reality in a neutral and holistic way, and that the introduction of GIS can only lead to better policies. The critical literature on GIS implementations reviewed in Section 2.3, in contrast, showed that the success (i.e. establishment) or failure of GIS and its implications are closely related to the local context and the shape given to GIS by the users and developers interpreting the technology.

Furthermore, Section 2.4 revealed that GIS, far from being able to represent the world holistically, should be understood as leading to a process of objectification which is selective, and which renders some aspects of sentient reality visible and others invisible. In addition to this, this section also showed that GIS is far from being a neutral technology: behind its illusion of transparency, it is possible to see a close relation between politics and the use of GIS. Sections 2.5 reviewed the literature on the relation between boundaries and practices, the various levels of engagement of joint work and the challenges this entails. Finally Section 2.6 reviewed the literature on the relation between joint work and artifacts, with particular focus on the notion of boundary objects. Specifically, this body of literature indicated that in particular circumstances artifacts might enable new forms of joint work due to their interpretive flexibility and informatic structure, but in others might become obstacles.

Based on the information above, it is now possible to outline the theoretical sensibilities that informed the data collection and analysis of the thesis. It is beyond the scope of this research to propose a 'definitive' theoretical framework that provides a 'clear definition in terms of attributes or fixed bench marks' of what the social dynamics related to GIS, let alone come with a new theoretical framework to deal with objectification and boundary objects. Instead, this subsection intends to outline three 'sensitizing concepts that give [...] a general sense of reference and guidance in approaching empirical instances [and...] of what is relevant' (Blumer, 1954: 7).

Boundary object are emergent and historically rooted

The first research question set by this thesis focuses on how GIS technology has become a central element in the formulation of territorial policies in the Amazon. As will be seen in the following chapters, the notion of boundary objects is a fruitful way to conceptualize the role of GIS in policy-making. However, in order to answer the question above it is necessary to reveal how GIS became an established boundary object.

In this context, this thesis conceptualizes boundary objects as emergent and historically rooted (Bowker et al., 1999; Engestrom, 2001; Levina et al., 2005). This statement has two implications. Firstly, in stating that a boundary object is emergent it is necessary to study its trajectory over time rather than simply its current role. For this reason, this study will attempt to trace the history of GIS from the mid-1960s in

order to uncover how this technology was implicated in the way different groups worked together in the elaboration of policies in the Amazon. Secondly, this sensibility also implies that the study of history should not be seen as an end in itself. Rather, the historical material is also intended to inform the research question concerning the current GIS practices. In this way the approach adopted by this study highlights the importance of understanding the relationship between the biography of GIS (Williams et al., 2009) and the *longue durée* (i.e. broader historical and institutional context) of the Brazilian government (Giddens, 1986: 170).

Practices are situated and boundary objects are performances

Another important theoretical sensibility for this thesis concerns the central role given to social practices. A key point highlighted by many of the studies reviewed above is the complexity and situatedness of work practices. That is, occupational communities tend to develop complex social practices which are only fully understood by those working in the same function (Brown et al., 1991; Engestrom, 2001; Hayes, 2001; Lave et al., 1991). This statement has important implications for the study of the second research question set by this thesis. Since an understanding of particular practices is restricted to the members of a given community, in order to collaborate with other groups, these members will have to learn to engage with the unfamiliar (Engestrom et al., 1995; Suchman, 1994; Tsoukas, 1996). In this context and by adopting this theoretical concept, the thesis aims to pay greater attention to the tensions and misunderstandings emerging from joint work.

Specifically in relation to boundary objects, the adoption of this theoretical sensibility implies that the functioning of GIS as a boundary object should not be taken-for-granted from the outset. Instead, it is considered to be the starting point from which to answer empirical question concerning the actual role of GIS in deforestation control practices in the Amazon. Given the limitations imposed on the fieldwork undertaken in the context of this doctoral research, this research cannot claim to be a practice-based study of technology based on lengthy fieldwork and detailed accounts of actions (e.g. Barley, 1986; Zuboff, 1988). Nonetheless, by drawing inspiration from this approach, the research is intended to develop a sensibility towards the practices behind boundary objects and go beyond the traditional bird's-eye view which has dominated the study of GIS so far.

Boundary objects as the basis of coordination and collaboration

Based on recent theoretical developments, this study has a broad understanding of the notion of boundary objects. In particular, this notion is used here to explore not only cooperation within networks and other non-hierarchical configurations, but also joint work in more traditional lines of command within the environmental agencies being studied. Furthermore, based on the reconceptualization of boundary objects to encompass instances of collaboration, the study will also attempt to understand how GIS has (or has not) led to collaboration and related reflection and learning across boundaries (Boland et al., 1995). Finally, by analyzing the use of GIS in practice and by recognizing the implications of objectification and the possible contradictory outcomes of boundary objects, the study attempts to illuminate not only how GIS has brought about new forms of joint work but also how it may be preventing the government from improving its practices in the Amazon (Barrett et al., 2010; Star et al., 1999).

The next chapter shows how the data collection and analysis of this research was conducted. In particular, given the importance of practices and history for the theoretical sensibilities outlined above, it will discuss the methodological challenges that the study of these aspects demand.

Chapter 3: Research Methodology

3.1 Introduction

This chapter 'fleshes out' the research methodology that informs the thesis. In the preceding chapters an overview was given about the empirical backgrounds against which this thesis is set, and it defined the specific aims and research questions that this study attempts to address. In the last chapter, the current literature on geographic information systems (GIS) was also shown in more detail as well as the studies discussing the notions of boundary objects and objectification that provide the theoretical basis for this study. From this comes the importance of adopting theoretical sensibilities that are attentive to the historical trajectory and work practices pertaining to GIS. However, in the same way that 'culture' is the starting point for anthropology and is not its final destination, 'joint work', 'boundary object', 'practice' and 'history' are initial points that need to be investigated empirically.

The next section starts with a discussion concerning the social constructivist methodology adopted in this study. The third part explains the trajectory of this research and the issues it had to face in order to obtain access as well as how the research sites, informants and practices were selected. The fourth section justifies and describes the research methods adopted to collect the empirical data. Following this, the fifth section describes how the empirical data was analyzed, and how practice and historical accounts have been (re)constructed and validated. Finally, the sixth section explains the limitations of the research. By establishing how this research was conducted and how it dealt with the issues inherent in the approach adopted by the study, an attempt is made to give the reader the possibility of evaluating the extent to which the research has attained the validity and rigor it aimed for.

3.2 Philosophical stance

Every piece of research adopts a set of philosophical assumptions that more or less explicitly guides its data collection and analysis. This research attempts to answer a set of research questions which are very different from the current studies about GIS in the Amazon. As seen above, most studies within the mainstream literature on deforestation and GIS adopt the positivist paradigm. Specifically, these studies tend to adopt a naïve realist ontological stance (i.e. an understanding of the nature of reality)

which states that reality is independent of the subjective meaning provided by social actors. This particular assumption is reflected, for instance, in the tendency to focus on visible and measureable phenomena, such as land-use change as detected by satellite images. Furthermore, these studies are also inclined to adopt a positivist epistemological stance (i.e. a perspective on what constitutes valid knowledge) which seeks to establish causal relations between factors by testing a hypothesis, usually through the means of mathematical representations. The positivist epistemology can further be seen in the tendency of mainstream literature to produce knowledge about deforestation mainly though the calculation of statistically valid spatial correlations between visible phenomena, such as roads and land clearing, in order to confirm or falsify a hypothesis. An example of this is the statement 'road building leads to deforestation' (Guba et al., 1994; Johnson et al., 2000).

It cannot be denied that the positivist research methodology has been very successful in answering the 'what' questions in relation to the Amazon, such as the total amount of deforestation in the region. However, this study also needs to consider the social aspects of GIS in the region, where knowing total figures and other 'what' questions is not enough. Here, the study requires a philosophical underpinning that is particularly sensible to the practices and history relating to the role of GIS as a boundary object: dynamics that are hard to measure and represent with the positivist paradigm (Archer, 1988; Denzin, 1970; Easterby-Smith et al., 2002; Guba et al., 1994; Johnson et al., 2000). For this reason, this study has drawn its philosophical underpinning from a research perspective that could broadly be defined as a social constructivist approach. In particular, on the ontological front, this study departs from a subjectivist position which considers human practices and perspectives as the main element that constructs and maintains social reality (Myers, 1997; Orlikowski et al., 1991; Walsham, 1993, 2006). This does not mean, however, that reality is understood here as being the outcome of individualist fantasies, as some of the critiques of this perspective have suggested (Sokal, 1996). Rather, this ontological position states that social reality emerges from social practices that 'have been constructed, historically and collectively, by collaboration between humans and their artifacts' (Engestrom, 2000: 302; Schatzki, 2002).

The adoption of a constructivist research stance has epistemological implications. In particular, if it is accepted that reality is not simply 'out there' but depends on the

practices and perspectives of individuals, then it is also necessary to rethink how to capture reality. Hence, in order to deal with this issue, the study adopts the interpretive epistemology. Here, in contrast to the natural sciences and the social positivist epistemology proposed by Auguste Comte, and further developed by Émile Durkheim, the study adopts the suggestions of Max Weber (Calhoun et al., 2002). In particular, while Durkheim's positivist stance sought to discover causal relations between real 'social facts' that exist independently of its specific subjective manifestations, the interpretive sociology of Weber (2002) aimed at obtaining 'the interpretive understanding of social action [... whereby the] acting individual attaches a subjective meaning to his behavior' (*ibid*: 178). In this way, the interpretive epistemology allows the researcher to 'accomplish something which is never attainable in the natural sciences, namely the subjective understanding of the action of the component individuals' (Weber, 2002: 182).

Finally, the adoption of a constructivist stance also has implications for the manner in which this study represents its findings. While the positivist stance usually reduces reality to a set of mathematical symbols, it is necessary for this study to find a medium able (to some extent) to convey the complexity and richness of the empirical context being represented. For this purpose, an attempt was made to create an in-depth case study, this being a detailed examination of a specific set of events within a given social context (Walsham, 1993, 2006; Yin, 2003). Even though the in-depth case study developed in this thesis has been shorter in duration and less detailed than most ethnographies, practice studies and historiographies, it has nevertheless been inspired by similar principles. Firstly, the case study presented in this thesis attempted to provide thick-descriptions of the history and practices related to the role of GIS in the Amazon. In particular, this study attempted to uncover the webs of significance behind these practices and historical events by questioning the actors directly involved in them (Geertz, 1973). Secondly, where possible, an attempt was made to go beyond the oral accounts of the actors involved and efforts were made to observe the social practices as they unfolded. In this way, the study attempted to capture aspects of the social context under analysis these often being neglected or rationalized during interviews (Barley et al., 2001). Finally, in the case study provided by this thesis an endeavor was made to contextualize the practices and historic events into the broader social context. In this way, it attempted to trace the relation between the

longue durée (i.e. long term historical structures such as the emergence of modernism) and the practices described in the case study (Flyvbjerg, 1998; Giddens, 1986) (see more on this in Section 3.4).

However, the adoption of a constructivist stance also raises questions about the generalizability and objectivity of research accounts. Given the focus of the case study in this research, the thesis cannot claim to have produced findings that are universally valid (Easterby-Smith et al., 2002; Walsham, 1993). Likewise, the study also cannot claim to have produced accounts that are independent from the process of enquiry or my own subjectivity. Rather, by adopting a constructivist approach, the study aims to produce an interpretation of what was seen, heard and recorded during the fieldwork. Therefore, this account should not be seen as a reflection of reality, but a well-informed interpretation of it (Weber, 1917/1949). The remarks of Geertz (1973: 23) on his interpretive ethnographic accounts are also valid for the in-depth case study provided by the study:

> [Ethnographies] are interpretations, or misinterpretations, like any others, arrived at in the same way as any others, and as inherently inconclusive as any others, and the attempt to invest them with the authority of physical experimentation is but a methodological sleight of hand. Ethnographic findings are not privileged, just particular: another country heard from. To regard them as anything more (or anything less) than that distorts both them and their implications, which are far profounder than mere primitivity, for social theory. [...] The important thing about the anthropologist's findings is their complex specificness, their circumstantiality.

This does not imply, however, that the findings presented in the case study are invalid or that they can only be related to the specific events and people to which the research had direct access. By providing 'thick descriptions' of practices and historical events, the case study has 'aim[ed] to draw large conclusions from small, but very densely textured facts; to support broad assertions' (Geertz, 1973: 28). In this way, the findings of this study attempt to 'provide ways of making sense of the world rather than [making] discoveries about the world which represent absolute truth' (Walsham, 1993: xiii). The delineation of the philosophical underpinnings of the study is merely the beginning of the exploration of an empirical research. The next two sections of this chapter, provide greater detail about the trajectory and research methods used in this research, as well as their relationship to the philosophical stance outlined above.

3.3 Conduct of the research: limitations and workarounds

One of the key advantages of the positivist approach over the constructivist one in this study is the ability to control the environment where the empirical data is collected. Positivist researchers are frequently able to impose themselves on their subjects (be they satellite images, laboratory rats or questionnaire respondents) and to determine to some extent when and how they will provide specific portions of empirical data necessary for the execution of the experiment and the eventual confirmation or refusal of a given hypothesis (Easterby-Smith et al., 2002). The conduct of the research from a constructivist perspective could not be more different. Instead of neat experiments, constructivist researchers have to face 'messy organizational and technical hinterland[s]' which provide, at best, complex insights that need to be carefully interpreted (Law, 2004: 97). In addition to this, instead of the informants complying with the researcher's wishes, constructivist researchers are often the ones facing restrictions and impositions from their informants (Silverman, 1993; Wolcott, 1990). Hence, by adopting a constructivist approach, it is necessary to accept that data has been collected in largely unpredictable conditions. This section therefore explains the choices, unexpected events and emerging challenges that led to the empirical material which is the basis of this research. Specifically it explains how access to the research site was obtained, and the criteria used to develop the research design of the thesis.

3.3.1 Problems with access and surprises

The origins of this thesis can be traced back to exploratory research concerning the role of GIS in the Brazilian Amazon as developed in a Masters' dissertation at Lancaster University. Given the strict time frame allowed for the elaboration of the dissertation, it was necessary to restrict the scope of the initial research proposal quite drastically. This was done by focusing on the history of the relationship between GIS and the policies towards the Amazon, leaving an understanding of the actual practices and factors that led to the establishment of GIS for a later stage. To this end, I carried out a fieldwork in Brazil between 18th of June and the 16th of August in 2007. During this period, I conducted 18 interviews, mostly with the senior officials, politicians and scientists directly involved with the development of GIS as well as the formulation of policies in the Amazon. These interviews served a double purpose for the current research: they allowed me to obtain a broad understanding of the case, and also

offered a first point of contact from which to start negotiating access for my doctoral research.

The initial aim of the doctoral research was to focus mainly on the work of IBAMA (the Federal Environmental Agency) in order to observe how senior officials, scientists, managers, attorneys and forest rangers worked together and the role of GIS in this. This would have been done by obtaining full access to IBAMA's headquarters in Brasília, with some fieldtrips to the Amazon in order to understand some local practices. Hence, during one of the interviews carried out in the context of my Master's dissertation, I was able to obtain full access to the agency for my doctoral research in the following year from a senior official in IBAMA. Based on this promise, I planned to stay 5 months at IBAMA's headquarters and two months at the local offices in the Amazon, and to carry out participant observation in these locations. However, a few weeks before the beginning of the fieldwork of the doctoral research was due to begin, the senior official stopped answering my emails and no longer returned the calls to his mobile phone. After a few persistent inquiries, I discovered from one of his former assistants working in his department that he had left IBAMA for an international environmental non-governmental organization. For this reason, when I arrived in Brazil to start the fieldwork on the 1st of September 2008, I had to find another way of gaining access to IBAMA. I then had an interview with another senior official from IBAMA who promised he would be able to grant me access, and asked me to send a signed copy of a contract of collaboration between the agency and the Department of Organisation, Work and Technology at Lancaster University to the institute's presidency. However, even though Lucas Introna, the head of the department at the time, agreed to sign the contract and although, on different occasions, I had made official requests and lobbied with the help of a congressman from the Green Party, this formal agreement was never ratified.

Because I was denied full access to IBAMA, it was necessary to change the research design of the study in two ways. Firstly, even though the lack of formal agreement precluded the possibility of remaining stationary in IBAMA's headquarters, it was possible to negotiate visits for shorter periods of time with the local coordinators. Hence, for this purpose, both the personal support of the second senior official mentioned above and my ability to build trust with the informants was important. For instance, while my initial visit to the first local office was rather cold, during my third

visit to the same site I was invited to join the forest rangers for a birthday party and barbecue. Secondly, in order to reduce the risk of not having any in-depth empirical data, more research sites were added. Here, I specifically decided to expand the empirical focus by carrying out detailed practice observations and interviews at SEMA (the environmental agency of Mato Grosso) and INPE (the National Research Space Institute). Fortunately, these two sites were less problematic than IBAMA and I was able to obtain access without any major issues.

While the first part of the fieldwork was marked by negative surprises, during the second part, an unexpected ally emerged. Two United Nations (UN) senior officials responsible for advising policy-makers on issues concerning the Amazon become interested in my research approach following an interview I had conducted with them. In a field dominated by GIS-based studies on deforestation, they were puzzled by my interest in the work practices and social aspects of GIS and thought it could provide some new ideas to the government. For this reason, the officials encouraged me to apply for a position as a consultant in a project aimed at evaluating the deforestation control policies in the Amazon, this being related to the Millennium Development Goal of environmental sustainability. The position was duly offered to me and, in exchange for a report on the topic and three seminars for policy-makers, the UN funded the most expensive part of my fieldwork, including a considerable number of nights spent in hotels and many flights to and from Brasília and the Amazon region. Furthermore, since I had the official backing of the UN, I was able to obtain access to particular informants whom I would not otherwise have been able to reach. In addition to that, a deputy from the Green party helped me to get access to some key senior politicians, and in many cases allowed me to shadow him during his work in the congress in order to make contacts for my research. The deputy also asked me to write under his supervision a law proposal based on my research findings, and in exchange for my services paid one of my airplane tickets to the Amazon.

3.3.2 Selecting locations, informants and practices

Despite the unfolding nature of this research and its many pleasant and unpleasant surprises, I was largely able to explicitly select the research sites which form the basis of this study, and within these, the particular informants and practices. As outlined in the introduction of this thesis, the formulation and enactment of environmental

policies towards the Amazon are distributed among different powers and spheres of government. From the interviews conducted for my Master's dissertation as well as from secondary sources, it emerged that four organizations are particularly important at federal level: the National Congress, INPE, the Ministry of the Environment and IBAMA (the Federal Environmental Agency). While INPE is located in São José dos Campos in the state of São Paulo, the headquarters of the other organizations are in the Federal District in Brasília. In addition to these, each of the nine states of the Amazon region has its own environmental agency.

Based on this knowledge I decided to focus the data collection in São José dos Campos, Brasília and the state of Mato Grosso in the south of the Amazon rainforest. From the nine states that constitute the Legal Amazon, Mato Grosso is particularly relevant because SEMA, the state-level environmental agency, was one of the pioneers in the use of GIS for environmental protection. In addition to this, the local offices of IBAMA in the region are some of the most active in the country in relation to deforestation control. Paradoxically, the region also has one of the highest levels of deforestation in the Amazon. In particular, I spent a considerable amount of time in three parts of the state: Cuiabá, the state capital, the region surrounding the highway BR-163 (a major agribusiness axis running from the state capital into the heart of the forest), and the northwest of the state (a violent and still well-preserved region). Therefore, by locating the research site in Mato Grosso, it was possible to observe the use of GIS by both the state and federal agencies and the operation of these two agencies in a similar socio-economic context. In addition to the research considerations, Mato Grosso was also chosen for reasons of safety. While the whole of the deforestation frontier is notorious for being violent, Mato Grosso tends to be safer than some of its neighboring states, such as the states of Pará and Rondonia.

Having identified the main organizations and the related research sites, the second challenge was to identify and select the specific sectors, individuals and practices from which to collect data. A first step in this regard was provided by governmental documents and websites. For instance, the PPCDAm (Plan for the Prevention and Control of Deforestation in Amazonia) provides a full list of the senior officials who participated in its development. By crossing-referencing the names on this list with other secondary sources- such as governmental websites and initial interviews- it was possible to obtain a shortlist of names, emails and telephone numbers. With a list of

these names and contact details to hand, I then started sending emails and making telephone calls in order to book interviews. The interviewees were also an important aid in the identification of relevant informants and practices by allowing the use of a snowball sampling technique (Biernacki, 1981). In particular, it was possible to draw upon the informants' inside knowledge about 'who's who' in order to identify key and ongoing activities within the government.

Previous personal acquaintances were also crucial in allowing me to reach particular informants, especially politicians and high-profile senior officials. My grandfather was an ex-mayor of a small town in the state of Minas Gerais, which was also the hometown of a very influential politician on the national scene. Thanks to the acquaintance of this politician and his son (who is currently a congressman for the Green party) and in addition to other related political contacts, I was able to interview two ex-ministers and (with a little good fortune and opportunism) an ex-president of Brazil who was actively involved in the policy changes described in Chapter 4. I was also fortunate to receive the help of Andréa Azevedo, a researcher from Mato Grosso, who was finishing a PhD about SEMA. In addition to sharing her insights with me, she provided a list of key informants at SEMA and introduced me to them. Further to this, a UN official introduced me to an ex-director of the Ministry of the Environment and other contacts in Mato Grosso that proved to be very valuable. Additionally, because of personal acquaintances and chance encounters, I was able to conduct interviews and to negotiate access to observe the practices of local producers in the Amazon, these ranging from rich soybean farmers to native Indians. This included, for instance, a commercial director of a major soybean multinational whom I met by chance on a bus trip, and a childhood friend who migrated to the Amazon in the 1990s.

Overall, with perseverance, strategic-thinking and opportunism, I was able to collect the data concerning most of the actors and practices I deemed relevant for this research. Between September 2008 and August 2009, it was possible to visit each of the research sites at least three times and for periods that ranged one to three weeks. During these visits, I conducted semi-structured interviews, 'shadowed' governmental officials in their everyday work and undertook participant and non-participant observations. In total, I conducted 67 semi-structured interviews, which, together with those conducted in the context of my Master's research, provided me with a total of

85 interviews. Furthermore, it was also possible to conduct 48 observation episodes, each one ranging from 4 hours to a full day. The empirical data here mainly concerned IBAMA, the Ministry of the Environment, SEMA and INPE, with a smaller role played by informants from other parts of the government as well as local producers and environmental NGOs (see Table 8).

Another important aspect of the research design was the opportunity it provided to discover connections between the geographically distributed practices and to return to the same locations to collect more data on emerging themes (Marcus, 1995). In this way, it went beyond a strict interest in local practices and I was able to envisage issues relating to the connections between the joint work of different groups and how they work together at a distance. In the next section of this chapter, I will discuss in greater detail how and with whom the interviews and observations were carried out and the textual sources that form the empirical basis of this research.

3.4 Research Methods

While the previous section mentioned the research sites that provided the empirical material for this research, this section explains in more exact detail how the data collection took place, with the challenges this entailed. As observed in Chapter 2 and mentioned above, two elements are particularly important for the constitution of the case study that forms the base of this research, namely practices and history. With this in mind, the study adopted three research methods, all of which complement each other: documental analysis, interviewing and observation. This section explains how these methods helped elucidate the practices and history relating to GIS in the Amazon, and how the limitations of these methods were addressed.

3.4.1 Textual sources

Textual sources of different types and origins formed an important portion of the empirical basis of this research. In addition to the academic literature on the Amazon, newspaper articles, reports, legal documents and examples of fines and licenses gave important insights into the history of the establishment of GIS in the Amazon; these were also starting points from which to understand the current role of GIS in practice. Specifically, the main textual sources and related time frames used in this study and published in English (EN) as well as Portuguese (PT) were as follows:

Reports from non-governmental organizations: • Greenpeace (PT, EN): 2008-2010 • Instituto do Homem e Meio Ambiente da Amazonia (PT, EN): 2007-2010 • Instituto Socioambiental (PT): 2003-2009 • Instituto Centro Vida (PT): 2009 **Articles from newspapers and magazines:** • Folha de São Paulo (PT): 1994-2010 • New York Times (EN): 1965-2010 • Time Magazine (EN): 1965-2010 • The Times (EN): 1965-2010 • Google Alerts (EN, PT): 2007-2010	**Brazilian laws:** • Brazilian Constitution (PT): 1988 • Environmental law (PT): 1965-2010 **Reports from governmental organizations:** • INPE (PT): 1969-2010 • Ministry of Environment (PT): 2004-2009 • SEMA (PT): 1999-2009 • Food and Agriculture Organization of the United Nations (EN): 1972-2005 • Fines for illegal deforestation (PT): 2007-2009

Table 6 List of the main textual sources used in the research

Textual sources are an obvious choice for the study of history. In contrast to oral accounts, which may alter as people change their concerns and perspectives, documents can be easily stored in their original form for later consultation. For this reason, most of what we know about the past has come to us in the form of textual sources (Bentley, 1999). Here also, the analysis of textual sources provided extensive material from which to understand the different aspects of the history of GIS in the Amazon. Specifically, the extensive scholarship concerning the historical roots of the Brazilian government constituted an important source of material as regards the rationale behind the colonization of the Amazon (Hecht et al., 1989; Ribeiro, 1995; e.g. Viana Filho, 1975). Even though much of this material was not created with this specific purpose in mind, it nonetheless provided the basis for the study of the *longue durée* of the Amazon, that is, 'the analysis of change over long periods and the search for structures' (Bentley, 1999: 112; Flyvbjerg, 1998; Giddens, 1986).

In addition to books and academic articles, an analysis of the online archives from Brazilian, British and North American newspapers as well as magazines was an important source of material in terms of the main events that have shaped policy-making towards the Amazon from the 1960s onwards. This material is particularly useful since it tends to use more direct language than academic accounts and in this way indicates more clearly how prevalent worldviews changed over time. Further to this, the textual content of the policies themselves offered an important basis from which to understand how the focus of the Brazilian government and its relation with GIS technology has changed over time. For instance, a closer look at documents such

as the PPCDAm (a plan to control deforestation), the PAS (a plan for a sustainable Amazon), the PAC (a plan to accelerate growth) and the changes in the Forestry Code from the 1960s to the present allowed the identification of issues for further investigation.

Finally, scientific papers and internal reports from the INPE and other research institutes provided an important basis from which to understand how GIS technology evolved in recent decades and the rationale behind the investment in this technology. In particular, due to the generosity of some INPE librarians, I was able to obtain a copy of the internal documents concerning the role of GIS in policy-making and the country's vision of this technology over the last four decades. Furthermore, by analyzing scientific articles from INPE and other institutes, such as the Research Institute of the Amazon (INPA) in addition to the United Nation's Food and Agriculture Foundation (FAO), it was possible to appreciate how studies based on similar data sources and scientific practices could bring about different conclusions.

While textual sources have been mainly used to explore historical events taking place in a remote past, more recently, some authors have also been using this research method to investigate social practices (Barley et al., 1992; Hammersley et al., 1995; Miettinen, 1999; Pickering, 1995; Schatzki, 2002). In the context of this research, particular textual sources have contributed to an understanding of the role of GIS in practice in different respects. Firstly, contemporary textual sources, such as recently published news articles, were an important source of information about emerging policies, technologies and related practices. For example, in order to keep abreast of the unfolding of events in the Amazon, since early 2008, I have received weekly automatic emails from Google Alerts containing all the news with the keywords 'Amazon' and 'deforestation'. Then, based on an up-to-date understanding of the recent decisions of the government, I was able to explore them in more detail using other research methods.

In addition to that, textual sources also provided an overview of the 'situated vocabularies' that are an integral part of the work practices of policy-makers and forest rangers (Hammersley et al., 1995: 160). Officials use acronyms such as RL, APP and TAC in their everyday work that are often obscure to those outside the government. By immersing myself at an early stage in these textual sources it was

therefore possible to acquire this basic vocabulary and from it, use other research methods in a more focused way. In addition to this, even though legal texts tend to be very idealistic in relation to how the law is enforced, they offer a good starting point from which to understand what the government expects to obtain from its environmental agencies. Finally, the analysis of documents obtained during the fieldwork, such as the fines for illegal deforestation and related reports, provided insights that were crucial for an understanding of the outcome of the practices and the role of GIS in them. Clearly, an analysis of the fines alone without an understanding of how they were made in practice would be very limiting. Nonetheless, by analyzing the elements that were given prominence in the texts of fines and licenses and the types of evidence annexed to them (e.g. pictures, GIS-based maps), provided important insights into the priorities of forest rangers and what legal practitioners expect from them.

However, despite the importance of the textual data sources for this study, they have significant limitations. In relation to the uncovering of history, it has already been indicated by different scholars that written records tend to be very selective. In particular, while the elite have often had the means and the willingness to have their voices heard and recorded, other less privileged voices tend to remain unrecorded, and thus invisible for future generations. In addition, powerful groups are often able to shape official history to their advantage. In this way, textual sources should be understood as being partial in both senses of the word, namely incomplete and politically biased (Hammond et al., 1996; Thompson, 2000). In relation to the understanding of practices, textual sources can be even more misleading. With the exception of some excellent ethnographies, only a very select portion of what constitutes complex social practices is ever inscribed in textual form. Moreover, a considerable amount of glossing over, simplification and idealization occurs in the process of creating governmental documents, bureaucratic records and news articles (Garfinkel et al., 1967; Hammersley et al., 1995). Hence, textual data sources can only provide an indication of what constitutes the social practices being studied. Bearing this in mind, most of the empirical data about the practices examined in this thesis emerge from semi-structured interviews and observations. In the next two sections, I will explain how these research methods were applied.

3.4.2 Interviewing

Interviewing is one of the most important and widely used methods within the constructivist research approach. Even though the application of this method is often trivialized, the conduct of good interviews requires skill and sensibility. In particular, rather than being a straightforward technique, interviewing is an art that involves the construction of a 'purposeful conversation' where the interviewee feels comfortable about expressing his or her opinions. In accordance with the recommendations found in the literature and through the experiences gradually gained during my Master's and doctoral research, I tailored the interviews according to the competence of each individual within the organization and the natural progression of the discussion. In this way, even though I had considered the themes to be explored in the interview beforehand, I tried to avoid the imposition of a strict structure and the consequent distancing of the informants (Nicolini, 2009; Rubin et al., 2005).

Given the less structured format of the interviews, and the wide range of informants (e.g. from busy ex-ministers to forest rangers), the length of the interviews varied considerably. For instance, while some politicians allowed less than 30 minutes for their interviews, a group of GIS experts from IBAMA gave an interview that lasted more than 3 hours. The recording method also varied according to the situation. Even though I tried to use a voice recorder to register the mood of my interviewees and their accounts in as much detail as possible, this was not possible in some instances for different reasons. In some cases, I sensed that by taking a voice recorder out of my pocket and asking permission to make a recording, my informants would be less comfortable about expressing their views. In other cases, the informants asked me explicitly not to use the voice recorder for fear of retaliation. This was particularly the case when attempting to understand emerging tensions between senior officials and their subordinates. Therefore, when a tape recording was not possible, extensive notes were taken during the interview, including some word-for-word quotations of particularly expressive passages. These notes were than transcribed to the computer and translated into English - usually at the end of the interview - in order to register the accounts as precisely as possible (Hammersley et al., 1995; Mason, 2002; Rubin et al., 2005).

In order to render the interview data more manageable during the tape-recording sessions, I made notes of the topics under discussion and the specific times at which they took place. The notes then formed what I would term the 'index' of the interview (see an example of this in Table 7). Later on during the data analysis, all the interviews were listened to and the relevant topics were transcribed under the headings of the 'index'. In this way, I avoided being overloaded by the need to fully transcribe and translate 85 interviews, or having to pay someone to do this (which would also be negative, since it would distance me from the data).

3 min The federal pact was supposed to transfer powers to SEMA, but in practice nothing has changed. "IBAMA has given up the position but did not step down from the podium".
8 min IBAMA is unreliable: Marina proposed fire arch as a joint operation with SEMA, but on the final day IBAMA cut SEMA out of the project.
10 min SEMA's idea was to use intelligence and at its power like IBAMA does
12 min Different interpretations of the law. Is the legal reserve at 50% something acquired by right?

Table 7 Excerpt of notes taken during an interview with a senior official from SEMA

Despite the challenges described in the previous section, I was able to carry out 85 interviews, thereby covering most of the key actors involved in the formulation and enforcement of the deforestation control policy in the Amazon, as well as the role of GIS in it (see Table 8). Specifically, at the Ministry of the Environment I was able to interview at least one senior official from the three secretaries of the which shares the responsibility for protecting the Amazon rainforest. Moreover, it was also possible to conduct formal interviews with five officials who had written the PPCDAm document (the main policy in operation during the fieldwork), including the former Minister of the Environment behind the plan. At IBAMA, I interviewed most of the senior officials responsible for coordinating the actions and the scientists who offered training on GIS to the forest rangers in the Amazon. I also carried out extensive interviews with the many forest rangers working in the Amazon. Similarly, at SEMA I interviewed the Secretary for the Environment, and repeatedly questioned the senior officials who were directly involved in enforcing the law and introducing new GIS technologies. Here too I interviewed the rangers and bureaucrats who work under them. At the National Congress I held interviews with three congressmen and two legal assistants who were directly involved in the formation of the Amazonian policy.

Finally, at INPE I was able to interview the president of the institution, the current Director of the Earth Observation Department, the current Coordinator of the Amazon and the majority of other scientists who had previously occupied these roles. In this way, it was possible to interview most of the key actors who had developed GIS technology for the Amazon in the preceding decades. I also interviewed 10 people for a second or third time. These recurring interviewees were particularly important because they enabled me to follow particular issues longitudinally, to ask for clarification and (without citing the sources) to contrast the opinions of different informants. In this way, I could observe the eventual contradictions and tensions between the many groups working together in the Amazon (Engestrom, 2001). In order to help clarify my interpretations and follow particular issues longitudinally, I also maintained contact with seven officials (five forest rangers, two IBAMA scientists and one GIS expert from SEMA) through Skype (a voice-over-ip and messaging software).

Institution	Interviews
IBAMA	15
Ministry of the Environment	12
SEMA	12
INPE	10
National Congress	5
Other governmental agencies	13
Local producers	11
Non-governmental organizations	7
Location	**Interviews**
São Paulo	10
Distrito Federal	36
Mato Grosso	36
Other	3

Table 8 Number of interviews divided by organization and location; the observation episodes lasted between 4 hours and a full day

The interviews conducted with the actors mentioned above were important in order to elucidate the practices and history behind GIS and how different groups work together in the Amazon. Even though some authors within organizational studies and anthropology have criticized the overreliance on this method (Barley et al., 2001; Bate, 1997), different studies were able to offer crucial insights into past and present work practices, mainly based on interviews (Blackler et al., 1999; Joshi et al., 2007; Ribeiro, 2007). In particular, the semi-structured interviews were useful because they illuminated three aspects of the social practices of GIS. Firstly, they elicited an initial

description of what the informants do from their own perspective (Nicolini, 2009). The ability to have an overview of what is involved in, for instance, issuing a fine or creating a new law, proved to be an important basis from which to understand those with whom these people work and to establish what the role of GIS in their joint work practices is. Secondly, the use of semi-structured interviews allowed informants to articulate the rationale behind their practices – a clarification that is often unavailable from the direct observation of practices (Hammersley et al., 1995). Thirdly, by questioning interviewees about their relation with other groups it was possible to have an idea of the issues, tensions and breakdowns involved in joint work practices. Finally, the interviews with the practitioners proved to be an important instrument in comprehending the practices of particular contexts, based on the observations conducted in other contexts (Neyland, 2008). As mentioned in the previous section, due to access limitations, I was unable to attend policy-making meetings at IBAMA, and because of time restrictions, it was not possible to undertake fieldtrips with SEMA rangers. Despite these issues, however, by comparing the content of the interviews with the observations of the law making practices at the National Congress as well as the law enforcement practices from IBAMA, it was possible to gain a better idea of the practices being pursued in these two contexts.

The use of interviews was also important in order to understand the history of the Amazon; utilizing oral accounts of history is an important but still largely neglected method within the study of technology and organizations in general. With a few exceptions, studies either rely almost exclusively on textual sources or only use oral accounts to describe recent events (Williams et al., 2009). Broadly speaking, oral history aims at uncovering events that occurred in the past based on the unregistered accounts of people who were the protagonists (Hammond et al., 1996). This method initially emerged in the study of the history of peoples who do not have a written tradition, such as with particular tribes in Africa, and for this reason are precluded from other forms of research. In the last decades, however, oral history has also become a key method for going beyond the limitations of the textual sources mentioned in the previous subsection. Thomson (2000: 23) one of the main scholars in this field, defines oral history in the following way:

> Oral history is a history built around people. It thrusts life into history itself and it widens its scope. It allows heroes not just from the leaders, but from the unknown majority of

> the people. […] Equally, oral history offers a challenge to the accepted myths of history, to the authoritarian judgement inherent in its tradition.

In line with the purpose of oral history outlined in the excerpt above, this research has used interviews as a way of uncovering the voices of the social groups that are often excluded from grand narratives and official accounts. These include, for instance, the voices of local farmers who migrated to the Amazon in the 1970s and who have their own understanding of the events during that period. The accounts from old forest rangers have also been important in understanding the history of IBAMA and how it was transformed by the introduction of GIS, as well as the arrival of forest rangers with higher degrees. However, in addition to this, by interviewing more prominent actors it was also possible to uncover aspects of important historical events which are often excluded from official accounts because they are judged to be too sensitive or simply irrelevant. For instance, the interviews with former ministers and INPE senior scientists were crucial in revealing the political struggles behind the major events, the intentions behind specific policies and the rationale of technological designs choices (Williams et al., 2009).

Overall, the semi-structured interviews provided the main data source for this study, and for this reason, it is important to recognize the limitations of this method in the context of the study of practices. Firstly, informants tend to engage in 'impression management', (whether they are aware of this or not). This means that they present themselves and their activities to external 'audiences' (Goffman, 1959) according to a certain 'logic of representation' (Czarniawska, 2001). In addition to that, some informants were reluctant in talking about their relation with other groups, especially with their direct managers. In some cases it was clear that an IBAMA local manager feared being punished by senior manages for 'speaking too much'. Hence, accounts of practice based exclusively on interviews run the risk of being glossed over since informants naturally substitute, delete, rearrange and add elements to their descriptions in order to present an account that is thought to be legitimate (Van Leeuwen, 2008). Secondly, even when it is possible to obtain more open accounts of practices, these can only be partial 'because most work practices are so contextualized that people often cannot articulate how they do what they do, unless they are in the process of doing it' (Barley et al., 2001: 81; Tsoukas, 1996). For these reasons, observational techniques have also been used in the study to register in a detailed way

particular key social practices. The next section outlines the principle behind these techniques and explains which practices were observed.

3.4.3 Observing

Observational methods such as direct and participant observation are considered to be some of the wealthiest sources of primary data. By adopting these methods, the researcher can attempt to assume the role of a 'fly on the wall', observing the manifestations of social practices as they occur in their natural settings (Easterby-Smith et al., 2002; Ely, 1991). With this approach, and after many months of data collection at a specific site, the researcher should be in a position to produce a 'thick description of a certain social world; this should therefore go beyond the logic of representation and the complexities that shield these practices from outsiders (Geertz, 1973). For these reasons, observational methods have been increasingly adopted for the formulation of ethnographies in order to describe the work practices related to the use and development of information systems (Bruni, 2005; Hughes et al., 1994; Myers, 1997; Nardi, 1996; Newman, 1998; Schultze, 2000; Suchman, 1995; Zuboff, 1988). In addition to this, observational methods have also been used in the constitution of case studies which are more attentive to social practices and the challenges involved in joint work (Barrett et al., 2010; Blackler et al., 2000; Engestrom, 2001; Levina et al., 2005; Orlikowski, 2000, 2007).

In practice, however, the time limitations for fieldwork, issues with access and recent societal changes pose considerable strains on the use of observational methods for the elaboration of case studies. In this regard, different authors have pointed out that modern organizations are becoming increasingly distributed and dynamic, rendering tradition single-sited observational methods unsuitable in some instances (Czarniawska, 2004). This dynamism is particularly evident in the case of the Amazon. During the period of this research, there were a succession of Ministers of the Environment, changes in norms and laws which attempted to curb deforestation and the development of new GIS systems. Furthermore, rather than taking place in a single location, these changes had repercussions in many social sites since the GIS and laws created by one section of the government have to be used by another section, often thousands of kilometers away. In addition to this, it is very difficult obtaining access to carry out long-term participant observations (Czarniawska, 2007). This can

usually only be done when the researcher becomes a member of a particular organization, such as in the case of anthropologists who have assumed the role of trainees in McDonald's (Watson, 1997) and in the International Monetary Fund (Harper, 1998). However, as seen above, in heavily regulated sectors such as the bureaucracies of the Brazilian government, this is often not possible. For this reason, many practice studies have increasingly drawn upon shorter and more focused sets of observations (Blackler et al., 2000; e.g. Engestrom, 1998).

Specifically in relation to this study, I adopted different strategies in order to overcome these constraints and to be able to collect sensible observational data as regards to practices. Firstly, in order to use the best means possible in the shortest time available for the direct observation of each research site, I attempted to make observations using a focused mode (Neyland, 2008: 92). Even though this term might resemble the frequently criticized 'quick and dirty' (Hughes et al., 1994), 'blitzkrieg' (Rist, 1980) or 'jet-plane' (Bate, 1997) ethnography, it is fundamentally different as regards its focus and aims (Jeffrey et al., 2004). In contrast to more traditional observational methods which attempt to capture a wide range of social phenomena in the site being observed (i.e. 'the broad webs of significance'), this research selected a much smaller set of issues to explore in order to constitute its case study (Czarniawska, 2007; Jeffrey et al., 2004). Hence, I went into the field already having an idea about which work practices might be more relevant for this research (as a result of the interviews and textual sources). For instance, IBAMA performs a wide range of practices including environmental education, investigating biopiracy and examining air and water pollution among others. In this study, however, I focused specifically on the GIS-centered joint practices relating to the formulation and enforcement of policies concerning deforestation reduction in the Amazon; this is an important but much reduced portion of the government's work in the region. Moreover, given the importance of joint work for this study, a particular emphasis was given to the practices involving the participation of multiple groups operating across boundaries. As a result of this, broader and more demanding issues, such as the local culture and the identity of the forest rangers, were regarded as secondary. This does not mean, however, that I returned from the field with the same set of interests that I went in with. Rather, on my various visits to the research sites it was possible to follow particular issues that had unexpectedly emerged during previous visits.

Institution	Observation episodes
IBAMA	15
Ministry of the Environment	2
SEMA	8
INPE	8
National Congress	3
Other governmental agencies	1
Local producers	11
Non-governmental organizations	0
Location	**Observation episodes**
São Paulo	8
Distrito Federal	9
Mato Grosso	31

Table 9 Number of observation episodes categorized according to organization and location. The observation episodes were between 4 hours and a full day

Another strategy adopted to compress the ethnographical time of the observations was the use of 'shadowing', this being a particular observational technique (Czarniawska, 2007). The idea behind shadowing is simple: here people are followed for a few days as they naturally carry out their everyday activities in order to observe their contextualized actions and how the relate with other groups. In this way, it is possible to be simultaneously immersed in the full richness of the social practice but not be carried away by the sheer amount of actors that constantly leave and enter a specific research site. Furthermore, by accompanying the key actors as they performed their work, and in some cases helping them in their tasks it was possible to render transparent some aspects of the inner logic of their work (see Figure 5). Moreover, having followed particular actors for a few days, I was able to establish a certain intimacy with them and through informal conversations, to hear comments about more delicate issues (e.g. criticism towards their superiors), these being omitted during formal interviews. As a result of the multi-sited character of the observations, it was therefore possible to identify unexpected connections among practices that would not be visible otherwise; I also gained some insights into how joint practices takes place and the role of GIS in this process (Falzon, 2009; Hine, 2007; Marcus, 1995).

Figure 5 The researcher helping a team of IBAMA forest rangers to inspect a sawmill suspected of illegal logging

During the data collection, I made extensive notes, took pictures and collected documents such as forms and reports which directly related to the practices being examined. Here, in order to avoid omitting important details, I constantly kept a notebook and pen to hand, noting the time of particular events (e.g. arrival at a rural property), short descriptions of actions and quotations from informal conversations which I judged to be relevant. These notes were then transcribed, fleshed out and translated into English on the day of the observation in order to avoid losing key details. This generated a set of episode observations, namely detailed written descriptions of how a particular group carried out its practices (see Table 10 for an example of this).

Samuel [a senior official] comes out of his office and questions bluntly the technician: "Do you want to talk with me?" "Erh, mm, yes, I want to know what should we do about this maps for this operation, since the deadline for it has expired yesterday". "Mmm, let me see", and after a few moments of hesitation Samuel replied: "No! This operation is for then next month! There are many other maps that must be generated prior to this one". Miguel at this point shows very clearlyin his face a mixture of frustration and puzzlement about what Samuel has just said.

Table 10 Excerpt from an observation episode concerning the joint work practices of SEMA

It was possible to conduct a total of 48 observation episodes, with different parts of the government and local farmers, the duration of these being between four hours and a full day (see Table 9). One of the most relevant observation episodes concerned the uninterrupted shadowing of a team of IBAMA forest rangers who were conducting

fieldwork in the north of Mato Grosso for 6 consecutive days; this was followed by another 3 days observing the office work of the forest rangers from the same local office. I was also able to spend 8 inconsecutive days observing the office work of SEMA forest rangers and bureaucrats.

3.5 Data Analysis

In the positivist approach, data analysis is the specific phase of the research process where the data collected by the researcher is closely scrutinized in order to confirm or falsify a certain hypothesis. With the constructivist methodology adopted in this study, however, data analysis was not confined to a specific phase of the research process (Hammersley et al., 1995). Instead, it began even before the fieldwork: while reading the literature and secondary sources used to define the initial focus of this research. This also continued during the fieldwork, when, alongside field notes and interview transcripts, I wrote small notes to myself as well as emails and reports to my supervisors containing topics for further analysis or potential research themes. Nonetheless, there was a point in my research, following the end of the fieldwork and my return to Lancaster, when it was necessary to re-engage with the empirical data and from this to constitute the empirical case study that forms the basis of this thesis.

As pointed out in Section 3.2, because of the interpretive epistemology adopted by this study, the outcomes of this study cannot be separated from my own subjectivity and the specific actors and events that I came across during my fieldwork. However, as indicated by Walsham (1995: 79), '[r]eporting on "soft" human issues is not an excuse for sloppiness'. With this in mind, this section of the chapter describes the challenges involved in the analysis process and the concepts and techniques adopted in order to systematically formulate a coherent and rigorous case study.

3.5.1 Tagging the text and identifying practices and historic events

In order to assist me in the management of the vast amount of empirical material collected during the fieldwork and to produce detailed, empirically informed interpretations, I drew upon (but did not limit myself to) the model proposed by Auerbach and Silverstein (2003). These authors understand the process of qualitative data coding and analysis as a series of discrete steps. Firstly, the 'raw text' is skimmed through in order to extract the 'relevant text' for the study at hand. The

relevant text is then analyzed in order to identify a set of 'repeating ideas' which are then aggregated into 'themes'. These themes are finally analyzed and then compared with the relevant literature in order to form progressively 'theoretical constructs' for a 'theoretical narrative' (see Table 11).

MAKING THE TEXT MANAGEBLE
1. Explicitly state your research concerns and theoretical framework.
2. Select the relevant text for further analysis. Do this by reading through your raw text with Step 1 in mind and highlighting the relevant text.
HEARING WHAT WAS SAID
3. Record repeating ideas by grouping together related passages of relevant text.
4. Organize themes by grouping repeating ideas into coherent categories.
DEVELOPING THEORY
5. Develop theoretical constructs by grouping themes into more abstract concepts consistent with your theoretical framework.
6. Create a theoretical narrative by retelling the participant's story in terms of the theoretical construct

Table 11 Six steps for constructing a theoretical narrative (based onAuerbach et al., 2003: 43)

As stated in the research aims and questions in Chapter 1, this research is mainly concerned with GIS-centered joint work practices relating to the formulation and enforcement of environmental policy in the Amazon rainforest and the establishment of this technology in the last four decades. Consequently, and by following the guidelines mentioned above, when reading through the observational and interview notes and other data sources I attempted to stick to these aims.

The next step proposed by Auerbach and Silverstein (2003) is the identification of 'repeating ideas', which in this case translates into finding 'repeating patterns of actions' common across different actors that might constitute specific social practices and important historical events. In order to identify these practices, I used TAMSAnalizer, an open source qualitative data analysis tool. After loading all the notes into the software (from both the observations and interviews), I re-read the texts

and carefully inserted ‘codes’ (e.g. ‘Identifiying_deforestation’) indicating the portion of text containing the elements of interest. The coding procedure varied slightly depending on the prevalence of the observational data and the complexity/messiness of the empirical data. In the case of the IBAMA and SEMA practices, I created three sets and attributed different colors to them so that it was possible to analyze particular practices, issues/tensions and views/values separately. Because certain events may contain elements of different practices or tensions and at the same time express certain views about the world, the codes overlap in many cases or are nested into each other. An example of this is the way in which it is possible to represent an instance where IBAMA agents use monitoring systems to identify deforestation and comment about the lack of land ordering as well as the view that local farmers are environmental criminals (see Figure 6).

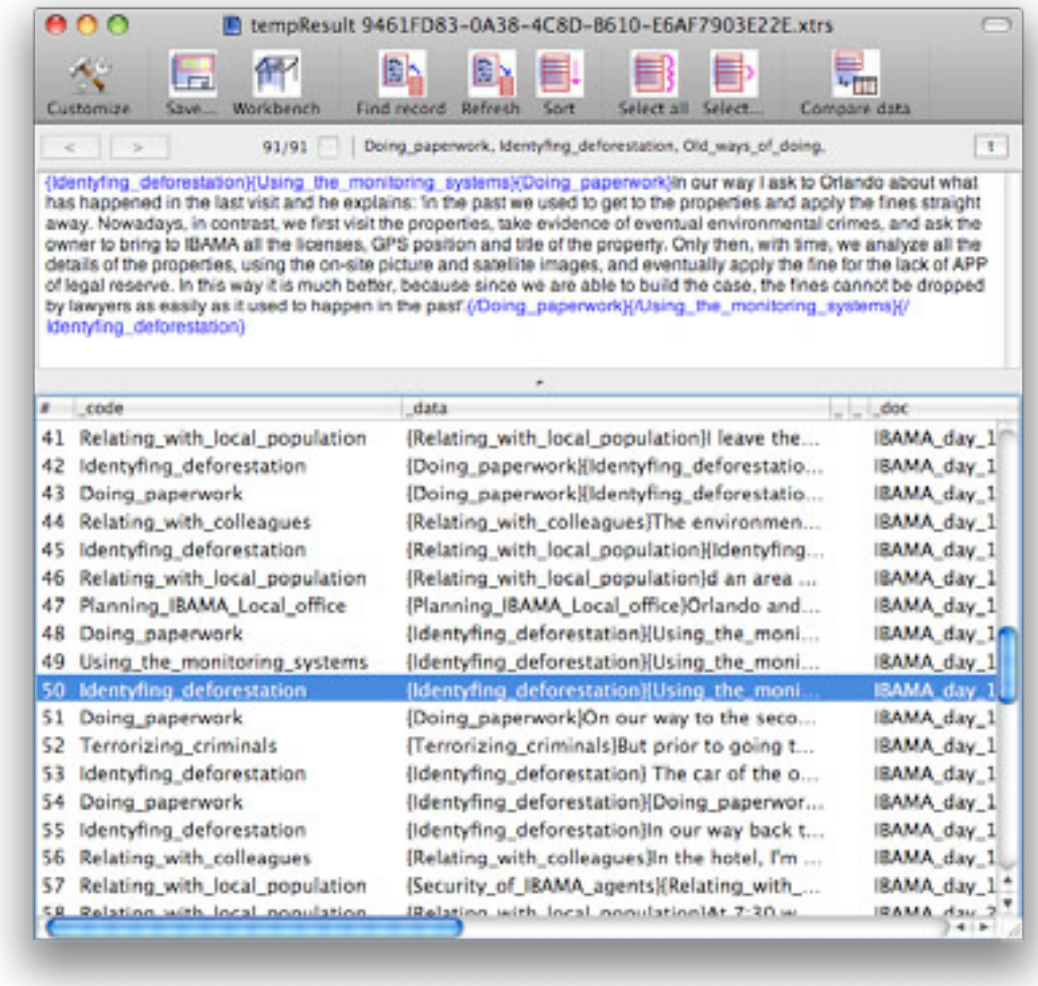

Figure 6 TAMS Analyser user interface with IBAMA's data

A similar procedure was also adopted in relation to the history of GIS in the Amazon and its role in policy-making. However, instead of highlighting the practices, particular emphasis was placed on specific historic events (i.e. changes in the Forestry Code in 1996) and other views (i.e. the relationship between the environment and the economy). Furthermore, in contrast to the procedure proposed by Auerbach and Silverstein (2003), this coding process was iterative. Therefore, during the analysis, and as new patterns were identified, I created new codes and re-analyzed the data. Finally, after all the textual material had been properly coded, it was possible to analyze the data by searching through the text for references to a certain code or set of codes and by comparing different text fragments referring to the same code (see Figure 6).

3.5.2 (Re)constructing accounts of practices and history

The next step in Auerbach and Silverstein's data analysis framework is the aggregating of 'repeated ideas' into 'themes', and finally into 'theoretical narratives' and 'research concerns'. In the case of this research, however, I was particularly interested in (re)constructing the accounts of the social practices and historical trajectories. In order to help me in this task, I adopted the concept of triangulation, this being a technique used originally in navigation to obtain the precise location of a point based on the distance of two known points, given the angles of the triangle formed by the three points. Authors have adopted this term in qualitative social research to indicate an attempt to obtain a more precise understanding of a given social reality (Jick, 1979). Denzin (1970) identifies four different ways in which this idea can be applied in social research: (a) data triangulation, where data is collected at different times or from different sources; (b) methodological triangulation, where multiple methods of data collection are used; (c) investigator triangulation, where different researchers independently collect data and compare the results; (d) theory triangulation, where different theories are adopted to interpret the same set of data.

In this study I have used the first two types of triangulation. Data triangulation was used in order to compare the accounts provided by the different interviewees or observations of the same work which were practiced at different moments in time and by different informants. In this way, it was possible to observe if there was a common pattern, thereby providing hints about how disseminated that given practice actually

is. It also allowed me to see particular variances among practitioners and to identify tensions or issues which could be explored further (Hammersley et al., 1995).

The triangulation between the different methods also allowed me to observe differences between various groups. This use of triangulation was particularly useful when comparing the technocentric accounts of senior officials as regards the role of GIS and the observations in the field concerning the actual use of this technology by the forest rangers and bureaucrats working in the region. It was also useful as to compare how different sides of joint work practices saw their own role as well as the role of others in enforcing the environmental policy in the Amazon. Finally, the comparison between the textual sources and the interviews about the historic events was also important in order to deal with tendency of oral accounts to provide approximate date references. Specifically, by identifying in the archives the references to these events, it was possible to pinpoint more precisely their timeline and establish a more coherent account. Nonetheless, the aim of this analysis was not to produce a more 'precise' description of the practices and history so that the 'true' descriptions were separated from the 'false' ones - as with the positivist uses of triangulation in social research (Denzin, 1970; Jick, 1979). Rather, the analysis was aimed at obtaining a richer multi-dimensional account of the social reality where the perspectives of the multiple actors and the incoherent and emerging nature of the social life were taken into account (Czarniawska, 2008; Engestrom, 1987; Wolfram Cox et al., 2005).

3.5.3 Validating the case study

A final and important step in the scientific process is the validation of the research findings. In the realist positivist methodology, this is usually achieved through a control sample or test data sample that was not used in the experiment. By comparing the results of both samples and determining that the two are statistically different, it can be established that the results of the experiment were neither random nor natural occurrences. Generally, in interpretive methodology and qualitative research, the question of how to establish the validity of research findings is much more controversial. Authors tend to disagree on what constitutes validity, how to achieve it and even whether it is worthwhile discussing this issue in interpretive research at all (Golden-Biddle et al., 1993; Maxwell, 2002). However, most authors agree that

'respondent validation' (the verification of the research findings by some of the people subject to enquiry) is one of the most powerful and important forms of establishing credibility and validity in qualitative research (Creswell et al., 2000: 127; Hammersley et al., 1995: 227; Lincoln et al., 1985: 357). This form of validation is even more important for the constitution of case studies inspired by practice theory and ethnographical approaches such as this. As discussed in the previous chapter, due to the complexity of the practices, the actors who perform them on a daily basis are the people best suited to evaluate the extent to which the researcher produced a fair account (Barley et al., 2001; Tsoukas, 1996).

In this research, I attempted to perform respondent validation in three ways. Firstly, in the last phase of the data collection, I interviewed a scientist, a senior official, a forest ranger and a farmer – all being interviewed two or three times. In addition to following up some issues I conducted informal conversations with the informants in order to give them my interpretation of the issues they are facing. Secondly, under the auspices of the United Nations and through my own initiative, I gave four formal presentations about the preliminary findings of this research. Two presentations were held at IBAMA headquarters, one at the UN headquarters (both organizations being located in Brasília) and another was at INPE's headquarters in São José dos Campos, near São Paulo. These presentations were attended by key informants, including the scientists from INPE directly involved with the development of the GIS, environmental policy-makers and the Secretary of the Environment of Mato Grosso. Finally, I provided copies of the earlier versions of the empirical chapters of this thesis to an INPE scientist, an IBAMA forest ranger and a researcher actively involved with SEMA. Even though some points caused discomfort or even disagreement, overall the informants found that my study provided a fair account of many aspects of their practices. For instance, at the end of the seminar I presented at IBAMA's headquarters, a senior official approached me stating he was impressed by the fact that I was able to come to them and discuss how they work in detail, a point that was also later reinforced by the UN official organizing the seminars.

3.6 Limitations

Even though I have attempted to make the best use of the year I spent conducting fieldwork in Brazil, it is important to recognize that the account provided in this thesis

has some limitations. Firstly, this research cannot claim to have provided a comprehensive account of GIS-centered social practices. As mentioned above, practices cannot be reduced to descriptions of practices, and to do so would be a serious betrayal of its central sensibility. The full complexity of practices can only be realized in the everyday concrete instances of their enactment. Moreover, only the actors socialized to that practice, such as the IBAMA forest rangers, fully understand their practice, even though they might not be able to express it in an oral or written account (Barley et al., 2001; Tsoukas, 1996). The account of the practice presented here is therefore a simplification of these practices for the purpose of answering the research questions and aims of this thesis. Nonetheless, through this simplified account, I hope to have captured some crucial aspects of these practices, and from this, to provide a glimpse of the complexities, challenges and the social context in which they are enacted.

This research is also limited in geographical terms. While the description of the establishment of GIS and its role in policy-making at federal level cover to some extent the whole Amazon, the descriptions of the role of GIS in law enforcement were limited to the state of Mato Grosso. Even though Mato Grosso is an important research context due to its high rates of deforestation and social variety, it is only one of the nine states of the Brazilian Amazon. Furthermore, although in the early part of the present century SEMA was a pioneer in the use of GIS for law enforcement, since then many other states in the region have followed and developed their own systems. This means that this research only had access to some of the law enforcement agencies operating in the Amazon, leaving others for future research.

Even within the narrower empirical context of Mato Grosso and Brasília, some potential informants were not interviewed due to the lack of time or access. These informants included, for instance, the current Minister of the Environment and the President of IBAMA, who despite my insistence, could not find time for this research in their busy schedules. Finally, due to budget and time limitations, the study had to make observations and interviews in a focused way in order to make the most of the little time spent at each research site. Hence, during the year spent in different locations in Brazil, it was often necessary to depart from the research sites leaving many potentially important strands for further investigation behind. This research was also limited as regards the degree to which it had access to the social diversity of the

Amazon. As pointed out by Gonçalves (2005), the Amazon is not one but many. Even though in this study I tried to obtain different local perspectives by interviewing and observing some soybean farmers, cattle rangers and native Indians, it was not possible to engage with important groups such as the quilobolas (afro-descendents), gold miners, land grabbers and rubber tappers. Therefore, this doctoral research should be seen as a first step in exploring a complex social landscape, rather than providing an exhaustive and definitive account of the Amazon.

This does not mean, however, that this research provides only a bird's-eye view of the empirical context under focus. Rather, by obtaining in-depth 'samples' of key practices and historic events, it attempted to provide rich insights into how GIS was developed and how it is used in the Amazon. Furthermore, even though I am not as knowledgeable about these practices as the people that perform them on a daily basis, I have had the rare opportunity to circulate among the various groups and have a multi-sited picture of the whole topic which is not available to most of them.

Having set out the theoretical and methodological considerations that informed this study, the following three chapters offer the case study that are at the core of this doctoral research. The next chapter describes the history of the Brazilian Amazon and the emergence of GIS as a central element of policy-making towards the region in the last four decades. Chapter 5 then moves from the formulation of the environmental policy to its enforcement by IBAMA forest rangers working in the region. Finally, Chapter 6 provides an account of SEMA practices in order to highlight the differences between these two agencies.

Chapter 4: The establishment of GIS in policy-making in the Amazon

4.1 Introduction

This chapter explores how and why geographic information systems have been developed and applied in the formulation of governmental policies for the Amazon from the 1960s to the 2000s. It will be shown how GIS technology and its related practices have been involved in colonization projects in the 1970s, in the emergence of conservationist policies in the late 1980s and in the creation of protection areas in the 2000s. Further, it will also be indicated that the establishment of GIS in policy-making was a negotiated and conflictual process that involved the reframing of this technology in relation to different political agendas and social contexts. However, it will be argued that when these conflicts were temporarily resolved, GIS became the common ground for scientists, members of non-governmental organizations and governmental officials who worked together in the formulation of policies towards the region.

The chapter is organized as follows. The next section describes the role of the GIS in the colonization of the Amazon and highlights the synergy of this technology with the high-modernist aspirations of the military junta that took power in the mid 1960s. The third section describes the negotiation process that led to the acceptance of the GIS developed by INPE by groups inside and outside the government, and the role of this technology in the formation of the current environmental policy in the Amazon. The fourth section then discusses the limitations of GIS in policy-making and discusses some issues stemming from the overreliance on this technology. The final section summarizes and concludes the chapter by providing an overview of its main empirical findings.

4.2 The colonization of the Amazon

The transformation of the Amazon into pasture and crop fields was an old dream of the Portuguese colonizers and their Brazilian descendents. When considering the history of Brazil, it is possible to see a series of policies that attempted in different

ways to 'flood the Amazon with [European] civilization' as the military rulers would later put it (Hecht et al., 1989). From the beginning of the colonization of Brazil in the early 16th century until the mid 18th century almost all the European settlements were placed along the Brazilian coastline. The countryside (including the Amazon region), in contrast, was considered to be largely empty. For instance, Frei Vicente de Salvador, the author of the first history of Brazil, lamented in 1627 that 'so far nobody has walked [in the countryside] due to the negligence of the Portuguese, whom despite being great conquerors of territories fail to make proper use of them, contenting themselves with scratching the coastal areas like crabs' [3] (Salvador, 1982/1627: 8). Even today, the countryside of Brazil is popularly known as '*sertão'*, which is short for '*desertão'*, or big desert (as in unpopulated region) in Portuguese.

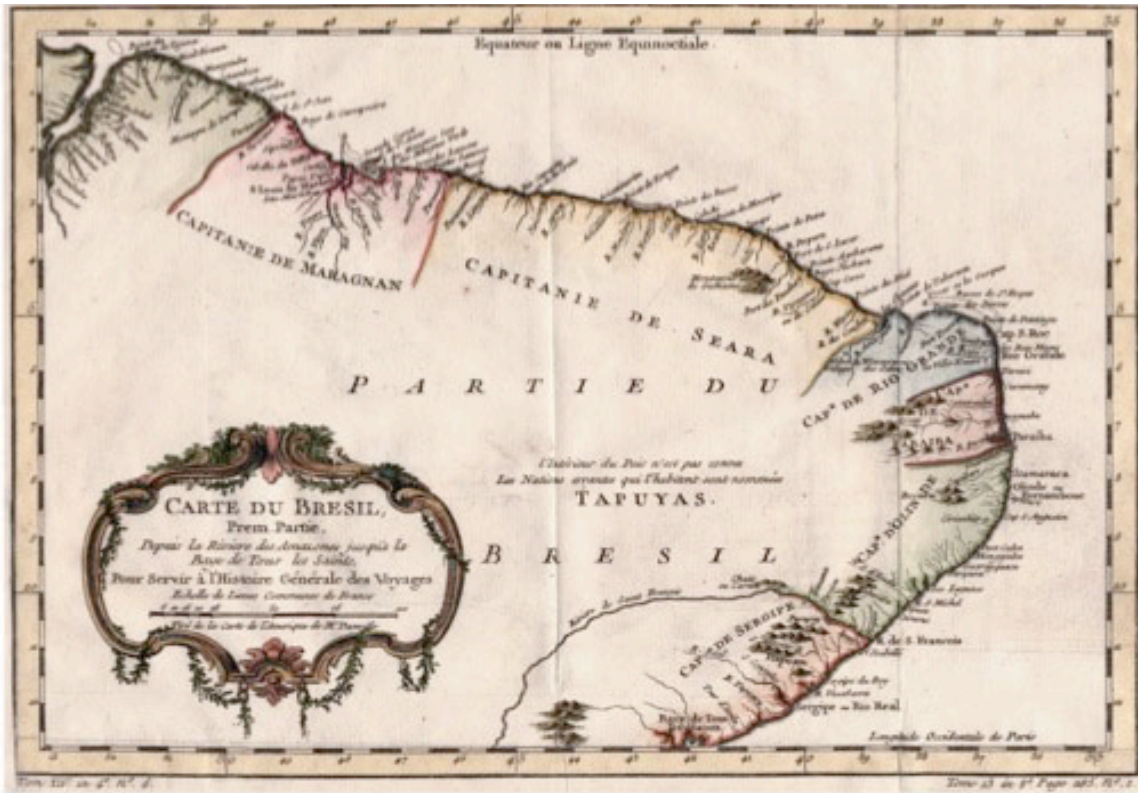

Figure 7 Map of northern Brazil published by Chez Didot in 1749 (Didot, 1749/2010; Image kindly provided by the University of Florida)

The cartographic representations of the Amazon provide a good illustration of the idea of the emptiness of the Amazon in the minds of the Portuguese, and later the Brazilian government over the centuries. Figure 7 shows a map of northern Brazil in

[3] All quotations from other languages were translated into English by the author.

the mid 18th century. The many city names as well as the indication of rivers and some topography along the coastline give a good indication of the extent to which the central government knew those regions, since it was by using maps such as this that the sailing ships from Europe would trade goods, sell slaves and collect taxes. However, in stark contrast to the almost crowded coastline, the only aspect the map indicates concerning the Amazon is that 'the countryside of the country is unknown. The nomads that live in it are called TAPUYAS', which was the word for 'foreigner' or 'barbarian' in the native Tupi-Guaraní, an Indian ethnicity on the coastline that had earlier contact with Europeans (Didot, 1749/2010). In the 20th century, the situation did not change considerably, since, as noted by Lévy-Strauss (1955/1988: 53), the Brazilian official maps in 1918 indicated that 'the territory is unknown, inhabited only by Indians'.

The military junta that stepped into power following the *coup d'état* in 1964 was determined to succeed where other governments had failed with the help of GIS technology. For the new military government, the civilian governments that had steered the country during the previous decades were plagued by corruption, patrimonialism, empiricism and communist tendencies. In order to reverse this trend, the military government aimed at creating a bureaucratic administration based on high-modernist aspirations, namely rational planning, technical expertise and scientific principles. The military were not the first to have boosted modernist ideas in Brazil and it is possible to trace the roots of high-modernists in Brazil to the 18th century. Different authors point out that French enlightenment and positivism were founding principles behind the formation of the Brazilian state (Holanda, 1936/1995; Saldanha, 1968/2001; Schwartzman, 1980/2008). The influence of these principles are clear not only in the different constitutions of the country but also in the Brazilian national flag adopted in 1889 which contains the motto 'Order and Progress' from the French philosopher Auguste Comte (Luz, 2005). During the twentieth century, these positivist ideals were translated into a particularly strong form of modernization, defined by Scott (1998) as the high-modernist ideology. Getúlio Vargas (in power between 1930-1945 and 1951-1954) and Juscelino Kubitschek (in power between 1956-1961) were among the main promoters of high-modernism in Brazil having carried out major modernization policies, such as the promotion of rapid industrialization and the construction of Brasília. For this reason, Ortiz (1988)

concludes from his analysis of the Brazilian culture that modernity has already gained the status of a national tradition, a long-standing aim sought from one generation to another in an uncritical way.

One of the main aspects that differentiated the military government which seized power in 1964 from previous governments was the combination of an unprecedented enthusiasm for high-modernist ideals and their ability to implement these ideals in an authoritative way (Bresser-Pereira, 1972; Scott, 1998). While the previous government had (in most cases) to negotiate its actions with other political groups, the military were able to formulate and implement their projects in an independent way based mainly on the technical expertise of its planners. A minister of Justice during the militarily government provides an illustration of this:

> Everything in the government was planned. It ended an irrational era, dominated by improvisation on the service of political demagogy, and started a period of analysis of the problems and planning of the solutions. After addressing the problem of the Northeast, the [military] President now turned his attention to the Amazon, which for its poverty […] turned into the Mecca of corruption (Viana Filho, 1975: 251-252)

However, for the new military government to have 'everything planned' in the Amazon in a rigorous way it was important for it to determine its territory based on a modernist epistemology. Local accounts from travelers and potentially corrupt officials no longer sufficed. It was therefore essential for the military government to map the Amazon in a scientifically rigorous way. Different sources suggest that the perceived lack of knowledge prevalent during this period was considered an issue from both a military and economic points of view: it was problematic for the military security of the country because the opacity of the region did not allow the central government to verify, for instance, if settlers from neighboring countries were invading remote parts of the Amazon; it was also problematic from an economic point of view as the government held that the Amazon was the country's most treasured resource (Gonçalves, 2005), but it was not clear what those resources were nor how they could be exploited in a rational way. Among the different groups and technologies able to fulfill the expectations of the military government, remote sensing scientists and geographic information systems (GIS) were seen early on as the best solution (Machado, 1969). For instance, a contemporary commentator explained that GIS was essential to 'separate the legend from reality' by capturing with scientific rigor 'the secrets that nobody knows' (Pereira, 1971: 90). The following

excerpt from an interview with a senior scientist from the INPE illustrates the belief of the military government that GIS was key to solving the lack of knowledge about the Amazon:

> The lack of knowledge was considerable, and in addition to that, the fear of international greed was consistent, as shown in the slogan [of an important governmental project of the 1970s] "integrate [the Amazon into the rest of the country] to avoid losing it [to foreigners]". [...] From the beginning, INPE had the mission to address this issue by assessing the country's natural resources with remote sensing: geological [resources], monitor the forests' coverage, some hydrographical applications and agriculture (Interviewee #35, 2007)

The radar in the Amazon project (RADAM) was among the first GIS projects carried out by the Brazilian government. In particular RADAM aimed at assessing the Amazon's natural resources via radar-based sensors on board airplanes, which systematically covered the whole region. Figure 8 provides an example of the output of the RADAM project. In contrast to the emptiness and mystery suggested by early maps of the region, as shown in Figure 7, the GIS-based map in Figure 8 makes a vast expanse of the Amazon clearly visible to policy makers. In this case, the emphasis was on the vegetation structure and the related wood stock of the state of Mato Grosso in the southern portion of the Amazon, but RADAM and other similar research programs also created Amazon-wide maps indicating soil fertility, minerals and watercourses, among other natural resources. In order to consolidate the research in the field of remote sensing and GIS, the government created the INPE (the National Institute for Space Research) in 1972 and started acquiring satellite images a year later. In this way, Brazil become the first country outside North America to have an orbital remote sensing research program (Biache, 1983; Machado, 1969; Tardin, 1982).

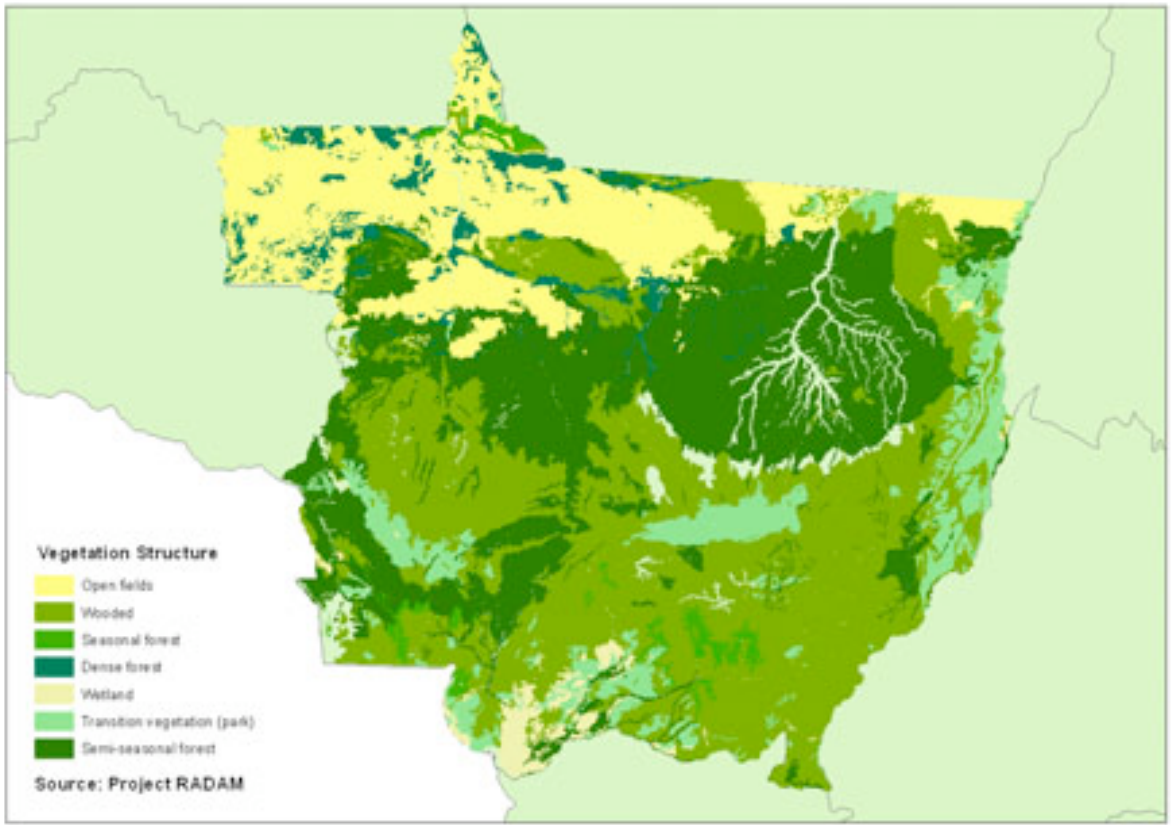

Figure 8 Vegetation structure of the state of Mato Grosso assessed in the context of the RADAM project

As intended by the military rulers and scientists, GIS soon became a central piece in the formulation of the policies towards the Amazon. Based on the maps provided by RADAM and other GIS-based research activities, scientists and policy makers were able to work together to define the future of the Amazon. In particular, the holistic GIS-based representations of the Amazon allowed scientists to communicate with policy makers in an intuitive manner in order to indicate complex data sets showing the availability of natural resources and the challenges concerning the colonization of the region. In this way policy makers were able to plan new roads, the location and size of new agricultural, logging and mining projects in an apparently rational way. This passage from a scientific article published in the prestigious Science Magazine illustrates the central role of GIS and RADAM scientists in the colonization of the Amazon:

> RADAM is highly regarded in Brazil, as well it might be. More to the point, the information it is providing is being actively sought and used by government planners who have responsibility for development activities in the Amazon Basin. Even the proposed land use designations seem not to have become controversial, and there are

> indications that they are being adopted by other agencies. In any case, it is clear that RADAM has provided the means for what one Brazilian [official] describes as "a rare opportunity - the chance to plan a continent's development before it happens". (Hammond, 1977: 516)

In addition to adopting a rational approach to policy-making it was also important for the military rulers to monitor the execution of their plans in a centralized manner and to avoid corruption. GIS practices also played an important role in this activity. In order to obtain a macro understanding of the extent of the success of the new colonization policies, it was important to evaluate how much of the forest was being converted to farms and cattle ranches. Hence, the INPE and the Brazilian Institute for Forestry Development (IBDF), an arm of the Ministry of Agriculture, carried out three Amazon-wide deforestation assessments between the late 1970s and mid-1980s (Tardin et al., 1979). The formulation of these assessments was a complex, expensive and lengthy process. From the observation of the current practices of INPE scientists it is possible to summarize the deforestation assessment practices in the following way. The calculation of deforestation rates starts with the reception and printing of satellite images at the T_0, that is, the initial moment in time that served as the base line for the rate. Then, the scientists and image technicians manually draw the outline of roads, rivers and vegetation types (i.e. forest versus non-forest) and land use (i.e. original vegetation versus farming) on tracing paper positioned on top of the satellite image. The interpretation of these features demanded considerable scientific knowledge about how remotely sensed objects interact with the different light frequencies captured by the satellite. For this reason, the interpretation of a satellite image is often carried out by the scientists themselves or by experienced technicians under the close supervision of scientists. After the scientists finish making the outline for T_0 on the tracing paper, the sheet is positioned on top of a satellite image at T_1 (usually a few years from T_0) at the same scene (i.e. geographical location). The scientists then highlight on a second piece of tracing paper the difference between the tracing paper of T_0 and the image of T_1. More experienced scientists then audit these interpretations in order to check if specific areas had remained unidentified or were wrongly highlighted. Based on the outlines of the audited tracing papers, the scientists calculate the deforestation estimate by adding the area of land use change found in each individual satellite scene and through normalizing these figures, taking into consideration the presence of clouds and the differences of the date of the satellite images for each scene. The final outcome of the assessment is a figure of the

deforestation that took place between T_0 and T_1 in the whole Amazon and in the nine states in the rainforest region.

GIS technology and the work of the scientists were also important for monitoring the progress of the colonization policy at a micro level. Given the modernist aspirations of the military government and the notoriously long record of the Amazon in relation to corruption scandals, it was of central importance to make sure that the public money directed towards the region did not go to waste. This particular use of GIS is evident in the context of the second plan of national development (PND II) to colonize the Amazon. Here, due to the low deforestation figures shown in the first assessment by the INPE, the military changed the emphasis of its colonization strategy from small settlers to big private investors and corporations in the mid-1970s (Mello, 2006). In return for almost free land, low-interest loans and subsidies, private investors were expected to clear large tracts of the forest in order to create big cattle ranches (Little, 2001; Parayil et al., 1998). However, the provision of large sums of money for projects in places where access by land is very difficult, made the government particularly concerned that this policy would provide the opportunity for corruption schemes. Therefore, in order to obtain the resources from the government, investors had to develop a plan specifying, among other things, the geographical coordinates of the future location, the size of the project and the schedule for its execution. The government feared, however, that most farms would only remain 'on paper'. This meant that the government was worried that investors would bribe governmental officials and inspectors in order to confirm the execution of the project as scheduled, and thereby receive the subsides illegally.

At this point, GIS practices came into play. Different senior scientists at the INPE reported that one of the main activities carried out by the institute during the 1970s and 1980s was to verify if the rural development projects in the Amazon were being carried out as promised by the investors using satellite-based GIS (Tardin et al., 1975). Based on the information provided by investors, scientists from the INPE obtained satellite images of the project's locations at different moments in time. Then, by comparing the satellite images, the scientists outlined the changes in the forest cover and measured the sizes of the clearings, were any to be seen. Finally, by comparing the evidence provided by the satellite images and the details of the plan, INPE scientists were able to establish if the investor was indeed using the resources

provided by the government to develop (i.e. clear) the rainforest as promised. According to this assessment, the government would then carry on paying the installments of the loan for the continuation of the project, or prosecute the investor for corruption. Clearly, the INPE was not the only agency able to provide information about the execution of settlement projects. If forests were being cleared and cattle was being raised in the Amazon, it is clear that an official would have been able to verify if those subsidized projects were being executed as promised through actual observation. Nonetheless, soon after the beginning of this activity at the INPE, GIS became the only appropriate way to monitor the subsidized projects since it was considered to be much more trustworthy than the observations of officials on the ground. In fact, for the senior officials and scientists interviewed, GIS was seen as the only way the government could properly monitor the development policies in the Amazon; as senior scientist from INPE directly involved in this activity in the 1970s asked rhetorically: "How would the government inspect such remote areas if not with satellites?" (Interviewee #72, 2009).

4.3 The environmental protection of the Amazon

The previous section suggests that soon after the initial investments in GIS, this technology became the central point of contact between investors, scientists and planners in the central government. In this process, the capacity of GIS to fulfill the expectations of rationality and scientific certainty of the military regime seems to have played an important role. However, the military government was not the only group interested in the future of the Amazon. This section therefore describes the ways in which GIS was implicated in the emergence of conservationist policies towards the Amazon. Specifically, the next subsection sets out the emergence of the idea of deforestation as a global issue and explains how groups supporting the development of the Amazon used GIS to dismiss the concerns of environmentalists. Following this, Subsection 4.3.2 explains how GIS was eventually subverted and become a central element in the attempts of some scientists and activists to influence the policy towards the Amazon, and the related U-turn in the Amazonian policy at the end of the 1980s. Finally, Subsection 4.3.3 indicates how the controversy surrounding the 'correct' GIS-based deforestation figures for the Amazon was settled. It also discusses the establishment of GIS data as generated by the INPE as a reliable

common ground for debates concerning the future of the Amazon, and its role in the key policy changes of the 1990s and 2000s.

4.3.1 The emergence of deforestation as a global issue

When the military rulers initiated the large-scale colonization of the Amazon, the scientific community did not consider deforestation to be a major issue. The idea of forestry management for the efficient production of wood has existed since the 18th century (Scott, 1998). In fact it was with this logic that in 1965 the Brazilian government created its Forestry Code (Ahrens, 2007). Similarly, the idea of conservation parks for aesthetic and nationalistic reasons can be traced to the 19th century (Bocking, 1997; Guha, 2000). However, it was only in the early 1970s that the term 'tropical deforestation' emerged in reference to land clearing as an environmental issue with global consequences, and not simply as a matter of timber supply (Keck et al., 1998). One of the earliest references to deforestation in this sense can be found in the report – 'Man's impact on the climate', prepared by the influential Massachusetts Institute of Technology's Centre for the Study of Environmental Problems for the then upcoming United Nations Conference in Stockholm (Matthews et al., 1971). In the introduction to one of the sections of the report, the editors commented that a recent article about the colonization of the Amazon rainforest published by *The New York Times* caused concern among some scientists. This concern, in turn, prompted the meteorologist, Professor Reginald Newell to write a three-page comment asking for more research into the area and hypothesizing a link between tropical deforestation and potential changes to large-scale atmospheric circulation (see also Richards, 1970). The geographer William Denevan (1973) published another influential paper that provides an early example of what became a standard way to refer to tropical deforestation. In this paper, Denevan highlighted the value of the Amazon for its wildlife, hydrology and as a 'genetic reservoir for the future' setting the tone for much of the future arguments for the reservation of the Amazon (132) as well as mentioning Newell's hypothesis concerning the link between deforestation and the global climate.

During the early 1970s, some anthropologists and journalists conducting fieldwork with local Indians also highlighted the negative effects of the colonization projects on the local population (Bourne, 1978; Denevan, 1973; Jackson, 1975; Meggers, 1971;

Price, 1989; Shoumatoff, 1977). What brings these accounts together is an image of the Amazon that was radically different from the one prevalent at the time. Instead of an image of the Amazon of as an invincible jungle, these accounts were claiming that the rainforest and its people were extremely fragile and deserved protection. Hence, even the slightest interference in their habitat and culture might lead to grave consequences at a global scale. However, despite these increasing levels of alarmism, the calls to save the Amazon rainforest initially had a modest impact outside a niche of the academic community and the newly founded environmental non-governmental organizations such as the World Wildlife Fund (Keck et al., 1998). Local farmers reported, for instance, that colonization projects had enjoyed considerable popular support in Brazil in the 1970s and 1980s. To break into the jungle and establish a new farm was seen in that period as both an act of patriotism and an opportunity to a better life. The following excerpt from an interview with a farmer who migrated to the Amazon at the time gives a hint of the enthusiasm and public support for the colonization policies:

> In the 1970s there was a call from the state to [colonize] this region. The military told us that the land was cheap and the soil good, and the people [from the south] indeed came here. People from the south, like us, would sell their lands there and buy here 10 to 15 times more land. Information about the region spread through the press, TV, radio and the other people from the south that had already moved here. The news back then spread very fast! It used to be a big [financial] advantage to come here. (Interviewee #70, 2009)

With the exception of the few dissenting voices, the ongoing colonization of the Amazon was also received very positively in North America and Europe. For instance, in 1971 the USA news magazine *Time* described the building of the *Transamazonica* highway as 'the work of the century' (Time, 1971). On the other side of the Atlantic the tone of the news was similar. For instance, a front-page article of the British newspaper *The Times* in 1973 showed pictures of the modernist Brasília and the construction of the *Transamazonica* highway (see Figure 9) side by side to highlight how the country's 'industrial expansion and development [was] almost unparalleled among countries of the Third World' (Frenchman, 1973: 1). This optimism about the development policy in the Amazon was also reflected in the support Brazil received from many multilateral institutions and multinational corporations. Against the recommendations of anthropologists hired by the World Bank to evaluate the impact of projects on the native Indigenous population (Price, 1989), this and other multi-lateral organizations provided substantial loans for the

construction of roads, dams, mines and the execution of colonization projects in the Amazon (Hecht et al., 1989: 116). Private international capital was also very keen to take advantage of the business opportunities in the region and the generous tax breaks and subsidies offered by the government in the second plan for national development (PND II). Here, large corporations from developed countries were directly involved in running a series of activities in the Amazon rainforest, including cattle ranching (e.g. Volkswagen, Nestlé), mining (e.g. U.S. Steel), logging (by various Japanese corporations) and paper production (e.g. that of the US magnate Daniel K. Ludwig) (Little, 2001; Oren, 1987; Parayil et al., 1998).

A country in the making: new buildings in Brasília symbolize the development of the interior and the Transamazonia highway which will cut a 3,000-mile path through the Amazon jungle.

Figure 9 Pictures from an article published in *The Times* on November 18, 1973 referring to the colonization of the Amazon and the construction of Brasília (Frenchman, 1973)

A closer look at the scientific debates concerning the Amazon helps to explain why the initial calls to save the rainforest were largely ignored. Even though among those calling for the preservation of the Amazon there were preeminent researchers, their claims did not appear to be sufficiently strong at the time from a positivistic point of view. Of course, the anthropologists Betty Meggers (1971) and David Price (1989) and the ecologist Paul Richards (1970) had convincing evidence concerning the effects of deforestation for specific indigenous populations and for the wildlife in a portion of the rainforest. Their empirical data was however restricted to specific parts of the rainforest and was not considered strong enough to support their concerns about the future of the whole Amazon. In addition to this, in that period as today, qualitative studies about deforestation, such as the one carried out by anthropologists, were often

dismissed by natural scientists and policy makers for being biased towards the interests of the local population and for holding an antagonistic stance towards the developmentalist sector of the government (Schor, 2008).

There is a widespread view among INPE scientists that the only way to obtain rigorous scientific evidence about deforestation in the Amazon as a whole is through the use of GIS and satellite images. This means that only those with access to this technology are able to make reliable statements about the Amazon. There is also evidence that during the 1970s and early 1980s, the agencies using GIS were more closely aligned to the Brazilian government than the portion of the scientific community concerned with the protection of the rainforest. For instance, even though some INPE scientists showed their concern about the concentration of deforestation in certain parts of the Amazon in official reports during the 1970s and 1980s, they did not challenge the governmental colonization policy (Tardin et al., 1979). Instead, as explained in a report, they seemed to be largely aligned with INPE missions to 'provid[e] information to improve the process of occupation of the Amazon', and not to protect it (Novaes et al., 1980: 10). The scientists from the United Nation's Food and Agriculture Foundation (FAO), one of the few other institutions with the capability to use GIS, seemed to be even closer to the developmentalist project of the Brazilian government. During the first UN conference on the environment in 1972, some countries showed their concern about the ongoing deforestation of the Amazon. In particular, they suggested that the FAO and other research bodies should create a 'World Forest Appraisal Programme' to make 'use of advance technology, such as satellites which use different types of imagery and which could constantly survey all [the] forest' (UNCHE, 1972: 5). However, despite the intention of some countries at the conference, the 'FAO was in effect instructed to aid […] the exploitation of tropical forests' (Emmelin, 1972: 136). The effects of this alignment can be seen, for instance, in FAO's reports during the 1970s and most of the 1980s where satellite technology was described as mostly a tool to facilitate the identification and management of wood resources 'to meet the threat of a world-wide wood shortage and to help the development of those countries possessing these forests' (FAO, 1976).

During this period, some scientists with access to GIS also used this technology to dismiss the claims that the rainforest was in danger. For instance, the deforestation assessments carried out by the INPE and the IBDF during the 1970s and 1980s

usually concluded that 'taking into consideration the surface [of the Amazon…], 4,975527 km^2 can be considered low' (Tardin et al., 1980: 10). This particular claim allowed governmental officials to dismiss environmentalist concerns and related anthropological and biological studies by pointing out that the ongoing deforestation was very limited and thus harmless (Bourne, 1978). The scientists from FAO were even more assertive in criticizing environmentalist concerns about the Amazon. When the report with the first global assessment of tropical forests was finally released in 1981, the data was framed as proof that deforestation was under control and that it was necessary for the development of tropical countries (FAO, 1981). In this regard, in an article published in *The Times*, the FAO scientists indicated how their study showed that fears of tropical deforestation were 'excessive and misdirected'. In the article, FAO scientists also criticized environmentalists for being too 'speculative' in their assessments of the relation between deforestation and global warming (Clayton, 1982). The final report of the study makes this point even clearer:

> Comments and judgments on deforestation in the Brazilian Amazon are found in many documents and many more newspapers and magazines. This literature does not provide unfortunately the factual and quantitative data that could allow for a sound estimate of the magnitude of the problem in terms of affected areas and of the quantitative aspects of degradation and reconstitution of the forest cover. (FAO, 1981)

This statement suggests that GIS practices were initially not only put into the service of the developmentalist policies of the military government, as shown in the previous section, but were also used to dismiss environmentalist concerns about the Amazon. Underlying the criticisms of environmentalist concerns is the idea that for deforestation to be considered a global environmental issue the evidence supporting this claim should also be on the same scale. Hence, the scientific evidence has to show that deforestation is not a local, small-scale process, but rather a large-scale issue that can produce negative effects on a global level. In this process, the lack of the capability of some groups to tailor GIS to their ends was an important factor that explained why they were not able to cooperate with policy-makers and have their concerns heard. The next section describes how the scientists concerned with the environment were finally able to tailor GIS to their own ends and how this allowed them to contribute to the U-turn in the Brazilian official policy towards the Amazon at the end of the 1980s.

4.3.2 Subverting GIS to environmentalism

While the initial calls to save the Amazon rainforest had fallen mostly on deaf ears, the situation was very different from the end of the 1980s onwards. During most of the 1980s, the government vehemently denied any wrongdoing in relation to the Amazon and even intensified its developmentalist policies with the roll out Polonoroeste, a large-scale colonization project financed by the World Bank. By the end of the decade, however, a young civil government was busily writing one of the world's most environmentally friendly constitutions which viewed the Amazon rainforest as a 'national patrimony'. Furthermore, with the program *Nossa Natureza* that was announced at the end of 1988, the government 'recogniz[ed] the gravity of the current tendencies of the occupation process of the Amazon' and showed a willingness to change it (Brasil, 1988 cited in Mello, 2006: 69). The measures relating to *Nossa Natureza* included a series of presidential decrees creating new national parks, establishing environmental education projects, setting new regulations concerning the use of chemical products in agriculture and, most importantly, abolishing subsidies towards cattle ranching, which had long been considered to be the main driver of deforestation in the Amazon (Browder, 1988). Five months later, the government also created the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and provided considerable financial resources in order to intensify the law enforcement activities to control deforestation in the region (for more on IBAMA see Chapter 5). The Brazilian government also considerably changed their diplomatic position in relation to the environmental protection of the Amazon. In contrast to the first UN conference on the environment held in Stockholm in 1972, when the Brazilian government strongly refused to accept criticism regarding its policies towards the Amazon at the UN conference held in Rio de Janeiro in 1992, Brazil championed the signature of 'Forest Principles […] for a global consensus on the management, conservation and sustainable development of all types of forests' (United Nations, 1992).

This policy change did not go unnoticed by the academic community. Different fields of study in the social sciences highlighted the role of non-governmental organizations (Keck et al., 1998; Price, 1994), grass-roots moments (Gonçalves, 2005; Hecht et al., 1989), the mass media (Bendix et al., 1991; Slater, 1996) and some progressive senior officials within the government (Guimarães, 1991; Mello, 2006) in the U-turn over

Amazon policy (see also Keck, 2001; Kolk, 1998; Lemos et al., 2008; Moran, 1996). In addition to these groups and their lobbying practices, there is evidence that some scientists and GIS practices also played an important role in this policy change. In contrast to the 1970s when conservationist campaigners and scientists failed to engage with GIS, from the beginning of the 1980s onwards it is possible to see increasing use of GIS and satellite images within conservation biology and other fields, with the call for the preservation of the Amazon rainforest (Fearnside, 1982; Malingreau et al., 1988; Skole et al., 1993). For instance, a review of the conservation biology literature shows that while in the 1970s there was virtually no study using satellite images and GIS, from the mid 1980s onwards, an increasing number of studies drew primarily on this technology for their empirical basis (Leimgruber et al., 2005: 97).

It has emerged from interviews and the analysis of documents as well as journalistic and academic articles that scientists tailored GIS and satellite imagery to support a conservationist agenda in two main ways. Starting in the early 1980s, it was argued in different studies that the Brazilian government was systematically underestimating the total deforestation in the region (Fearnside, 1982; Malingreau et al., 1988; Menzel et al., 1992; Petit, 1989). One of the main points of criticism was the non-inclusion of deforestation that occurred prior to the 1970s. Even though the scientific debates were centered on technical matters, some sources suggest the presence of a political struggle as well. For instance, in an article published in *Folha de São Paulo*, Brazil's most influent newspaper, a journalist voiced these concerns by accusing the INPE of 'making-up' the deforestation data for the state of Maranhão in the east of Amazonia in order to please the former president, José Sarney, who is from that region (Tuffani, 1989).

However, while the questioning of the INPE's data generated some reaction, green scientists were even more successful when they started to use of GIS to create their mathematical projections for the region's future. Scientists from the INPE and FAO were very conservative in relation to making predictions about future deforestation. For instance, the FAO (1981) predicted that by the end of the century the tropical forests would have lost only 6% of their area (Clayton, 1982). In contrast, many scientists who were more concerned with the negative impact of deforestation predicted that the 'forest as a whole may have ceased to exist by 2005' (Kerr and Sioli in Bourne, 1978: 204). Philip Fearnside (1982), one of the main figures in the field,

expressed an even more catastrophic view. In a famous article, he used the INPE's deforestation data for the years 1975 and 1978 to predict that the Amazon rainforest would be completely cleared by 1991 (see Figure 10). At the heart of the difference between the predictions from the FAO, on the one hand, and Fearnside, Kerr and Siole on the other, is the assumed basis for the growth of deforestation. According to the FAO, deforestation would follow a linear trend, and as such proceed at a steady pace in the years to come. Fearnside (1982) and others, in contrast, argued that deforestation could occur exponentially. In this way, this prediction 'collide[d] with one of the Amazon's great illusions: the illusion of infinite size' (*ibid*: 82).

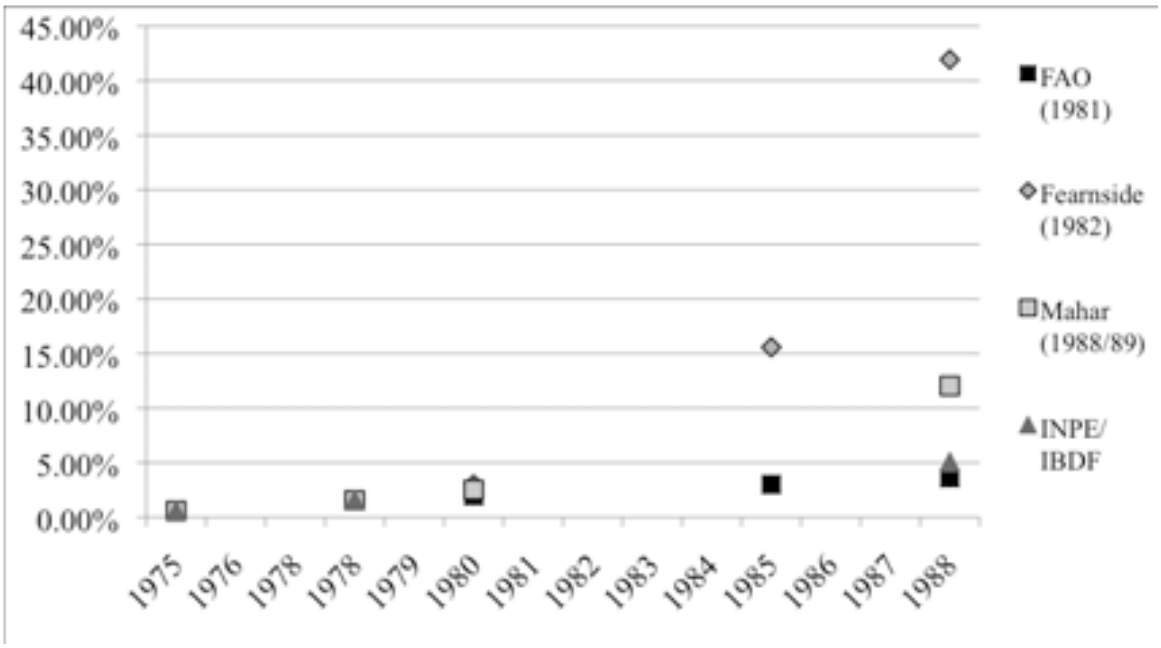

Figure 10 Estimates of the accumulative percentage of rainforest loss between 1975 and 1988

While the challenge of INPE's data and the proposal about deforestation trends at exponential rates caused some debate within the government, one the most influential studies in this regard was published by the World Bank economist Dennis Mahar. Drawing upon Fearnside's initial work, Mahar (1989) published a study in 1988 making the striking claim that 12.5% percent of the Amazon rainforest was already cleared, and blaming the policies of the Brazilian government for this ecological disaster. According to different interviewees and documents, Mahar's study had an immediate impact in Brazil. Shortly after the report was published, the central government asked the INPE to create PRODES, a new GIS that would measure deforestation rates on a yearly basis. The aim of PRODES was two-fold. On the one hand, the government wanted to 'demonstrate to the international community our

[Brazil's] preoccupation with the environment', as a senior politician who was one of the protagonists of these events explained (Interviewee #7, 2007). Hence, by creating a better system with which to monitor on a regular basis, the government intended to present itself as a capable and rational manager of the rainforest. Secondly, the Brazilian government set out to challenge Mahar's figures by providing 'measured values' in contrast to the projections provided by his study (Tardin et al., 1989: 3). A senior INPE scientist involved in the event summarized the political motivation behind the creation of PRODES:

> Back then it was clear that PRODES was only about generating a number before an adventurer does so. Because, you know, back then you had the Americans and other people researching the Amazon and the government wanted to be the first to say the numbers (Interviewee #35, 2009)

Despite the government's effort, PRODES was not able to placate the growing criticism and turn attention away from Mahar's study. As a result of a successful lobbying campaign by NGOs (Keck et al., 1998) and the strikingly high figures published by Mahar (Petit, 1989), the World Bank and other international institutions decided to suspend the payment of loans to colonization projects in the Amazon (Hecht et al., 1989). In the meantime, grass-roots movements such as the one led by the rubber-tapper, Chico Mendes, were able to attract attention both in the Brazilian and the international mass media, and this increased after the assassination of Mendes in December 1988 (Gonçalves, 2005). It was in the context of this mounting diplomatic and political crisis that the government signed the decree for the creation of *Nossa Natureza*, IBAMA and the other environmental measures mentioned at the beginning of this section, this representing an important change in the official policy towards the Amazon (Mello, 2006).

A number of factors help to explain why GIS (and in particular Mahar's study) successfully provided a bridge between green scientists and policy-makers more than other scientific instruments and studies. Firstly, in contrast to anthropological and ecological studies, which were only able to make truthful claims about a specific patch of rainforest, these GIS practices were able to refer to the present and future process of deforestation as a whole. Secondly, in contrast to local assessments and narratives from the indigenous population, which may be considered biased and dramatic, the figures of deforestation have the appearance of objectivity and scientific rigor which appeals to policy-makers. Finally, Mahar's study appears to have been

particularly influential due to both his position as an economic advisor to the World Bank and because of the way in which he downplayed the uncertainty of his deforestation figures in order to avoid skepticism from policy-makers. At the beginning of 1988 when Mahar published this study, the last Amazon-wide deforestation assessment available was for the year 1978, with some extensive but incomplete assessments for the years 1980 and 1983 (Fearnside, 1986). Therefore, in order to present a current deforestation figure, Mahar used a mathematical projection based on past figures from the Brazilian government, which, in the case of Mahar, appeared to follow a mathematical function of exponential order (Passarinho, 1989; Tardin et al., 1989). Therefore, the steep increase in the total loss of the rainforest from 2.5 to 12% between 1980 and 1988 appeared as a sound and empirically measured figure, and not merely an approximate projection, as indicated by Mahar:

> [E]arly Landsat images were cited as proof [by the Brazilian government] that the environmentalists -some of whom had predicted the demise of the Amazonian forest by the end of the century -had greatly exaggerated their case (Denevan 1973). More recent data, however, make it clear that there was no cause for complacency. [...] The 1988 figure is equivalent to 12 percent of Amazonia and is larger than France. (Mahar, 1989: 7)

In the excerpt above, it is clear that Mahar is keen to emphasize both the empirical certainty of his deforestation figures and the scale of deforestation, suggesting that environmentalists were right in claiming that the rainforest was in danger. However, what is interesting about the debate concerning the 'right' scale of deforestation is not which side was wrong or right in relation to what was actually going on in the Amazon. Rather, the main significance here is how different groups, holding varying political agendas and concerns were able to tailor GIS to depict different situations for the present and future of the Amazon rainforest; by simply making calculations in different ways and choosing to include/exclude certain types of deforestation, these groups were able to present radically different versions of the Amazon reality - a change that relied more on the methodological and political choices of scientists than on the changes in the Amazon according to the experiences of its inhabitants.

As observed in the previous sections, the notion that the Amazon is fragile emerged from ecological research and represented an important change in relation to past views. However, this suggests that it was only these claims based on GIS practices where this view was able to influence policy on a global scale. However, the end of the 1980s was just the start of the role of GIS as an interface between scientists,

activists and policy-makers. The next section describes how the establishment of PRODES and other forms of GIS during the 1990s and 2000s as trusted tools allowed different groups to cooperate in the formulation of policies towards the Amazon.

4.3.3 Negotiation, GIS data access and policy-making

While the tailoring of GIS to suit the green agenda in the 1980s played an important role in changing the direction of the policy towards the region, it was from the 1990s onwards that GIS became a key interface between an increasing number of groups attempting to influence the future of the Amazon. This section traces how the use of GIS became less controversial following a process of negotiation and opening of INPE. From this it will be shown that the establishment of the INPE's GIS PRODES, and more recently, DETER, as trusted common ground between the different groups made it even more central to policy-making.

PRODES did not have an easy start. The circumstances of its creation referred to above led environmentalists and some members of the scientific community outside the government to cast doubts over the INPE's initial deforestation assessments. However, in contrast to the 1980s when the INPE ignored many of the criticisms, the end of the military rule led the institute to adopt a much more open stance towards the scientific community as a whole. For instance, following the criticisms concerning PRODES's deforestation data, the INPE accepted an inspection from NASA scientists (Petit, 1989) and later worked with Philip Fearnside (one of the most vociferous critics) in the development of the new deforestation assessment methodology. From this collaboration a new study emerged that took into consideration the deforestation that had occurred before the 1970s, increasing in this way the final number of cleared forest up to 1988 by 67% in relation to PRODES' initial figure (Fearnside et al., 1990). The scientific community appeared to be further reassured when three years later scientists from NASA and the University of New Hampshire in the USA published a GIS-based assessment of deforestation in the Brazilian Amazon showing the numbers to be very similar to the INPE's revised figures (Fearnside, 1993; Skole et al., 1993).

The openness of the INPE to negotiate and accept the suggestions of the wider scientific community brought good results. Since the late 1990s, different studies published in prestigious journals suggested the emergence of a consensus concerning

the quality and trustworthiness of the INPE's deforestation assessments (Fuller, 2006; Kintisch, 2007: 536). Even Dennis Mahar, in a more recent publication, dropped his own initial estimate in favor of the deforestation figures calculated by the INPE for the state of Rondônia, which amounted to half the figure he had initially published in 1988 (Mahar et al., 1999: 18). From time to time it is still possible to observe the emergence of conflicts and mistrust. For instance, in 2008 GIS experts on the behalf of SEMA, the state-level environmental agency of Mato Grosso, wrote a report that challenged INPE's figures of deforestation based on DETER, its real-time deforestation detections system. Privately, these scientists and senior officials from SEMA reported that they felt INPE might be conspiring against them in an attempt to smear the image of the state as an agricultural powerhouse (see Chapter 6). At the other end of the scale, members of NGOs and scientists also reported that they feared that INPE might submit to the pressure of the central government to show low deforestation figures. In most cases, however, the challenges to INPE's GIS were conducted mainly privately or labeled as a strict 'technical matter'. In this way, the GIS data provided by INPE has slowly become (for all practical purposes) common ground for the joint formulation of the policies towards the Amazon by different groups.

The use of INPE's GIS data as common ground can be seen today in many policy-making forums. Here INPE provides the main data source for news reports in the Brazilian and international media report on increases or decreases in deforestation rates, even if the name of the institute is at times omitted. Similarly, today the vast majority of studies and reports published by environmental NGOs use the INPE's GIS-based deforestation rates without questioning the figures (Greenpeace, 2008; IPAM, 2008; Micol et al., 2009). However, it is within the government that the position of INPE's data is even more hegemonic. INPE's GIS-based deforestation rates are often the main if not the only data source in debates concerning the region in the national congress and the different ministries. For instance, the data provided by INPE (and GIS data in general) tend to be the central focus of the annual seminars organized by the Ministry of Environment. In these events, scientists, members of NGOs and governmental officials present their own interpretations of GIS data and discuss future policies in the region (INPE, 2010).

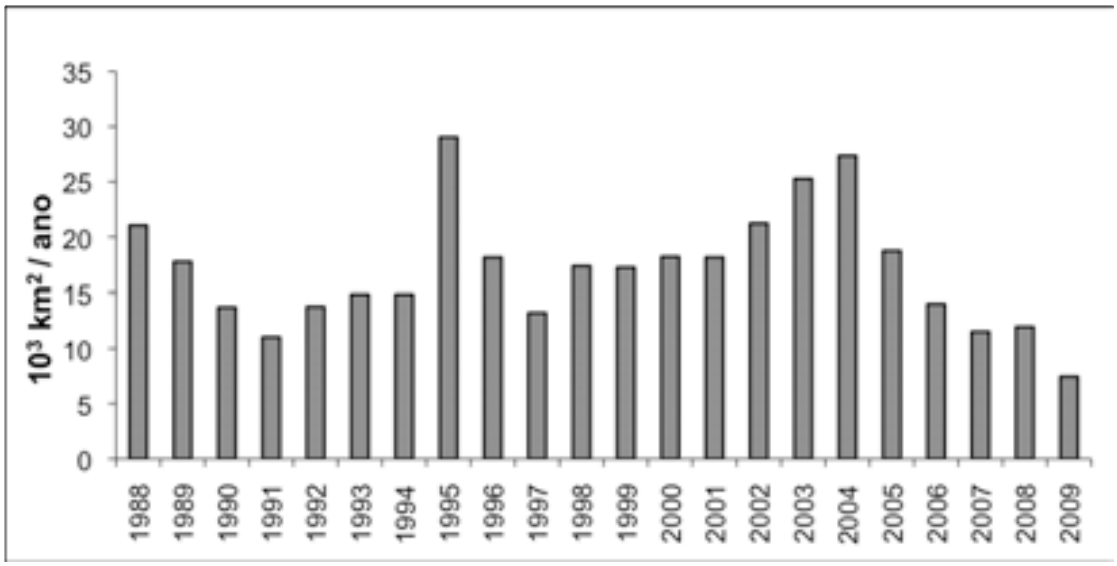

Figure 11 Annual deforestation rates calculated by the INPE through PRODES, a satellite-based monitoring system

It is possible to link the GIS data provided by the INPE and its appropriation by different groups to at least four important changes in the policy towards the Amazon that took place from the mid 1990s onwards, namely, the increase in the legal reserve, the creation of conservation areas as barriers, the limitation of bank loans to farmers and the construction of roads. As briefly mentioned above, the 1965 Forestry Code was initially conceived as a way of managing the country's wood resources (Pereira, 1950). Nevertheless, when concerns about deforestation began to emerge in the 1970s and 1980s, this piece of legislation started to be reframed as a conservationist law aiming at ensuring the environmental preservation of the Amazon (Ahrens, 2007; Figueiredo et al., 2001). Among the many changes in the Forestry Code and related regulations in the last two decades, the most significant and controversial one was the increase in the minimum legal reserve (the share of private lands that cannot be cleared) from 50% to 80% for all private properties in the Amazon rainforest. Hence, with a stroke of a pen, all the individual farmers in the Amazon saw their farmable area reduced from 50% to less than 20%. Even though some studies have provided a scientific justification for this increase (Metzger, 2002), a number of interviewees from the government reported that the appropriation of the 1995 GIS-based deforestation figure by environmental NGOS was a key factor behind this change (see Figure 11). For example, a senior official who was personally involved in the policy change in 1996 provided evidence of this link:

> There was a lot of pressure to preserve the Amazon rainforest. It was as an answer to these pressures that they changed the law in 1996. It was following the release of data showing a hike in deforestation in 1995. […] So we changed the law and raised the forest reserve to 80% to say that we were doing something about it. […] It was very fast, [INPE] released the data and one or two weeks later we changed the law. (Interviewee #23, 2009)

During this century it is possible to find many instances where groups both inside and outside the government tailored GIS to influence policy decisions in relation to the Amazon. In 2003, the INPE decided to publish online the map of deforestation (i.e. the data set containing each individual deforestation polygon) behind the PRODES deforestation rates. In this way, the INPE expanded access to GIS-based deforestation analysis and modeling beyond the traditional centers such as those of NASA and well-resourced universities in the USA and Europe. One of the first organizations to take advantage of this new data set was the *Instituto Socio-ambiental* (ISA), an NGO with good visibility within the Ministry of the Environment. In particular, the ISA superimposed the INPE's data on the maps of conservation areas and indigenous reserves (ISA, 2003). This study found that deforestation in protected areas is almost ten times lower than in other areas, so acting as a barrier for the expansion of deforestation. This initial finding was further confirmed by a series of other more detailed studies drawing upon the same data set offered by the INPE (Ferreira et al., 2005). In particular, these GIS studies have increasingly described protected areas as barriers to forest cutting and fires along the 'arc of deforestation'—the front line of forest destruction moving north from the south and southeast of the Amazon (Ferreira et al., 2005). Hence, GIS practices have led to a reframing of the role of protection areas from the protection of endangered populations and biodiversity to a strategy of reducing or even containing the expansion of the agricultural frontier in the Amazon.

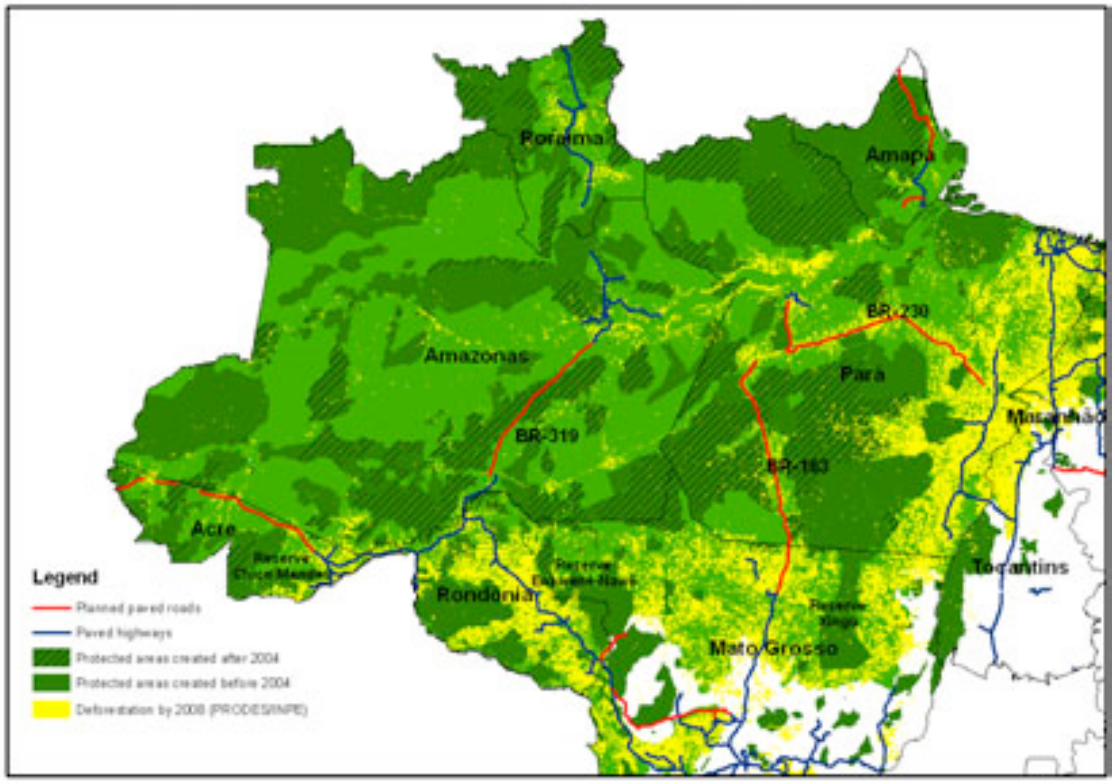

Figure 12 Map showing deforestation patterns, main roads and protected areas in the Amazon (Source: IBAMA, PRODES/INPE and IBGE 2010)

This new rationale for the creation of protected areas has been very influential in the formulation of the PPCDAm, the Plan for the Prevention and Control of Deforestation in the Amazon launched in 2004. One of the ex-directors of the Ministry of the Environment directly involved in the formulation and implementation of the PPCDAm confirmed that the creation of new conservation areas based on GIS data was undoubtedly one of the two main components of the plan (the other being DETER, the real-time GIS-based monitoring system described in Chapter 5). The results of this policy can be seen in a GIS representation of the Amazon that was created using the same GIS application and data set generally adopted by policy makers (see Figure 12). Here, the first feature to notice is the substantial increase in the number of protected areas after 2004 (hatched areas). Moreover, it is also possible to see in the GIS-based map that while most pre-2004 protected areas were created away from the agricultural frontier or in areas traditionally inhabited by forest dwellers, the new conservation areas are mostly located in the arc of deforestation or alongside planed paved roads (see BR-163 and BR-319) – areas which GIS studies had indicated to be particularly vulnerable (Laurance et al., 2001; Pfaff, 1999).

More recently, the further opening of deforestation data of INPE on the internet led to other important policy changes. In 2004, the INPE developed DETER, a GIS that was initially conceived as a system to support the work of IBAMA's forest rangers by providing 'alerts' with the location of new deforestation every 15 days (see Chapter 5). In addition to these alerts, the INPE also calculated the figures of the total deforestation on a monthly basis for internal purposes. As different scientists explained, the INPE decided to keep these monthly deforestation rates inside the government because they were based on satellite images with a much lower resolution than PRODES' yearly assessments. Hence, the scientists wanted to avoid being a source of criticism for the academic community by publishing less reliable data, while still informing the government about the progress of deforestation. To the surprise of some scientists, however, the government was not willing to respond to the rates generated for internal purposes in the same way as it has been responding to the publicly announced yearly deforestation rates. For instance, different INPE scientists explained that even though they repeatedly informed the Ministry of Environment about the increase in deforestation in early 2004, the government largely ignored their concerns. As one senior scientist directly involved in this event angrily recalled:

> I was sleeping less than two hours and I was tearing out my hair. But then I used to call the director of the Ministry of Environment and say, "You are not doing a thing about this. We have already delivered [DETER's figures] to you showing more than 13,000 [ha of deforestation]!!!" "But 13,000 is not much" he used to reply. But we were in JUNE and we knew it was too soon for such high accumulative numbers for the year. (Interviewee #35, 2008)

Following the experience of 2004 described above, and when deforestation started to rise again in late 2007, a group of INPE scientists took the polemic decision to publish the monthly rates on the Internet. The scientists explained that even though they still thought DETER was not as reliable as PRODES in providing area estimates, they felt it was necessary to publish DETER's data online. This was a risky decision since the less reliable data provided by DETER could be more easily challenged (as indeed it was in 2008 by the government of Mato Grosso). However, the same scientist quoted above explained that 'as a vigilante [of the Amazon] we may sin by making some mistakes, but we cannot sin for omission' (Interviewee #35, 2008). The strategy of INPE's scientists worked as intended. The release of the monthly deforestation rates from DETER showing an upward trend in deforestation after three years of reductions generated a series of protests and studies by environmental NGOs

and other scientists who had placed considerable pressure on the central government. Because of this pressure and related deforestation data, some officials from the Ministry of Environment were able to persuade the president to toughen the legislation. The measures included a decree prohibiting banks from providing loans to farmers who are not able to prove that they are complying with environmental law; and the obligation for farmers from municipalities with high rates of deforestation to update their land registrations at INCRA (the federal land agency) which includes a GIS-based system aiming at ensuring a more efficient control by the government. In particular, the credit restriction decree was considered by different officials to be one of the most successful environmental policies in recent years, since shortly after the publication of the decree, deforestation rates as shown by DETER, started to show a downward trend.

The fourth example of the role of GIS deforestation data suggests that not only environmentalists but also groups from other political positions were able to tailor GIS to suit their agenda. In 2001 the federal government proposed *Avança Brasil*, an ambitious plan to improve the country's transport infrastructure among other measures. The paving of highway BR-319, which crosses the heart of the rainforest, was one of the main points of the plan. However, following the publication of GIS-based studies by scientists with environmentalist concerns and NGOs showing the connection between deforestation and the construction of roads (Laurance et al., 2001), the government abandoned the project. Even though the Minister of Transport questioned the use of models to predict deforestation, the acceptance of the government regarding the suggestions put forward by Laurance et al. (2001) suggest that it was not willing to adopt the same stance of denial of the 1980s in relation to GIS-based deforestation data. Between 2004 and 2007, however, there was a gradual decrease in the annual deforestation rate detected by PRODES from INPE (see Figure 11). Taking advantage of this new situation, the developmentalist faction of the government decided to include a plan similar to *Avança Brasil* for the paving of the BR-319 in the *Programa de Aceleração do Crescimento* (PAC) (Brasil, 2007). Using the argument that the GIS data by PRODES was proof that the government was able to control deforestation, the Minister of Transport affirmed that 'not a single tree was going to be cut' because of the road (Salomon, 2009) and, as a result, the government was able to carry on the paving project. On the 23rd of April 2010, the then Chief of

Staff and the present President of Brazil, Dilma Rousseff inaugurated the first 208 km of the highway, starting in Porto Velho (DNIT, 2010).

The four examples above suggest that during the 1990s the government moved away from attempting to deny the existence of deforestation to accepting the INPE's GIS-based deforestation data as a mirror of what was going on in the Amazon. In this process, it is possible to observe that, as in the 1980s, GIS was still being tailored to suit the needs of different groups. In contrast to this period, however, most groups accepted that the figures produced by the INPE were correct, even though they might not have benefited their own agenda. It could also be observed that in order to reach the status of a trustworthy data source, the INPE had to negotiate with the broader scientific community and accept some of their suggestions, which had initially been ignored in the 1980s. Additionally, the increasing availability of GIS data meant that more groups were able to draw upon GIS in order to tailor it to their own agenda. Therefore, while the negotiation and opening process mentioned above left the government more exposed to criticism, it also seems to have contributed to the settlement of the debates surrounding INPE's data and the establishment of GIS as common ground for the debates concerning the future of the Amazon.

4.4 Replacing people by pixels

The sections above suggest that the establishment of GIS as common ground in the discussions between different groups both inside and outside the government allowed environmentalists to gain greater influence in policy-making, while not denying the possibility of the use of GIS to tailor the needs of the developmentalist agenda. The examples above also suggest, however, that GIS data has increasingly become both the target of new policies and the means to monitor their success. Hence, for policy-makers the environmental governance of the Amazon has increasingly become conflated into making sure that the numbers of deforestation produced by GIS are low. Evidence for this can be seen in the seminars held in Brasília by the Ministry of the Environment, where members from NGOs, scientists and senior officials contribute to the process of policy-making. In the last seminar held in May 2010 for example, all 22 presentations in the seminar were based on GIS deforestation data with the occasional inclusion of economic data such as the price of cattle and soybeans (INPE, 2010).

However, the unconditional embracing of GIS seems to have also contributed to the marginalization of other voices. Specifically, given the centrality of GIS practices policy decisions are increasingly being made without the involvement of the farmers and other groups living in the region. A relevant example of this trend is the transformation of the practices concerning the creation of protected areas over the last decades mentioned above. The creation of protected areas (i.e. parks, indigenous lands and extractives reserves) have been historically linked to the activism of natural scientists, anthropologists, NGOs and grass roots movements lobbying for the protection of endangered species and populations. Important examples include the Indigenous Reserve of Xingú created in the 1960s with the help of anthropologists (Garfield, 2004) and the extractive reserve Chico Mendes, created after the name of the rubber tappers' union leader who was killed in 1988 (Gonçalves, 2005). But from the early 2000s onwards, in contrast, the decision of where to locate new protection areas has been increasingly delegated to GIS practices. The problem with the prevalence of GIS practices is that in addition to it being less democratic than the previous one, it also reinforces an understanding of the Amazon based on stereotypes and misses important social dynamics in the region.

Figure 13 Young native Indian from a reserve in Mato Grosso watching a DVD of *sertaneja* (i.e. cowboy) music

Observations from shadowing and interviewing native Indians and farmers in the state of Mato Grosso provided some insights into the kind of phenomena that is currently being ignored by GIS policy-making practices. For instance, native Indians from the northwest of Mato Grosso have noticed a drastic drop in the fish stocks following the construction of dams upriver, forcing some of them to look for alternative sources of protein, including beef. In addition to this, cultural influences from TV and radio have led to a situation whereby "some Indians do not want to be Indians anymore", as the vice-chief of the tribe that hosted me explained (Episode #20/2009). The issue pointed out by the vice-chief was also evident in the behavior of some Indians. In one case, for instance, it was possible to observe that a young member of the tribe preferred to stay indoors watching a DVD and wearing a hat related to the cattle ranching culture instead of taking part in traditional dances, even though ranchers killed many of their ancestors only a few decades ago (see Figure 13). A congresswoman from the Amazon who works closely with the rubber tapper movement also noticed a similar trend. She reported that forest dwellers are increasingly frustrated by the environmental restrictions imposed by the government as they strive to reach better

standards of living. Many rubber tappers complain that the current legislation does not allow them to even "cut a bamboo to make a fishing rod", to use her words. She further reported that the rubber tappers also want to have air conditioning, TV sets and motorboats but the money they receive from extractivism is not enough (Interviewee #2/2007). These observations suggest that if this trend continues it is likely that in the near future some forest dwellers in the Amazon region are likely to adopt environmentally damaging practices such as mining, cattle ranging, farming and logging.

There is evidence that also farmers may also be changing their behavior. Many medium and big farmers in Mato Grosso reported that they have started to consider deforestation as a problem because of fears that international buyers might boycott their products on environmental grounds. For this reason this group may be more willing to comply with the environmental law today than a few years ago. These examples suggest that the GIS-based stereotypes such as 'Indians as guardians' and 'farmers as criminals' hide a more complex social reality that involves social and cultural change and other local phenomena that takes more than a glimpse in a satellite picture in other to be detected. Moreover, the above suggests that if the government continues to ignore the demands of the forest dwellers, these populations might end up adopting the same kind of unsustainable practices that were believed to be the antidote. Similarly, if the government insists on viewing farmers as criminals, it could be missing a crucial opportunity to reach an agreement which would lead to more environmentally sustainable practices. This implies that even though GIS has provided legitimacy to the concerns of environmentalists, sole reliance on this technology to understand the Amazon's social reality may ultimately be problematic for policy-makers.

4.5 Final remarks

This chapter has shown that GIS has been a central element in the formulation of governmental policies towards the Amazon over the last four decades. The chapter indicated that during this period the role of GIS was radically reframed to serve the purposes of different political agendas. As seen above, in the 1970s GIS was mostly used as an aid for colonization policies in the Amazon. Then, in the 1980s the scientists concerned with the future of the Amazon started using this technology to

highlight the finite and fragile character of the rainforest. Finally, in the 1990s and 2000s GIS technology became even more central as it was developed into the main source of information concerning the Amazon.

However, despite its different uses it is possible to observe that GIS has often provided a common ground between senior officials, scientists and members of the NGOs involved in the formulation of policies towards the Amazon. Specifically, it was possible to observe that GIS was much more successful in terms of becoming a shared point for discussion between these groups than ethnographies and other types of accounts. Purely technological arguments for the advantages of this technology, such as the capacity of GIS and remote sensing to collect data at a low cost in areas of difficult access and continental dimensions, were certainly valid. However, the account above also suggests that the attraction to GIS stems from the capacity of this technology to create representations of the Amazon which are closer to the modernist aspirations of policy makers. This helps to explain, for instance, why arguments for the preservation of the Amazon started having a stronger influence in policy-making from the moment when it started adopting GIS practices.

Moreover, the chapter also showed that the process by which the INPE's GIS established common ground between the different groups involved in policy-making was not smooth and unproblematic. At first, there was considerable disagreement and suspicion about the INPE's data and the political motivations behind it. However, following a process of negotiation between the INPE's scientists and other groups in the early 1990s, a relation of trust was forged around GIS. For this reason, environmentalists today (and occasionally developmentalists) are able to use the deforestation figures produced by GIS for their own purposes without being continuously questioned about the validity of their data. Nevertheless, despite the increasing emphasis on the GIS in environmental policy-making, this chapter also showed that this technology has limitations which may hide the key social dynamics taking place in the Amazon from the view of senior officials. The next two chapters will continue to explore the role of GIS in the environmental policy by considering in greater detail how this technology is involved in the enforcement of conservationist policies in the Amazon.

Chapter 5: IBAMA: GIS and the forest rangers' work in the Amazon

5.1 Introduction

The creation of a strict deforestation control policy, as described in the previous chapter, is undoubtedly crucial for ensuring the environmental protection of the Amazon rainforest. Had Brazil adopted a policy similar to countries like the USA and Paraguay, where private owners do not have an obligation to preserve a share of their forests, it is likely that the environmental sector of the government would have had still less means with which to lobby for their agenda. Nonetheless, if the policy directives and the strict laws reported above remained only on paper, their results would be equally negative. Bearing this in mind, this chapter and the one following will give a detailed analysis of how the Brazilian government at federal and state levels enforces the environmental policy in the state of Mato Grosso located in the southern part of the Amazon rainforest. In particular, the chapter focuses on how forest rangers actually use GIS to issue fines for illegal deforestation and how this compares with the expectations of senior officials and scientists.

The chapter is organized as follows. The next section introduces the history of IBAMA and DETER (the real-time GIS of INPE), reporting on how senior officials see the work of IBAMA rangers as well as the role of GIS technology. The third section provides an account of how forest rangers identify and issue fines for illegal deforestation, and the actual role of GIS technology in this. The fourth section indicates particular contradictions and tensions in relation to the use of GIS at IBAMA. The final section then concludes with a short summary of the main empirical points emerging from the chapter.

5.2 The history of IBAMA

The Institute for the Environment and Renewable Resources (IBAMA) is the agency responsible at federal level for implementing the policies approved by the legislative branch (in the form of laws) and the Ministry of Environment in the form of regulations and directives. Because of this role, IBAMA functions under the direct

supervision of the Ministry of Environment, one of the main organizations that make up the executive branch of the government (see Figure 14). IBAMA is responsible for a wide range of activities in relation to the environment. Given the tendency of the Brazilian legal system to regulate using a command-and-control approach (i.e. with the force of law and fines), IBAMA is similar to an environmental police force, responsible for tackling both urban and rural environmental issues. These include, for instance, the enforcement of laws restricting hunting, fishing, logging as well as air and water pollution.

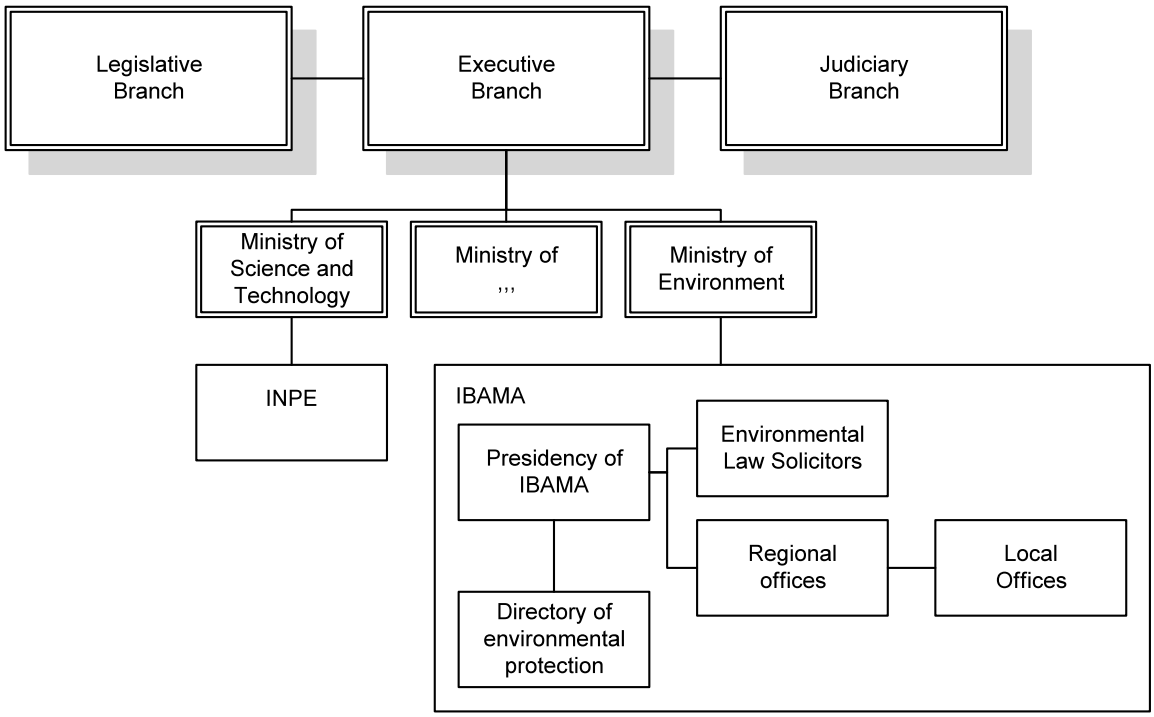

Figure 14 Simplified organogram of the environmental sector of the Brazilian federal government

Within the wide range of responsibilities of IBAMA, the control of deforestation in the Amazon is the activity that attracts most mass media attention and political pressure. As mentioned in the previous section, the Brazilian government was under pressure at the end of the 1980s to reduce the levels of deforestation in the Amazon. In order to deal with this crisis, the government launched the plan *Nossa Natureza* and a few months later approved Law nº 7.735/1989 establishing IBAMA. In fact, IBAMA was not a new structure but a fusion of the Secretary of the Environment with three other agencies: the Superintendence of Rubber (SUDHEVEA) under the Ministry of Industry, the Superintendence of Fishing (SUDEPE) and the Brazilian Institute for Forestry Development (IBDF), both under the Ministry of Agriculture.

One of the senior politicians responsible for the plan of *Nossa Natureza*, PRODES and IBAMA explained the context of the creation of the institute in an interview:

> During the 1980s, the international community was concerned with the Amazon. I created the IBAMA by putting together different pre-existing bodies as an answer to this pressure and as a way to prove that we have the competence to manage the Amazon. […] During the time of my role in government, I have also insisted on bringing the 1992 UN Conference on Environment and Development to Brazil, the ECO92. The idea of this move was again to demonstrate to the international community our preoccupation with the environment. (Interviewee #16/2007)

Given the need to reassure environmentalists in Brazil and abroad about the green credentials of the Ministry of the Environment and the newly created IBAMA, their presidents and senior officials have often been politicians or scientists who have a strong identification with environmentalist movement. For instance, Paulo Nogueira Neto and Roberto Messias, two of the ex-presidents of IBAMA, have higher degrees in subjects relating to ecology, as well as strong links with environmental NGOs.

However, the profile of the forest rangers who joined IBAMA following its creation in 1989 could not be more different from their superiors. In contrast to the well-educated, urban and environmentalist officials in Brasília, the vast majority of the rangers only had an elementary education and were recruited from the local population for their forest-wise skills. Furthermore, most of the IBAMA rangers originally worked for the IBDF, an agency which was created to exploit forests for their economic value rather than treating them as ecosystems to be preserved. Finally, in contrast to the well-paid managers in Brasília, the forest rangers had low salaries and scant resources to carry out their work. For these reasons, IBAMA rangers were reported to be much closer to the values and views of the farmers they had to inspect than to their managers in Brasília. As a senior official put it, "asking IBDF forest rangers to enforce deforestation control laws was like asking pyromaniacs to control forest fires" (Interviewee #23/2009).

These historic roots help to explain why the 1990s and most of the 2000s IBAMA has been marked by a long stream of corruption cases where, for instance, forest rangers sold logging and deforestation authorizations illegally or simply ignored cases of illegal deforestation and fires in exchange for bribes. As a consequence of this, IBAMA was and still is largely regarded both inside and outside the government as an inefficient and corruption-ridden organization. For example, a local farmer expressing a general view, stated: "My father told me and from my childhood I always knew that

IBAMA was a problematic agency. Everybody knows that with some sweet talk and money, they can forgive anything" (Field notes #26/2008).

This situation started to change significantly in 2002 when the government started to recruit to IBAMA only officials (including forest rangers) with higher degrees. In this way, the number of IBAMA officials with a higher education almost doubled between 2001 and 2007, while the number of technicians decreased as old officials retired (IBAMA, 2008). Even though IBAMA accepts professionals from different backgrounds, the majority of officials passing the examination have degrees in areas such as biology and forestry which involve the use of computers and in some cases GIS applications. Moreover GIS experts at IBAMA's headquarters offers GIS training sessions to a restricted number of rangers and provides technological support via telephone and Skype to officials working in the Amazon and other parts of the country.

The hiring of professionals with higher education and computer skills and the GIS training program paved the way for another major change at IBAMA: the adoption of GIS in the local offices. As seen in Chapter 4, GIS has been a key element in the formulation of the policy towards the Amazon since the 1970s. Nevertheless, until very recently, GIS technology was virtually absent from the enforcement of the environmental policy. One of the most critical pieces of legislation in the current environmental policy is the Forestry Code, which states (among other points) that 80% of the area of all private property in the Amazon rainforest biome should be set aside as a 'legal reserve'. Despite the specific need to establish the status of individual farmers in order to enforce this law, PRODES, the only system at the time, provided only yearly deforestation figures divided by state. Since the nine states of the Legal Amazon region have a total area equivalent to the newly extended European Union, this data is insufficient for the specific planning of environmental protection actions, let alone enforcing the law at property level. However, following a personal request from an IBAMA senior official to a scientist INPE developed DETER (Deforestation Detection in Real Time), a new satellite-based GIS that indicates the precise location of new deforestation in maps which are released every 15 days.

The impact of the new generation of rangers and DETER can be seen in different ways. Some figures collected by IBAMA headquarters suggest that the introduction

of GIS technology at the local offices has led to a sensible increase in IBAMA's capability to enforce the law. For instance, in 2004, IBAMA issued only 24 fines for illegal deforestation in the Amazon, but by 2008, following the establishment of DETER, this figure had jumped to 2,159 fines. Furthermore, different officials reported that GIS technology not only facilitated an increase in the number of fines, but also brought about improvements in their 'legal quality'. The following sections examine the increasingly central role of GIS in IBAMA and expose the contradictions emerging from the distance between the expectations and actions of the senior officials in Brasília and the actual practices of managers and rangers working in the rainforest. It will be shown that while GIS has improved the work conducted by IBAMA, the excessive focus on technology has prevented scientists and senior officials from seeing the actual work needed to enforce the law - an issue that has brought negative consequences.

5.3 GIS and the work practices of IBAMA

The aim of this section is to provide a general background to the work relating to deforestation control as carried out by IBAMA, as well as to make a detailed examination of the role of GIS in planning missions and issuing fines. IBAMA has three main hierarchical levels: the headquarters in Brasília, the regional offices located in the 26 state capitals, and the local offices located in the countryside. The headquarters jointly with the regional offices is responsible for three key aspects of the work done by IBAMA around the control of deforestation in the Amazon. Firstly, it sets the macro-law enforcement strategy for the country and negotiates the resources to carry it out. These strategies include, for instance, giving priority to certain parts of the country (e.g. nearby conservation areas) or to certain environmental crimes (e.g. recent deforestation). The regional and central offices are responsible for the provision of resources for the execution of missions at local level. These include the transfer of personnel between local offices in order to take part in operations, the provision of trucks and helicopters as well as financial resources for travelling. Secondly, the senior officials at regional and central levels are responsible for making promotions and accepting transfer requests from the forest rangers. As will be seen below, because of the difficult working conditions in the Amazon, rangers often request to be transferred to bigger cities in order to take on bureaucratic jobs rather than risky law inspections. Finally, attorneys working at the headquarters

are responsible for formulating normative instructions (i.e. explanations of how the rangers should interpret the law). Moreover, in the regional and central offices, senior officials in cooperation with attorneys deliberate on the defenses and appeals put forward by the farmers' lawyers as regards the fines issued by the forest rangers (see more on this below).

It is in the local offices, however, where most of the actual work of issuing fines and enforcing the law takes place. Here, local managers are responsible for assigning the location of law enforcement missions and coordinating (and controlling) the actions of the forest rangers. The local offices also provide the base from which most missions are launched and fines are issued. The IBAMA local offices in the Amazon are usually quite different from the headquarters in Brasília and the regional offices in the capitals. The first are usually located in modern concrete and glass buildings in the close proximity of the political center of the country. The second are usually based in improvised rented houses "at the end of the world where nobody wants to go", as one ranger described it (Field notes #15/2009).

The local offices that provided most of the data for this study are good examples of typical IBAMA local offices in the Amazon. The first is in Sinop, about 12 hours by bus from the state capital. Sinop is located in the north of Mato Grosso along the highway BR-163. It is in this region that Sorriso, Lucas do Rio Verde and other municipalities jointly produce an important share of Brazil's soybean exports. During the 1990s, the city experienced an economic boom fueled by cattle ranching and (mostly illegal) logging. Today, the many abandoned seesaw warehouses in the city's outskirts indicates the area economic downturn. Even though deforestation in the municipality of Sinop has stabilized since most areas were cleared in the last decade, many of its neighboring municipalities, such as Feliz Natal and Tapurah, are currently being deforested at a fast pace. The other local office is in Juína, about 17 hours by bus from the state capital, or even a week during the rainy season, depending on the condition of the roads. Juína is located in the northwest of Mato Grosso, a region which even though still well preserved is now the current location of the deforestation frontier. In contrast to the stability and relative security found in Sinop, Juína is a difficult region to work in. For instance, just a year before my visit, a group from Greenpeace was forced to leave town by armed local farmers. This recent incident

and dreadful local news, such as the discovery of the bodies of two men in a nearby road during my visit to the city, highlighted the prevalence of violence in the region.

Despite the geographical isolation of the local offices, the work here is part of a federal administrative legal system, and as such needs to be integrated within the regional offices and headquarters of IBAMA. It was possible to observe that GIS was used extensively in the integration between these different locations and groups. As seen in Chapter 4, during the 1990s GIS featured in the government mainly in the form of the deforestation rates used by senior officials from IBAMA and the Ministry of Environment. With the launch of PRODES Digital in 2003 and DETER in 2004, GIS also started to be used more intensively by the other levels of IBAMA's hierarchy. As explained by different officials, every six months the local directors meet with their superiors from the headquarters and the regional office. In this meeting, the two groups discuss and decide on how to distribute the financial and human resources for law enforcement across the different offices. In recent years, the GIS-generated maps showing deforestation trends in the region have become one of the central pieces of the discussion. Based on these maps, both local managers and senior officials attempt to reach an agreement as regards which offices deserve more resources and plan joint missions. Moreover, senior officials often monitor the outcome of their strategies based on the data provided by GIS. Specifically, the data provided by GIS, such as local reductions in deforestation rates and the total area as well as the number of fines and embargoed properties, allows senior officials to evaluate the performances of the local offices and to promote or punish local managers accordingly.

In addition to negotiating the budget, the creation of strategies and the monitoring of local offices, GIS has also been increasingly used by local managers to coordinate the work of forest rangers, as well as by the rangers themselves as a basis for cooperation with legal attorneys in the regional and central offices. The following two subsections explore in greater detail how these different groups use GIS to coordinate joint work. Within this it will be contrasted the expectations of the different groups in relation to the technology and how it should be used.

5.3.1 Planning missions

The identification of possible targets, planning and the coordination of missions at local level are the activities of IBAMA where GIS has had the most visible impact. Here, the officials interviewed were unanimous at all levels of the agency regarding the benefits of the introduction of GIS. In order to describe the changes brought about by the introduction of GIS, the officials often described the period before the GIS as the time when IBAMA was 'blindfolded', so that it had to rely on its 'forestry instinct' (i.e. sixth sense of where to go) or simply be at the mercy of luck. Furthermore, even though IBAMA has a toll-free telephone number to receive anonymous reports of environmental crimes, the tips are often misleading or not sufficiently detailed. On a more general level, a similar issue was also reported in relation to the planning and coordination of missions. Because the regional managers did not know about the municipality where most of the deforestation was taking place, they were often unable to position their personnel in a strategic way. This was because even though PRODES (the yearly deforestation rates) provided indicators of the deforestation rates, these numbers were not considered timely enough to be helpful. As a senior official explains, before DETER, "INPE's monitoring system used to take almost two years to release deforestation data, when it was too late to plan anything" (Interviewee #11/2008).

For these officials the introduction of DETER was an eye opener, both metaphorically and literally. They reported that with the introduction of GIS at local level and the availability of deforestation data at a higher temporal frequency, IBAMA "started being able to see deforestation while it was happening, and not the final result of deforestation", as an IBAMA senior official explained, this echoing the opinion of many rangers and managers (Interviewee #48/2009). By observing the practices of local managers and rangers it was possible to see that GIS has clearly become a central piece in the law enforcement coordination efforts. For the missions with a shorter duration or fewer targets, local managers provide only a set of geographical coordinates, these being inserted into the global positioning system (GPS) devices used by the rangers. For the more complex missions, however, a ranger with more GIS expertise usually creates a GIS-based map, commonly called logistic map by the rangers, under the supervision of the local managers. Figure 15 provides an example of a logistic map that was used by forest rangers in a mission. The map shows the

official and unofficial roads and main cities in the region of the fieldwork. The vertical and horizontal axes indicate the geographic coordinates, the numbered points the location of the centroid DETER deforestation polygons and the letters from A to F are the control points placed on particular crossroads as references to guide IBAMA rangers in the field.

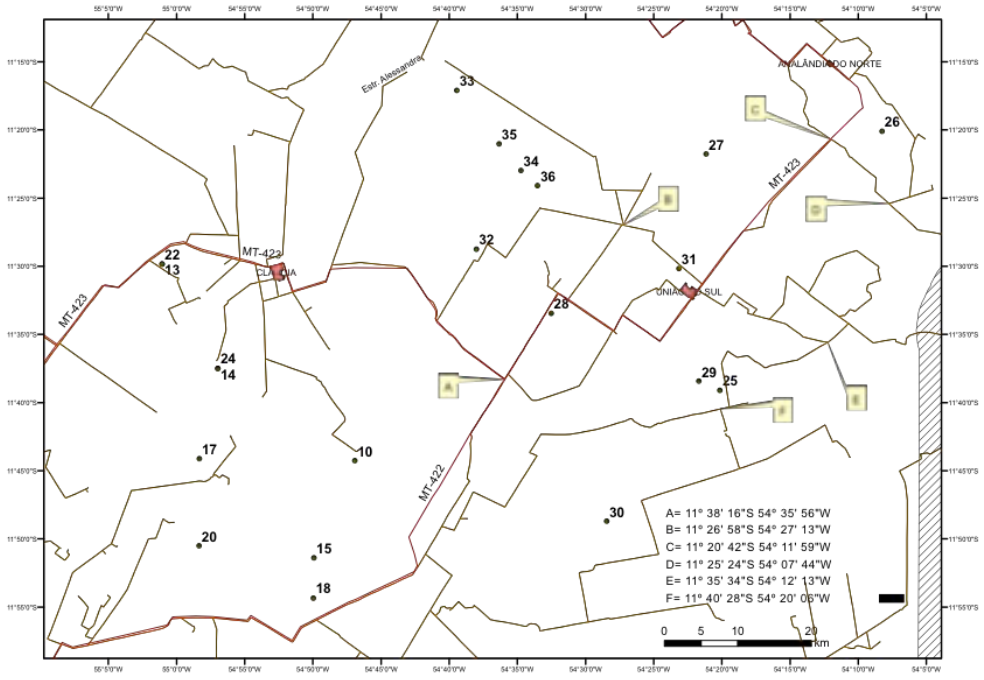

Figure 15 Example of a logistic map used by IBAMA forest rangers

A more sensitive practice that was also transformed by the introduction of GIS is the way in which local managers control the work of the rangers. As mentioned above, corruption is a historic issue within IBAMA. Even though the situation appears to have improved in recent years, senior officials and managers are particularly worried about the possibility that some rangers under their supervision might be implicated in illegal activities. Before the introduction of GIS, the rangers had considerable discretion when carrying out fieldwork. They could choose which farmers to inspect according to their 'gut feelings' but also according to their financial interests, and eventually blackmail or provide benefits in exchange for a bribe. However, with the introduction of GIS, local managers are able to specify which farms the rangers should inspect and, after the mission, request information on the related fine for illegal deforestation. In this way, the rangers cannot negotiate with the farmer and eventually ask for a bribe. Local managers from IBAMA and the rangers themselves were very discrete about this role of GIS; in addition to it being a shameful matter, it

is difficult for a manager to explicitly recognize that he does not trust his subordinates. Nonetheless, in some private conversations it was possible to see that corruption is still a constant cause of concern between rangers and managers alike. An ex-senior official from the state-level Secretary of the Environment in Mato Grosso (SEMA) (where there are similar problems with forest rangers) was more explicit about this issue and the role of GIS in avoiding corruption:

> In Brazil you should never send an agent to the field for whatever reason if you do not have a way to control his actions. […] The GIS gives me the size for each individual piece of deforestation. I would then tell the agent: "I want you to go in these five farms shown in the map and bring me back the fine. If you find other deforestation, you can do it, but I want you to bring me at least these five". In this way, we have taken away from the agent's hand the decision about whether to fine someone or not, because it was already decided by the system.

Even though there is considerable agreement within all ranks of IBAMA about the benefits of GIS, it was possible to observe a growing gap between the expectations of scientists and senior officials about how GIS should be used and how it is actually used to decide where to carry out the missions. The double meaning of the acronym DETER, the main GIS-based monitoring system used to identify new deforestation, provides evidence of the INPE scientists' design intentions. As already mentioned, DETER stands for Deforestation Detection in Real-time, which emphasizes that this form of GIS aims to detect deforestation as soon as it happens. In addition to this, DETER literally means in English (as in Portuguese) 'to deter', that is, to stop someone from doing something. As was later confirmed in interviews, many INPE scientists believe that by providing GIS data in real-time, IBAMA rangers will inspect the signaled areas as soon as they appear on the GIS and so catch the perpetrators in the act. This particular understanding of the aims of DETER and how it should be used by the local managers and rangers in the field was also shared by senior officials from IBAMA and the Ministry of the Environment. A senior official directly responsible for the setting up of the strategy for the use of GIS at IBAMA provides an example of this perspective:

> [Before DETER] we could not to interrupt ongoing deforestation. This was the problem at the beginning of the use of satellite images. With DETER there was a great improvement. We started receiving pointers from DETER every 15 days. It says "something is going on here, it is changing here" and INPE gives this information to IBAMA. It was a jump, a change of paradigm. After that we started to work with very short time strategies. And then people could go to the field and interrupt ongoing deforestation. Look, here, lots of deforestation points and fires, and then the people [rangers] would go there and find lots of people trying to do deforestation. (Interviewee #48/2009).

Evidence of the prevalence of this view can also be found in the way in which GIS is being used in the headquarters and the ongoing development of new GIS. In order to persuade the local managers to plan their missions according to the 'real-time' logic of DETER, a group of GIS scientists working for senior officials in Brasília has devised a priorities map. Every 15 days the scientists calculate a ranking of priorities for law enforcement based on DETER's data and other geographical information, such as the distance from the logging and indigenous lands, current and past deforestation rates among other quantifiable factors (see Figure 16). These GIS-based maps are then sent to the local offices where they are expected to be used by local managers to guide ongoing missions in the Amazon. In addition to this, both INPE and IBAMA have been investing considerable resources into the development of more sophisticated satellites and GIS with the expectation that the detection of deforestation activity closer to real-time will improve the ability of IBAMA to reduce deforestation.

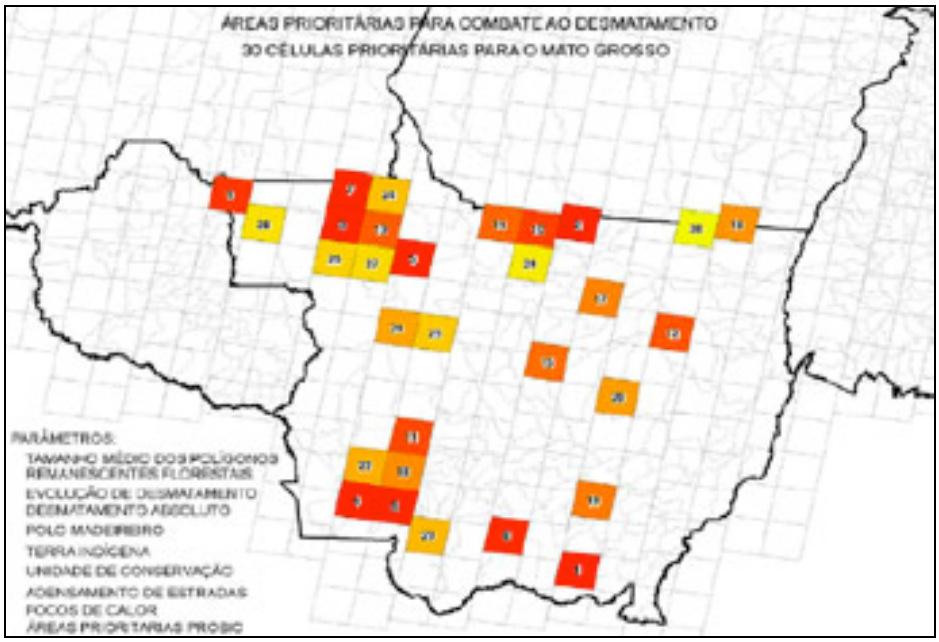

Figure 16 Example of deforestation control priorities map created fortnightly at IBAMA headquarters that is not often used by the local offices to plan missions

In observing the actual practices of the local managers and rangers, however, a picture emerged that differs from the expectations of scientists and senior officials in four main ways. Firstly, the tactic of going after single regions or deforestation points as soon as they appear in the GIS is infeasible due to the limited human and financial resources and the long distances that the rangers usually have to travel. As reported by

different rangers, it can take up to three days to reach some remote locations under their jurisdiction. Furthermore, local managers often have only one or two teams of rangers at their disposal. Consequently, local managers plan the missions in order to inspect as many deforestation points as possible within a certain location. This means that in many cases the local managers let the deforestation 'accumulate' for a few months before it is worthwhile sending a mission to the region. The following excerpt from an informal conversation with a forest ranger who was shadowed while doing office work illustrates that senior officials insist on the view of deforestation control in real-time even though it is considered infeasible in practice by those working in the Amazon: "In Brasília they have this utopia that we should be able to get the guy with the chainsaw in hand thanks to real-time monitoring systems, but in reality it is very far from it" (Field note #19/2008).

Secondly, because of its limited resources it was possible to observe that IBAMA is struggling to inspect all the deforestation pointed out by the INPE's current GIS-based monitoring systems. For example, by dividing the total area of the fines for illegal deforestation issued by IBAMA between 2004 and 2008 by the sum of the total deforestation detected by PRODES (which is illegal in the vast majority of cases), it emerges that only 17% of the detected deforestation actually led to a fine. This suggests that IBAMA, rather than being starved of more deforestation data to improve its work, the GIS is already creating a volume of work that is much larger than IBAMA's capabilities.

Thirdly, in contrast to the view that that the most efficient way to distribute law inspection efforts is by going to the latest deforestation site, local managers have also reported that they plan missions in order to 'show the presence of the state' in the territory under their jurisdiction. They explained that they attempt to visit every municipality under their control at least once every six months in order to indicate to the local community that IBAMA is 'watching them', even when a given municipality does not present the highest deforestation rate in the region. This and other examples suggest that in contrast to senior officials local managers are interested not only in the quantitative aspect of law enforcement shown by DETER and other forms of GIS, but also the psychological impact of their work.

Finally, it has emerged from observations that IBAMA fieldwork missions are often much more contingent and dynamic than they are thought to be by the senior officials in Brasília and INPE scientists. Local managers have reported that it is common to start a mission with a given aim and change it as new demands from other governmental agencies and events on the ground emerge. The following account from a local manager about an ongoing mission illustrates this matter:

> I sent a team to check some properties in Colniza, but that I also received a request from FUNAI [Foundation for the Indigenous Populations]. Since it was on the way to Colniza, and indigenous lands have priority, I asked them [the rangers] to check that first. After two days, we were not able to find the issues pointed out by FUNAI. However, we did find 70 logs in the region. Today we have just found another lot with more than 300 logs. [...] Ultimately, I spent 10 workdays on an issue that I thought would take only a couple of days. For this reason I can say that we always have to take decisions on the spur of the moment. (Personal communication #2/2009)

The excerpt above suggests that the actual practice of local managers deviates starkly from the expectations of senior officials and scientists. While GIS is an important tool with which local managers can coordinate and even choose the location of missions, GIS data is not the only factor that is taken into consideration here. Instead, the planning and coordination of missions involve a constant pondering of the resources at hand, with information coming from different sources and an ongoing unfolding of missions. The next subsection analyzes how forest rangers use GIS in order to follow the directives from the local managers, find deforestation and issue fines.

5.3.2 Doing fieldwork

Observations obtained by shadowing missions and interviewing rangers provided the evidence that GIS is also becoming increasingly central to the practices involved in issuing fines for illegal deforestation. The selection of the region to carry out the mission and the creation of the related logistics map are only the first steps in IBAMA's rangers' work. In order to enforce the law, the rangers have to reach the individual deforestation points, establish the causes of deforestation and identify the perpetrators. Forest rangers do not always have the time or skills to use GIS to assist them. As reported by some forest rangers who have worked in other regions, many local offices in the Amazon lack the ability to use GIS as it is used in the offices in Mato Grosso. Furthermore, forest rangers from the older generations, who often lack higher education and computer skills, have difficulty engaging with GIS and reading GIS-based maps. For this reason, in many places paper-based practices persist.

Nonetheless, the different rangers and senior officials have explained that the use of GIS has become a 'gold standard' within IBAMA, and the rangers who are not able to use it are being penalized. For instance, a senior attorney explained that her office accepts only fines that include geographical coordinates, and depending on the type of environmental crime, GIS-based maps of the deforestation. For this reason, the fines that do not comply with this new requirement are sent back to the local offices for ratification. The same attorney also explained how GIS has changed IBAMA's practices:

> The effectiveness [of IBAMA's work] was really low. After we started to indicate clearly in the fines the exact location of crimes with GIS and the GPS the situation has improved a lot. [...] Now we have notices of infraction [which are] much better formed: with the clear reference of the type of illicit [action] and the precise size of the area - which is directly proportional to the value of the fine.(Interviewee #49/2009)

As with the case of the role of the GIS in planning, (referred to in the previous section) all the rangers interviewed reported that they see this technology as a major step in improving their work. Nonetheless, it also emerged from observations and interviews that senior officials and scientists tend to have a simplistic understanding of the work carried out by the forest rangers. In particular, the accounts of governmental officials (particularly those at higher levels) indicates the belief that with the right satellite-based GIS, and with the legal and land property systems in place, this will lead almost automatically to an enforcement of the deforestation control policy. It is as if the *deforestation as detected* and represented by the GIS is the equivalent of *deforestation as a crime,* this being a legal entity with legal consequences, including heavy fines for its perpetrators. Furthermore, when the role of IBAMA rangers is mentioned, it appears to have switched roles with GIS technology: instead thinking of GIS as a tool in the hands of forest rangers, the rangers are seen as the helpers of GIS technology, which has not (yet) been able to obtain any particular piece of data (i.e. the presence of selective logging or property borders), and as such, requires human intervention to do this bureaucratic work. This view, which eliminates the need for human beings, was clearly suggested by a senior official who explained that "it would be ideal to follow this [deforestation] in real time: you plug yourself into something [a GIS technology] in order to be able to *see* what is going on in the area [and enforce the law]" (Interviewee #49/2009).

In stark contrast to this perspective, IBAMA rangers have to take on varying roles and deal with different groups in order to enforce the law. In a similar manner to a policeman issuing a parking ticket, the law entrusts the rangers with the role of being 'witness to the act' and bring offenders to justice. However, the farmers, like every other citizen, have the right of appeal as granted by the Brazilian constitution. On receiving a fine for illegal deforestation, the farmers often present a defense to the local or regional director (depending on the value) which attempts to challenge the fine issued by the ranger (on one ground or another). The local or regional director of IBAMA then has to evaluate the merits of the defense and decide whether to *annul* the fine or *reject* the defense. It would, however, be very dangerous for the local or regional directors to rely wholly on themselves in the task of judging the farmers' defenses as they could be guilty of a misjudgment or could even be accused of being part of some sort of corruption. This is why, in most cases, the local director asks IBAMA's attorneys in the headquarters or regional offices for legal advice[4]. If the local director (with the assistance of the attorney) decides that the defense is groundless and rejects it, the farmer can still appeal and take the case to a higher level. After many years, the case could eventually reach CONAMA, the National Council of the Environment presided over by the Ministry of the Environment, this being the final instance of environmental administrative law. Given the complexity and geographical distribution of the parties involved, it is not surprising that in many cases these processes take more than ten years to be resolved (see Figure 17).

[4] During the final months in the field some IBAMA officials reported the approval a new internal instructive normative was due to reduce the participation of attorneys in the analysis of some types of fines. It was not possible to observe, however, if this normative has led to changes in practice by the end of the fieldwork.

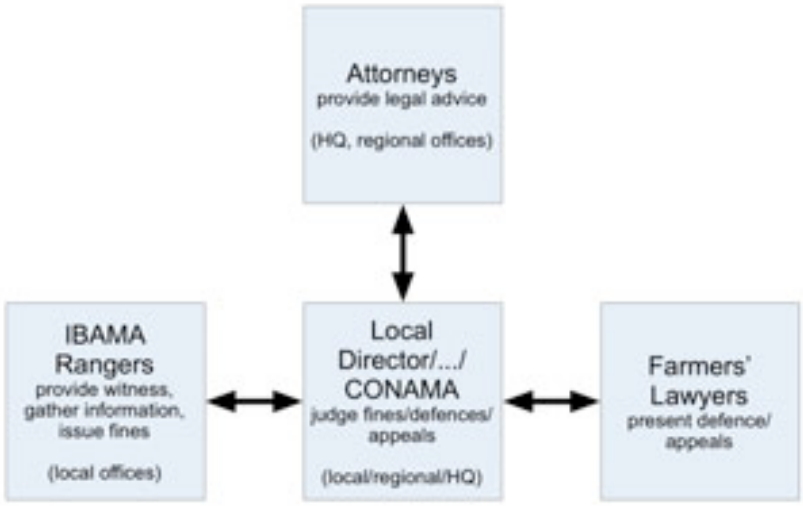

Figure 17 Main actors involved in the issuing and judging of fines for illegal deforestation

Given the geographic distribution and time lengths involved in the formulation and analysis of fines, it is crucial to forest rangers to be able to create fines that are deemed acceptable and considered trustworthy by attorneys, lawyers and directors even when they have never been to the Amazon or met the rangers. A closer observation of the practices of IBAMA forest rangers suggests that the rangers have to skillfully perform a series of GIS-centered practices in order to achieve this aim. These practices are as follows: finding the location, establishing the act and identifying the perpetrator.

Finding the location

The first practice the rangers have to perform is locating the place in the forest as specified by the local manager using the GIS-based logistic map. An important tool in this process is the polygon map, named after the technical term for the two-dimensional geo-referenced objects that are used to indicate the outer borders of deforestation. In addition to the shape of the deforestation, these maps contain the municipality and the presence of any special areas such as INCRA land reform settlements, conservation areas and indigenous reserves. When the farm in which the deforestation is detected or a nearby property contains an environmental license from SLAPR by SEMA (see next Chapter), these maps also include the landowner's name (see Figure 18). Quite often, however, rangers have only a point superimposed to satellite image in order to guide them in the field.

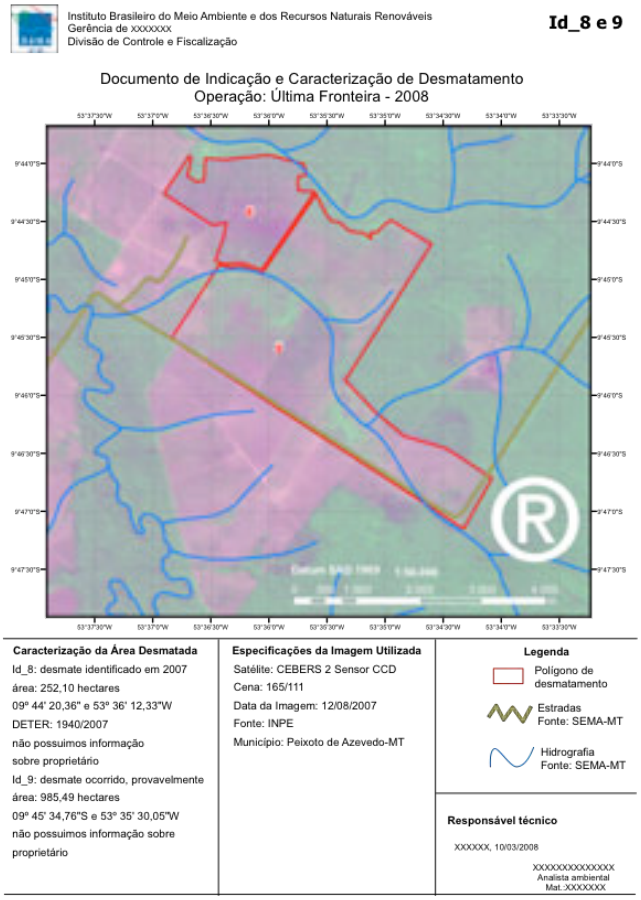

Figure 18 Example of polygon map containing two clearings detected by DETER

An aspect of polygon maps which contradicts the real-time logic of senior officials and scientists, is the type of satellite imagery contained in them. INPE scientists detect deforestation from DETER based mainly on the satellite images from the sensor MODIS on board the US satellites Terra and Aqua. One of the main advantages of the MODIS imagery is that it covers the whole planet every 1 to 2 days. The problem, however, is that these images are taken with a low spatial resolution (i.e. image quality), depicting 250 meters of land in each pixel. Because of this low resolution, it is not possible to identify from the image features on the landscape required for fieldwork. For this reason, the rangers with GIS expertise often make polygon maps using Landsat TM imagery, which has a spatial resolution of 30 meters (almost ten times higher than MODIS). This also means, however, that the rangers have to wait for weeks or even months until good Landsat TM image is made available, since this satellite obtains a full coverage of the Amazon only once every

16 days. The rangers explained that this wait is justified because it is possible to identify from Landsat images features such as clandestine roads, rivers and possible locations of farmhouse, that are crucial for allowing rangers to navigate in the forest (see Figure 19).

Figure 19 MODIS satellite image from which DETER identifies deforestation polygons (left), and a Landsat TM satellite image for the same area (right)

When travelling towards the deforestation indicated by the GIS and the polygon map, one ranger usually acts as a navigator, using the GPS to obtain the direction and distance from the deforestation polygon, while another agent drives the truck towards the target. By comparing the features on the road as they pass along it as well as the satellite image and the coordinates provided by the GPS the navigator can advise the driver on where to go (see Figure 20). However, in addition to the GIS, the rangers also need to know how to drive on roads with poor conditions and how to identify tracks that are more likely to lead to the deforestation based on clues such as markings in the ground and broken branches. Furthermore, the rangers often have to stop and ask for directions from the local farmers. As one ranger put it, they have to use the GPS as a global '*peão*' system, where peão in Portuguese stands for peasant or cowboy.

Figure 20 A forest ranger using the GPS and a polygon map in order to check if they are at the 'right' deforestation site

In addition to the practical advantages of GIS in helping the rangers to find the location of deforestation, GIS also contributes to the legal aspect of the fines. As some of the rangers explained, one of the strategies lawyers use to have the fines against their clients dropped is to question the 'good character' of the ranger. As already indicated, corruption scandals involving IBAMA rangers have been very common. In this context, it is not difficult for a lawyer to argue with a judge that the fine for deforestation was in fact part of an attempt of a corrupt ranger to blackmail his client. Furthermore, since rangers can be considered as people of 'dubious character', the lawyers can argue that their testimony should not be considered trustworthy. In this way, according to the lawyer's argument the fine should be considered faulty in terms of its material evidence, since it relies on an invalid witness, or is even part of yet another corruption scandal against hard working and honest farmers. The following extract from my field notes illustrates the importance of the GIS in this regard:

> It is around 11 am, after getting lost twice and and asking a local farmer for directions we finally reached the desired location. "Is this the point of DETER?" asked João. "Yes, we are not too far from the centroid", confirmed Valeria, looking at her GPS. "That's great!"

> replied João with relief. They explained that it was important to make sure of the location because in this way rangers reassure each other that they are in the location of the *right* deforestation, namely, the point that Bosco, the local manager, had explicitly requested them to check and not any other of the dozens of deforested areas we had passed. (Field note #13/2008)

The extract above suggests that while the rangers understand that local managers are using GIS to control them, they also see this technology as a way to delegate to others (i.e. the GIS and the local managers) the responsibility of deciding where and when to inspect. In this way, they also protect themselves from eventual unfair charges of corruption.

Establishing the act

The second practice that rangers engage in order to issue the fines for illegal deforestation is the establishment of the acts that have led to the deforestation. While scientists and senior officials tend to talk about deforestation as something that is self-evident from the satellite images, it emerged from a closer look at the practices of forest rangers that they must skillfully reconstruct what has happened in that specific location. Therefore, the rangers have to act much more like expert criminologists than as the simple-minded bureaucrats, as they are often portrayed. The following excerpt from the field notes and related photo taken *in situ* illustrate this point:

> By looking at the ground and at the trees João indicated to Valquíria the broken skin of some trees and their bent position in the same direction. For João, this indicated that the owner of the land used a *correntão*, a big iron chain pushed by two tractors to break the vegetation and increase the 'cleaning' effect of fire. He also showed Valquíria some small seeds of grass in the ground, which indicate that the final aim of the owner was to convert the forest into cattle pasture. He took a picture of the seed on his hand and told Valquíria, "this guy is going to put cattle here", and she nodded in agreement. Valquíria in the meantime was taking pictures and saving on the GPS device memory the location of the edges of the clearing. She was also writing the comments from João as well as her own impressions in a small notes pad that she keeps in her back pocket. Specifically, the visually messy scene of the dead forest became two keywords in Valqúiria's note pad: "correntão" and "pasture". (Field note #13/2008)

Figure 21 A forest ranger looking for clues of what has caused a clearing, in the back another forest ranger and a soldier from the National Guard

The need to collect small pieces of evidence such as seeds and pictures of scratched trees might appear to be exaggerated given the size and apparent 'unquestionability' of the existence of deforestation. However, as other rangers later explained, the detailed collection of 'objective' evidence with the help of GIS technology and investigative skills has become central to the establishment of a legally strong fine for illegal deforestation. In particular, they explained that for many decades now, fires have been prohibited both as a means of clearing the fields for the crops and for deforestation. A well established strategy adopted by farmers in order to avoid prosecution, however, is that when they are questioned by IBAMA they maintain that the clearing was the outcome of an 'accidental' fire by some unknown cause. However, by using their cameras to register the scars from the *correntão* and the presence of seeds, the rangers can offer proof which rules out the accidental nature of the clearing. Even for an attorney or senior official in Brasília evaluating this particular fine, it will become apparent that the farmer could not have made a considerable investment in tractors, chains and seeds 'accidentally'. This provides the evidence that the particular deforestation in this particular location (as recorded in the

GIS) was indeed the result of a premeditated *act*. Hence, what the rangers establish with the practice described above is not so much what has specifically happened in the area, but the human intention behind that state of affairs – an aspect that is only visible by combining GIS with the rangers' fieldwork skills.

Identifying the person

Even though the location and intention behind the specific deforestation might become clear through the practices mentioned above, these elements still need to be tied to a specific person – the perpetrator of the illegal act. Therefore, in order to identify the person behind the act, the rangers usually have to first find the farmhouse. The properties in the Amazon often exceed 500 hectares (circa 20 square miles). The sheer size of the properties together with the dense forest makes it difficult to see the farmhouses from the location of the potentially illegal clearings being inspected. In contrast to the deforestation point, which contains a specific geographical coordinate, the only way to find the farmhouse is by looking at Landsat satellite images and exploring the nearby roads: a practice that requires considerable experience and skill from the rangers. After finding the farmhouse, the rangers also have to engage in another complex practice. They call this 'the interview': an apparently unpretentious conversation with the person found in the farmhouse in order to elicit information that might be useful in the constitution of the fine for illegal deforestation. The following field note excerpt provides an illustration of what is involved in these interviews:

> Trial and error led us to the gates of a farmhouse, which according to João, was likely to be the origin of the aforementioned deforestation. While we walked towards the gates, João shouted: "Hello! Anyone there?" From a little house came a short thin man, wearing a ragged t-shirt from the political campaign of the governor Blário Maggi (one of the biggest soy-beans farmers in the world). The farmer greeted us with a toothless smile and invited us to take a seat and have a cup of coffee. From his modest manners and dirty clothing it was clear to the rangers that the farmer was not the owner of the farm, but the *caseiro*, the employee paid to take care of the farmhouse and the cattle. The conversation between João and the farmer occurred in the following way:
>
> 1 João: Nice farm you have here… Well-fed animals I can see.
> 2 Farmer: Yes… the *patrão* (boss) buys only white zebu cattle. They grow well here.
> 3 João: We are making some inspections in the region, and we saw an area where
> 4 they appear to be making pasture. Is it from this farm?
> 5 Farmer: Yes, it is... The *patrão* has brought some tractors for the *correntão*. I also
> 6 saw an airplane…
> 7 João: Airplane for the seeds?
> 8 Farmer: I think so. The *patrão* told me to go there and do the fence for the pasture.
> 9 João: Ah, ok… What is the name of your *patrão*?
> 10 Farmer: It is *Dotô* António from Tapurah, which is not far from here.
> 11 João: Do you remember his full name? Or have you any documents about the farm here?
> 12 Farmer: Not really, but there everybody knows him. It is the second house just after

13 the main square. (Fieldnote #13/2008).

In the short excerpt above, it can be seen how the rangers are taking a major step to create a link between the location, the act they have just established and the perpetrator. Firstly (in lines 1-2), by using small talk, the ranger creates a friendly atmosphere whereby he/she can start asking questions about the farm. Then (in lines 3-8), the ranger offers an unpretentious image of what is being done on the property and attempts to obtain confirmation from the farmer about the relationship between the deforestation and the farmhouse. Essentially, the ranger wants to obtain confirmation that the deforestation in question occurred in an area attached to that specific farmhouse, and not to a neighboring farm or in 'no man's land', as a lawyer might later try to argue. It should be noted, however, that the ranger does not refer to the deforestation in terms of its legal-scientific status, namely as new and potentially illegal deforestation detected by DETER. Instead, he/she refers to the deforestation as 'making pasture', a term used in farming practices alongside the more general phrase of 'opening a farm'. Finally (in lines 9-13), the ranger tries to obtain the full name of the owner of the farm, again using the same rural language as the farmer.

In the case reported above, it was necessary to return to a nearby city to find the person mentioned by the farmer who was the actual landowner. In many cases, however, the rangers issue in situ a *notificação* (notification), this being a legal document requesting more information about the property. This last act also signifies the conclusion of each inspection. At this point, the rangers should have all the details required for the formulation of the fine. In sum, the observations above suggest that the rangers are not simply gathering self-evident information about the farm through an objective dialogue. In contrast, they are actively establishing the relationship between the act of deforesting a specific area and a specific farm (and thus a specific perpetrator) for a future audience of lawyers and attorneys. This suggests that there is much more involved in imposing a fine for illegal deforestation than what is identifiable from satellite images and GIS.

5.3.3 Writing up fines

While fieldwork provides the opportunity for rangers to collect the evidence that will substantiate a fine for illegal deforestation it is often only when the rangers return to the local office that they actually bring all the pieces together and issue the fine. It is

at this point that the rationale behind the meticulous way in which forest rangers carry out their fieldwork becomes clear. As pointed out in the previous chapter, the positivist and later high-modernist movement have played a central role in the formation of the Brazilian government. This was central not only to the planning practices seen in the previous chapter, but also to the creation of the country's legal system (Holanda, 1936/1995; Maricato, 2002; Schwartzman, 1980/2008). In particular, Barroso (2001: 19) explained that a key belief of the Brazilian legal system is that the 'engagement between the subject and the object [of legal enquiry] compromises the scientific pretension of the law and, as a consequence, its ideal of objectivity' (see also Saldanha, 1968/2001).

IBAMA forest rangers strive to match these expectations in different ways. The introduction of GIS has changed the prosecution of environmental crime such as the illegal transportation of timber and the trapping of wild animals very little. For these crimes, the rangers are able to collect all the information they need and issue the fine on the spot. But, as seen above, for the cases of deforestation most rangers prefer to issue a *notificação* (notification) requesting further information instead of the *auto de infração* (fine) straight away. This represents an important shift in the way IBAMA rangers work. Different rangers have explained that before the introduction of GIS technology they would have handed the farmer a fine on the spot, specifying the location of the farm using local references, such as road names or landscape references, such as "near the tall nut-tree", which can be found in many parts of the Amazon. The total area of the deforestation would also have been established based on the ranger's '*olhometro',* a slang term that comes from the combination of the words *olho* (eye) and *metro* (meter) which indicates any sort of measurement made in an approximate way without the help of a technological device. Finally, on the bottom of the document would have been the value of the fine and a bank slip payable to IBAMA. In contrast, the *notificação* (notification), instead of establishing the crime immediately humbly requests more information from the farmer without even mentioning the type of crime that the farmer might be facing. In this way, the rangers are able to obtain precious information that will allow them to issue a more substantiated fine.

Different rangers explained that after returning from the field it is considered good practice to organize the many pictures, observations, GPS coordinates and pieces of

information obtained *in situ* into a single computer folder, and to write a fieldwork report in order to relate these elements, even if provisionally. Then, after the farmer hands in the documents requested by the notification, the formal issuing of the fine starts. As pointed out above, Brazilian law allows farmers to legally deforest 20% of their farms. Therefore, any given deforestation might be either legal or illegal and for this reason, the rangers request in the notification the presentation of any eventual 'authorisation of deforestation' and 'environmental license'. As will be seen in Chapter 6, in the state of Mato Grosso this authorization is issued by SEMA, the state-level environmental agency. Here, in order to avoid wasting scarce resources, IBAMA usually avoids going to the properties registered by SEMA when selecting the points to inspect, assuming that SEMA is going to take care of them through its own GIS. Thus, the rangers usually ask for this document in the notification mainly as a pretext to obtain the 'map and land title' of the farm, and where possible, with the relative geographical coordinates in order to facilitate the issuing of the fine and related supporting documents. Showing me an example of these maps, a forest ranger remarked that "in fact they [the farmers] give us the bullet with which we shoot them back" (Fieldnote #15/2009).

With all these pieces of evidence at hand, the rangers return to where they began, namely the satellite images and the geodata provided by INPE. Knowing where the deforestation occurred and the borders of the property (through the GPS points taken *in situ* and the documents sent by the farmer), the rangers download new high-resolution satellite images of the farm. From this they patiently produce a 'map-image': a detailed cartographic representation of the farm and the related status in relation to the environmental law. In contrast to what is commonly believed, satellite images do speak for themselves. In order to produce the map-image the rangers have to highlight the contours of the forest-deforestation border on the satellite image. In the cases of clear-cut deforestation, this is a relatively straightforward process. However, in the cases of areas that have been logged or damaged by fire, such as in Figure 22 on the left, this distinction is much more blurred. Of course, there is no lack of mathematical solutions for this problem. It would be possible, for instance, to define space in terms of fields with statistical distributions in order to capture situations where a certain area is deemed half-deforested (Fonseca et al., 2002). However, the law does not allow for fuzzy logic. The Forestry Code prescribes that a

hectare of rainforest can be either pristine or affected by a human agency (be it logging, deforestation or another act). Therefore, the ranger has to define a polygon that, as with any other Euclidean geometrical form, represents a space with a homogeneous character; it is based on this mathematical representation of space that the rangers calculate the area of deforestation and the respective value of the fine.

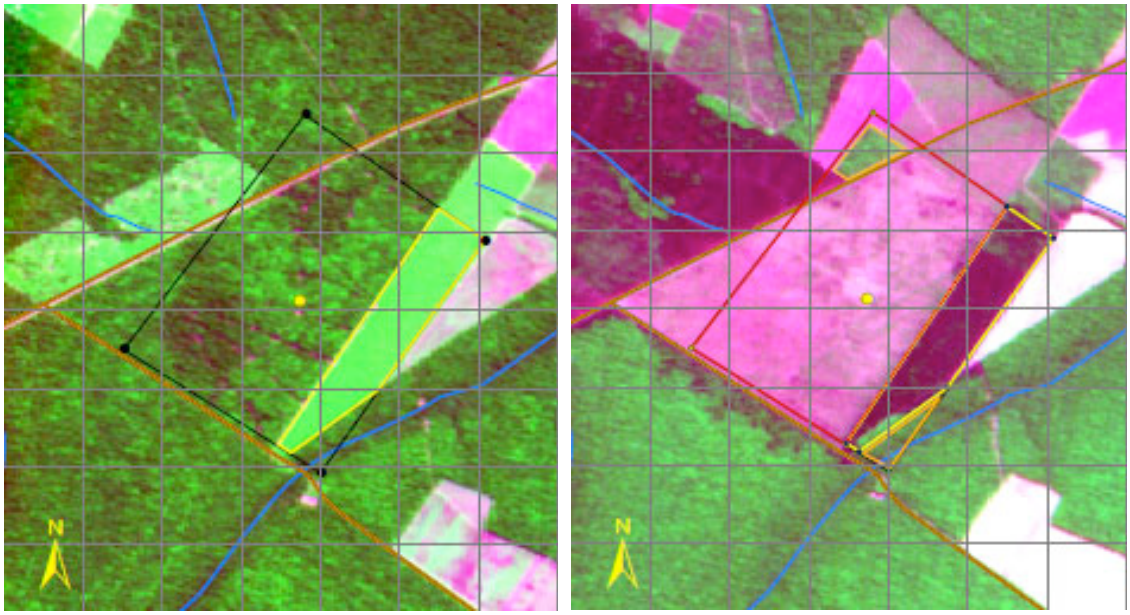

Figure 22 The map-image of the farm in 2004 (left) and in 2008 (right) produced by a forest ranger from IBAMA

The Brazilian environmental code is extremely complex, and depending on where, when and how the deforestation was done, it might fall into different legal categories. These could include sanctions that go from a light fine to imprisonment. Therefore, it is very important for the rangers to establish if a particular deforestation was recent (i.e. occurred in the preceding 5 years) or not. While in the past the rangers could only rely on usually uncooperative and legally untrustworthy local witnesses, they now seek help by downloading from INPE's website satellite images dating as far back as 1973 (just after the first Landsat was launched). In this way, they are able to produce what they call a 'deforestation dynamic', showing at which moment and with which mechanisms (i.e. fires, selective logging) the deforestation occurred. In this way the rangers fix deforestation not only in space but also in time (see Figure 22).

In order to organize the different pieces of evidence in a coherent and convincing way, the rangers create a technical report. It is in this document that they tie all the elements of the case together in order to 'materialize' the fine (the legal term used by

rangers and lawyers to describe the provision of factual evidence for the fine). In the box below there is an excerpt from a technical report concerning illegal deforestation written by a forest ranger from Sinop, which also serves as a template for new reports for other rangers in the region. In the 'motivation' (1.3) and the first paragraph of the 'description of the fact' (1.7), the report highlights the fact that the decision to inspect a specific farm was delegated to a third-party. Hence, it shows that it was DETER that pin-pointed the deforestation, and the local coordinator who issued the inspection order (1.2) asking the team to visit that specific point. Consequently, it was due to this impersonal and scientific-bureaucratic mechanism that the rangers ended up in that particular property, and not because of their own biased or even allegedly corrupt choice, as some lawyers could have argued in order to have fines against their clients dropped (see Box 1).

INSPECTION REPORT

1.2 INSPECTION ORDER NO: MM/YYYY

1.3 MOTIVATION:

Operation Arco Verde. Suspicion of deforestation detected through satellite image.

1.4 STAFF: [IBAMA rangers names]

1.5 LOCATION:

Glebe XXXX, Sector XX, Parcel XX – Tapira

1.6 COORDENATES: XX° XX' XX" S e XX°XX' XX" O

1.7 DESCRIPTION OF THE FACT:

Following the inspection order XX/YYYY, the IBAMA law enforcement team (mentioned above) travelled in search of the deforestation polygon identified through satellite ID-37 (identified by DETER with images from MM/YYYY). In the indicated place (coordinates above), it was possible to establish that the area has suffered intense logging, followed by fires (pictures 01, 02 and 03).

In the point with coordinates XX°XX'XX,X" South / XX°XX'XX,X" West the agent [ranger's name] found a person using a chainsaw, who stated that the farm is owned by [farmer's name]. The team went to the address mentioned above and issued a notification [notification number] requesting him to present the documents of the chainsaw and the property. […]

From this we proceeded to formulate the geo-referenced satellite map-image of the area (annexed), where it was possible to verify the dimension of the area affected by deforestation. Based on the satellite map-image, we proceeded to the issuing of the fine [fine number] with the embargo and interdiction term (TEI) [embargo number] against [farmer's name].

2. AUTHORSHIP AND QUALIFICATION:

[farmer's name], CPF [farmer's ID card]

2.3 REASON:

Destroyed 291,41 ha of native forest in the Amazon biome, object of special preservation.

2.4 LEGAL FRAMEWORK:

Art. 70 of the Federal Law 9.605/1998;

Art. 2, paragraphs II, VII e XI and Art. 37 of the Federal Decree 3.179/1999 and

Art. 225 paragraph IV from the Federal Constitution of 1988.

3. SANCTION:

3.1 FINE/VALUE:

R$ 437,115.00 [around USD 25,000.00]

3.2 DOSIMETRY:

The decree stipulates a value of R$ 1,500.00 for each hectare or fraction destroyed.

3.3 APREHENSION/EMBARGOE/DEPOSIT:

The area stays embargoed and the object of the infraction notice number XXXXXX-D, for any forestry, agricultural or livestock activity until a further decision from the competent environmental organ.

4. SUMMARY OF THE DOCUMENTS:

NOTICE OF INFRACTION	EMBARGO/DEPOSIT	EMBARGO/INTERDICTION	DONATION
XXXXX D	XXXXX D	XXXXX D	XXXXX D

5. ANEXES:

X Photographic report

X Satellite map-image

6.: PLACE AND DATE

Sinop, DD of MM, YYYY.

7. STAMP AND SIGNATURE OF THE TEAM

Box 1 Example of technical report of a fine for illegal deforestation

The location of the deforestation is represented in the usual, old-fashioned style, drawing on *local references* only known to those in the region (1.5). However, the locally-bound spatial reference is not enough for the attorneys in Brasília, thousands of kilometers away who have to be certain that this fine refers to a specific farm and that the rangers are able to visit the farm again if necessary. For this reason, the geographic coordinates, the 'scientific universal' reference of space (1.6) are written

immediately after the address, in order to put the farm and the farmer in a Cartesian plane that can be easily identified by someone who has never been to the Amazon.

The description of the fact (1.7) is the central point of the document. In a few powerful paragraphs it states that ‘it was possible to establish that the area has suffered intense logging followed by fires’. However, instead of basing this on the eye-witness account of the rangers, the document provides external evidence for the statement by pointing to the pictures and satellite images (allegedly unbiased mirrors of reality) taken in the area. This also revealed that someone found in the area told the rangers the name of the owner of the farm (the person responsible for the act), transforming in this way an unpretentious informal conversation into a key piece of objective evidence in the fine.

In this document, the rangers also make reference to the specific laws by which deforestation is ‘framed’ (2.4). Even without going into the particular details of Brazilian environmental law, it is possible to notice the sheer complexity of the legal case at hand in this document. In these three lines, the rangers refer to the law of environmental crimes as approved by the Brazilian Congress, stating what a fine is; a decree signed by the President and the Minister of the Environment explaining how the Forestry Code should be applied and establishing the values of the fines; finally, there is the Brazilian national constitution, which is unique in the world for stating that the country’s forests are a ‘national patrimony’. To add more to the complexity, the law is also constantly changing. For instance, since the inspection report (transcribed below) was issued, decree 3179/1999 has been superseded by decree 6514/2008, which in turn has also been modified substantially by decree 6686/2008 with minor additions by decrees 6695/2008 and 7029/2009. Furthermore, since neither the constitution nor any other law explain the legal implications of the notion of ‘national patrimony’, IBAMA's rangers interpret it as the equivalent to the‘object of special preservation’ (see point 2.3) found in the law of environmental crimes. In this way, the enforcement of the environmental law triggers a fully-fledged criminal process in the judiciary alongside such charges as theft and murder, in addition to an administrative process at IBAMA.

Finally, the rangers issue a fine where the total area of deforestation (2.3) and (respective) value (3.1) are calculated according to the GIS. Lawyers have reported to

me that because of this procedure they feel that they cannot argue about the area of deforestation being miscalculated since it is based on the GIS and related satellite images (and not on the rangers' testimonies). The actual fine, an old-fashioned hand-written bureaucratic form, is then issued with an indication of the area of deforestation (2.3) and the value of the fine (3.1) is rounded up to the second decimal place. When properly carried out, the final result of this new generation of GIS-based fines issued by IBAMA is a legal document that can travel long distances and be read and accepted as an objective representation of what has happened in a given property by the senior officials, attorneys as well as the farmers' lawyers. In this regard, some rangers, lawyers and even farmers have confirmed that it is much more difficult to challenge GIS-based fines on the basis of a lack of materiality. Hence, it is difficult to deny in court that deforestation did not take place.

This does not mean, however, that the legal processes described above always go smoothly and the fines are paid straight away. Different rangers and attorneys suggested that breakdowns in communication are common despite of (and sometimes because of) the use of GIS. In particular, sometimes the lack of local knowledge of the Amazon by attorneys prevented them from understanding even the GIS-based representations of the region contained in the fines. An example of this sort of breakdown took place while shadowing a team of rangers doing office work in the Amazon. While working through the communications sent by an attorney a forest ranger was infuriated by the fact that his fine was rejected because it did not say textually that a given farm was located in the rainforest biome even though, as the ranger explains "everybody knows that the municipality of [where the deforestation occurred] is bang in the middle of the rainforest" (Fieldnote #15/2009). Similarly, some attorneys complained that forest rangers often do not have a full grasp of the legal requirements of fines for illegal deforestation, and for this reason incur in basic mistakes. For instance, they reported that rangers often do not state explicitly in their fines and technical reports that a specific person caused the deforestation. Therefore a skilful lawyer may challenge in court even well formulated fines, such as the one in the example above, based on the argument that the fine did not formally accuse his client of committing a crime.

5.4 Emerging conflicts at IBAMA

Ultimately, it is possible to say that the introduction of GIS at IBAMA is a success story. Following the introduction of GIS at the local offices in 2004, the total number of fines issued for illegal deforestation in the Amazon jumped, while in the same period the deforestation detected by PRODES dropped substantially. Behind this success of GIS and the reduction in deforestation, however, it was possible to observe a growing distance between the expectations of senior officials and scientists and the work practices of local managers and forest rangers. The lack of understanding about the work carried out by other groups is not an issue *per se*. Rather, in order for a complex organization such as IBAMA to function it is necessary to establish a regime of labor division. This implies a process of specialization which hides the specific work done by a certain department or group of workers from the view of other groups. However, the problem is that the gap described above is becoming so wide that it is starting to interfere in the provision of the conditions with which to conduct the practices necessary to enforce the environmental law.

As mentioned above, scientists and senior officials are placing considerable emphasis on the development of the new GIS and the provision of GIS data as a way of controlling deforestation. Frequently, however, their emphasis on GIS goes to the point where they imply that it is the GIS and not the rangers who are actually protecting the Amazon. Statements such as "DETER is a system able to control the rhythm of deforestation because it detects deforestation in real time" (Interviewee #7/2007) from an ex-Minister of the Environment confirm a view that seriously underplays the work carried out by the rangers in enforcing the deforestation control policy in the Amazon. It is not surprising, therefore, that a report formulated by the Ministry of the Environment for the last UN conference in Copenhagen to explain how Brazil was able to drastically reduce deforestation in the previous years placed considerable emphasis on the role of INPE's GIS, while barely mentioning IBAMA (Brasil, 2009a). Moreover, some senior officials and scientists indicated that they found the understanding of IBAMA practices for the protection of the Amazon irrelevant. For instance, following a seminar where I presented the findings of this research to a group of INPE scientists, one of them rhetorically inquired: "Why should we understand IBAMA practices if they are so inefficient?" (Fieldnote #21/2009).

The emphasis on GIS has also been translated in action. Until 1995, PRODES from INPE was the only GIS in operation in the Amazon. However, following the success of DETER (which was created in 2004), this number increased to 7 in 2009 with at least three other systems being run by state governments and NGOs. Furthermore, consecutive with the writing of this thesis, IBAMA has been developing a new advanced GIS based on radar technology which is able to "see under the clouds", as an IBAMA senior official explained, while INPE is investing hundreds of millions of dollars in the construction of eight new satellites aimed at detecting deforestation at high resolution on a daily basis.

In contrast, the government has invested proportionately very little in its personnel. During the time I spent shadowing the forest rangers in the Amazon, they often complained about the harsh working conditions, which included spending weeks away from their families, sleeping in shabby hotels or even in tents in the forest. This was in addition to the constant threats from the local population and the risks involved in carrying out missions in places where *pistolagem* (i.e. contracted killers) are common. Furthermore, IBAMA forest rangers with a better standard of education earn an initial monthly net stipend of R$ 3,000 (about £1,000), which is less than half the amount received by the civil servants with similar qualifications from other federal agencies, such as ANA, the national waters agency (Alves, 2010). Finally, it was possible to observe that while IBAMA headquarters have invested some resources for training in GIS, most forest rangers still have no formal training in this technology. As such, they often have to rely informally on their GIS-savvy colleagues in order to carry out more complex tasks. Moreover, some rangers complained that they lack legal training and incentives to continuously improve the quality of their fines. Hence, they reported that while the rangers endeavor to fulfill the expectations of attorneys and lawyers, senior officials seem more interested in the total number of fines and other GIS-based indicators than the quality and efficiency of the rangers' work.

In this context of undervaluation, and for some rangers, even abandonment, it was possible to observe a growing tension between the workers in the field and the senior officials in Brasília. Different rangers reported that they felt that those in Brasília largely ignore their voices. For instance, they often call the headquarters a 'Fantasy Island' when referring to the tendency of the headquarters to make requests, plans and

develop technologies which are not feasible in practice. As an example of this, a ranger reported in an informal conversation while I shadowed his work that:

> [T]he problem in Brasília is that many times they develop technologies that nobody asked for, like this electronic fine, while the technologies that we really need they don't develop. The guys from Brasília do not know our reality and do not like coming here because they think that here is the end of the world. (Field note #19/2008)

As reported repeatedly by the local managers and rangers, because of the hard working conditions the rangers try to stay in the Amazon region as little as possible. One local manager stated that in his office all the rangers except himself and the other manager had made a request to be transferred to the headquarters or the capital of Mato Grosso. As a result, the ranger with the best GIS skills from that office was transferred to Cuiabá, making it even more difficult for the rest of the team to use this technology. The lack of satisfaction of the rangers with their work was also reflected in a two-month strike in the first semester of 2010, when they demanded better salaries and working conditions: a strike that helped to explain the recent surge in deforestation (Alves, 2010). This suggests that while GIS has brought considerable advantages to IBAMA, the overemphasis on it seems to have created a smokescreen which prevents senior officials and scientists from understanding that they hold infeasible expectations and that the rangers are working in increasingly unbearable conditions.

5.5 Summary and final remarks

After a close examination of how GIS is actually deployed by the IBAMA forest rangers, it was possible to observe that the introduction of this technology at the local offices has improved the way IBAMA organizes its macro-strategy, plans its missions and issue fines. In particular, in different instances GIS has assumed the middle ground between different groups allowing senior officials to talk and negotiate with local managers, the managers to coordinate and control the rangers, and the rangers to formulate fines that can be interpreted by attorneys and lawyers at a distance.

Nonetheless, it was possible to observe that senior officials in Brasília have downplayed the ways in which GIS is actually used in the Amazon in different ways. Firstly, the notion of 'deforestation control in real-time' as defended by the scientists and senior officials is impractical in the context of the Amazon rainforest. The continental dimensions of the region, coupled with the scarcity of human and

financial resources means that the local law enforcement coordinators have to target regions in rounds, instead of inspecting individual 'ongoing deforestation', as envisaged by the scientists of INPE and senior officials. With DETER, the rangers already appear to be overwhelmed with data, since they are unable to check all the new deforestation detected by GIS.

Secondly, the transformation of deforestation (as detected by DETER) into a fine is far from being the result of a straightforward bureaucratic operation, consisting as it does of collecting self-evident information and making comparisons with what is lawfully allowed. In fact, in order to constitute a fine for deforestation, the rangers have to skillfully weave together three elements: the location, the act and the person behind the clearing. Finally, it was argued that by ignoring how the work of the rangers is actually carried out, senior officials are undermining some of the conditions that make this work possible. In the next chapter we are going to examine the practices of SEMA, the state-level environmental agency of Mato Grosso.

Chapter 6: SEMA: GIS and politics in Mato Grosso

6.1 Introduction

Even though IBAMA, the Federal Environmental Agency, still has a preeminent role in enforcing the environmental policy in Brazil, its importance is often rivaled by the state environmental agencies. Among the nine state-level agencies in the Amazon, SEMA in Mato Grosso is one of the most active. In recent years, SEMA has invested considerable sums in the development and use of GIS, becoming one of the most technically advanced state-level agencies in the country. This chapter aims at showing how the use of GIS at SEMA is related to the historical and political context of Mato Grosso. Furthermore, it intends to show the tensions that are emerging from the difference between the expectations surrounding GIS and its actual use.

The chapter is organized as follows. The next section outlines the colonization history of Mato Grosso, its relation to the current political situation and the position of SEMA in this context. The third section focuses on how GIS is used by SEMA forest rangers to enforce the environmental law. The fourth section looks at SLAPR (a GIS developed by SEMA) and analyses how bureaucrats use it for the issuing of environmental licenses. The fifth section highlights the political struggles within SEMA from the perspective of its senior officials, rangers and bureaucrats. The chapter ends with a summary and some concluding remarks.

6.2 Historical background

6.2.1 The colonization of Mato Grosso

The geographical location of the modern state of Mato Grosso could not have been more distant from European civilization in the 16th century. At the very center of South America, the region is equidistant from the Pacific and the Atlantic oceans, the main access routes of colonization. This isolation meant that despite the many attempts from the Brazilian and Portuguese rulers, the region remained largely unchanged for centuries. It was only in the 1970s that the population of Mato Grosso

and other parts of the Amazon started to boom. In the last four decades farmers from all parts of Brazil (but especially Italian and German descendants from the South) migrated to Mato Grosso, creating roads, establishing farms and transforming the forest into pasture and crops. The population of the state went from a mere 319 thousand in 1960, doubled in size by 1970 and reached more than 2 million people in 1991 (de Souza-Higa, 2008: 253). It was also in the 1990s that the 'heroic effort' (as the government of the 1970s described it) started bearing fruit for the newcomers. Scientists as well as farmers have reported that since then there has been a heated discussion about the 'vocation' of the Amazonian soil for high-yield agriculture instead of extensive cattle ranching, the latter still being the prevalent economic activity in the region. In the south of Mato Grosso, the soil was considered too acidic for the development of successful crops while in the forested and humid north it was too thin and infertile (Ab'saber, 1989; Denevan, 1973; Wood et al., 2002). However, in the 1990s, some farmers from Mato Grosso started adopting new capital-intensive technology to change the soil composition with heavy machinery and make it suitable for the highly profitable soybean crops. From the mid-1990s onwards the agribusiness industry flourished, making Mato Grosso one of the main producers and exporters of soybean. In this way, the region not only became increasingly integrated economically with southern Brazil but also with the rest of the world (Becker, 2005).

The history of Mato Grosso as well as this new wave of wealth is visibly evident in most towns along the BR-163, the highway that links the capital Cuiabá with the heart of the Amazon rainforest in the north. Along almost the entire extension of the highway the only landscape that can be seen is that of endless soybean fields punctuated by enormous silos from food multinationals such as ADM, Monsanto, Bunge, Cargill and Amaggi. The small dusty towns alongside the highway of a few decades ago are now booming centers, well served by shops, the internet, cable TV, and trafficked by luxurious sport utility vehicles (see Figure 24).

Figure 23 A medium size soybean farm in the transition area between savanna and rainforest

Sorriso, located in a transition between savanna and rainforest, is a good example of this transformation. Funded in 1987 by southern settlers, in only two decades it became the municipality with the biggest agricultural output and one of the highest incomes per capita in the country. Moreover, its neighbors, Tapurah, Nova Mutum and Lucas do Rio Verde, are following in its footsteps (IBGE, 2004). In informal conversations with one family in Sorriso and another in Campo Verde (who both allowed me to shadow them for almost a week) it was possible to note a strong sense of pride in this accomplishment. They often depict themselves as self-made men, abandoned by the state in the middle of a 'green desert', who, thanks to their determination, were able to build one of the most prosperous regions in the country with their bare hands.

6.2.2 The origins of SEMA

The political context of Mato Grosso is a clear reflection of its origins and recent history. The majority of the wealth produced in the state is related to the agricultural sector, in particular cattle ranching and soybean production. The dominance of the rural sector in the economy is also reflected in local politics. Historically, all the

governors of Mato Grosso and the vast majority of its assemblymen have more or less directly supported the rural sector. Blário Maggi, the last governor of Mato Grosso and now elected senator for the state, is a clear example of this. Maggi, like many other inhabitants from Mato Grosso, was born in the south of the country from a family of Italian descent. After finishing a degree in agronomy in the 1970s, he moved to Mato Grosso with other pioneering farmers where he and his family established soybean farms in different parts of the state. During the 1990s, Maggi's company, Amaggi, emerged as one of the biggest soybean producers in the world, being responsible today for about 5% of the entire output of Brazil. In 2002, Maggi entered into politics, and was elected state governor in a landslide victory. One of his main campaign promises was the defense of the interests of local farmers and the reduction in environmental restrictions established by the federal government. His government was so successful that he was re-elected to the post in 2006 and was able to bring about the election of his vice-governor, Silval Barbosa, as the new state governor in the 2010 elections.

The rural activities defended by the political class of Mato Grosso are closely related to illegal deforestation. Cattle ranching in particular as well as soybean farming require extensive tracts of land, which in most cases were claimed from the wooded savanna and rainforest that covered most of the state until a few decades ago. For this reason, the state of Mato Grosso, along with neighboring Pará, has been responsible for a large share of the deforestation of the Amazon (see Figure 24). Furthermore, because of the strict restrictions set by the federal environmental policy and the complex bureaucratic procedures required to obtain authorizations for deforestation, the majority of the clearings were carried out illegally.

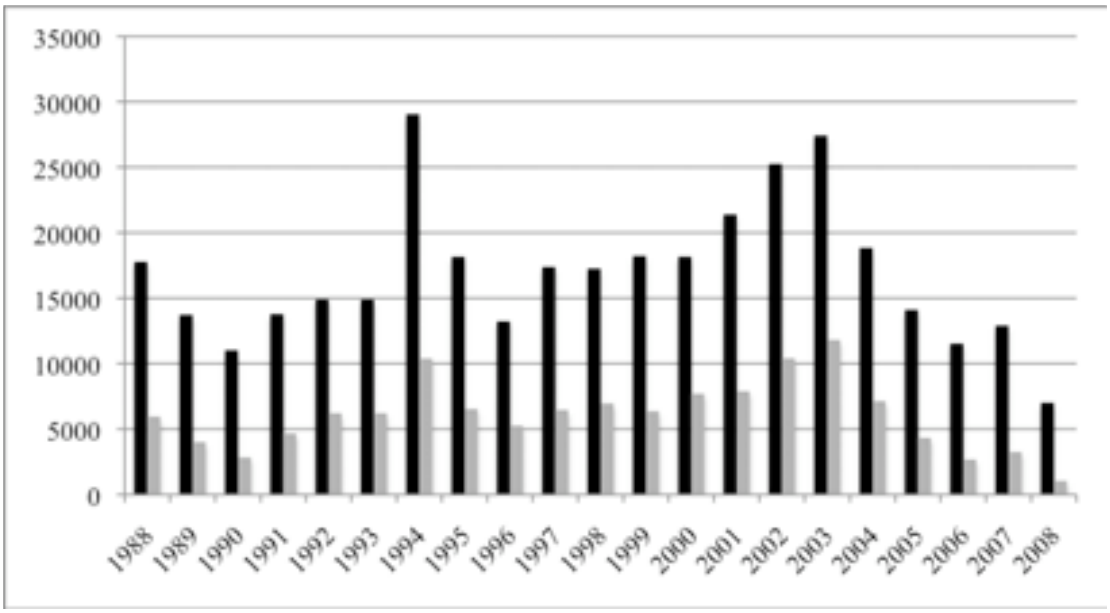

Figure 24 Deforestation in the Legal Amazon (in black) and Mato Grosso (in grey), measured in Km^2 (source: PRODES/INPE, 2009)

As already mentioned in Chapter 1, the Brazilian environmental policy was devised as a decentralized system involving agencies at federal (i.e. IBAMA), state and municipal level. With this purpose, the state of Mato Grosso created in the late 1980s SEMA. However, as in most state-level agencies in the Amazon created at the time, SEMA followed the structure and aims of the environmental agency of São Paulo, this being one of the oldest in the country. During their interviews, different senior officials recalled that in line with the state agency of São Paulo, SEMA focused its activities on urban pollution and the regulation of mining activities, largely ignoring issues relating to deforestation and the rural sector. In this way, SEMA was placed in a position where it did not interfere with the mainstream economic activities of the state.

This pattern began to change towards the end of the 1990s, when increasing national and international political pressure gave greater prominence to the issue of deforestation in the region. Among the different events that contributed to this change, various sources suggest that a series of intensive fires in 1998 were particularly significant. As mentioned in the previous chapter, the use of fire for land clearing is a common and long-established agricultural technique in Brazil. However, in contrast to previous years, a particularly intense and long dry season in 1998 helped to intensify and spread the fires in the region, causing problems due to the excessive smoke. Additionally, the smoke from the Mato Grosso burnings crossed the state

frontier and also caused disruption in Rondônia and Acre, with the result that the state governors from these two regions went to Brasília to make a formal complaint. Following this, the National Council of the Environment (a regulatory body) told Dante Oliveira, the governor at the time, to provide an explanation and deal with the problem urgently. This represented an important change. Even though environmentalists had accused the federal government of causing the destruction of the Amazon for more than three decades, the state governments had not explicitly been held accountable before. In addition to that, different farmers, politicians and representatives from multinational companies pointed out in their interviews that this period was also marked by economic concerns. In particular, different interviewees reported that they feared that international concerns over deforestation would be translated into a boycott of Mato Grosso's products by consumers in Europe and USA, creating major loses for the local economy.

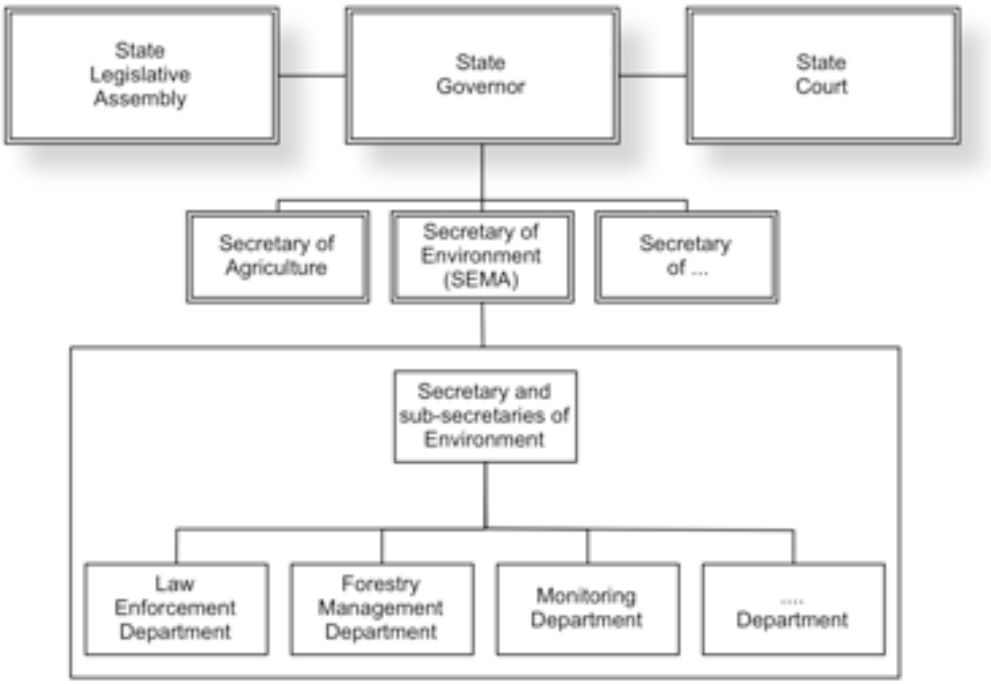

Figure 25 Current organogram of the state government of Mato Grosso and SEMA

In order to tackle this scenario of increasing pressure, the state governor asked SEMA to explicitly include among its activities the monitoring and controlling of fires and deforestation. One of the main actions in this direction was the creation in 1999 of SLAPR, a GIS-based environmental licensing system for rural properties. In addition, SEMA hired a team of forest rangers to carry out inspections, and more recently has

also started using DETER, the real-time deforestation detection GIS developed by INPE. Different informants suggested that SLAPR was specifically conceived to provide environmental licenses that farmers can use to demonstrate to their buyers that they are obeying the environmental law. In addition to that, some senior officials explained that by creating SLAPR they aimed at enabling the efficient handling of requests for legal deforestation: an activity that was up to that point in the hands IBAMA. In this sense, SLAPR was conceived not only as part of an environmental policy, but also as an economic one too. A senior official directly involved in funding SLAPR illustrates this point:

> Frederico Muller, the [Environment] Secretary at the time, was a man with a strategic vision. He knew that the state of Mato Grosso needed a strong monitoring and licensing system for rural activities in order to remain Brazil's biggest producer and exporter of soybeans. This system aimed at allowing the state to keep its legitimacy and to avoid being a victim of this process [agricultural expansion]. (Interviewee #12/2007)

The excerpt above as well other sources suggest that SLAPR emerged as a way of ensuring that the project of Mato Grosso would become one of the biggest agricultural powers in the world and that it would not be threatened by environmental concerns. The next two sections examine the work practices of the three departments of SEMA responsible for enforcing deforestation control in the region, namely, law enforcement, forestry management and monitoring departments (see Figure 25). In particular, an examination will be made of how these groups use GIS to identify and prosecute illegal deforestation and register rural properties within SLAPR as well as how the broader historical and political context mentioned above have influenced these practices.

6.3 DETER and fines for illegal deforestation

The identification and punishment of illegal deforestation is one of the chief legal functions of SEMA in relation to environmental law. This work is mainly carried out by the law enforcement department, an organization that was formed in the late 1990s as part of the events described in the previous section. SEMA's law enforcement department is composed mainly of an enforcement manager overseeing a group of 20 forest rangers, most of whom have higher degrees in forestry and other subjects. The forest rangers and other SEMA officials see this department as being almost 'another SEMA'. They point out that while many SEMA officials are seen (and see themselves) as bureaucrats and environmental experts, the rangers in the law

enforcement department have an image closer to that of a policeman. This image is also reinforced by the fact that during the period of this research a high-ranking official from the state's military police led the law enforcement department. Furthermore, most SEMA officials work in the headquarters in Cuiabá and the rangers from the law enforcement department have a separate office within a police station.

As with most rooms in the SEMA headquarters, desktop computers, piles of paperwork and printouts of maps dominate the office space of the law enforcement department. However, in addition to these, it is possible to observe that much of the work in the office also relates to the use of GPS devices and GIS software applications. The rangers and senior officials interviewed for this research explained that GIS is central to their work. It was also possible to observe the intensive use of GIS in relation to the two activities carried out by the department: mission planning and writing up fines.

6.3.1 Planning missions

Most law enforcement missions start in the rooms of SEMA's GIS experts at the headquarters. Senior officials on different occasions have highlighted the importance of GIS for SEMA. For instance, both the Secretary of the Environment and his assistant-secretaries have pointed out that the recent acquisition of high-resolution images from the French satellite SPOT will generate a jump in the quality of the rangers' work. In particular, these senior officials explained in their interviews that SPOT will be better than DETER by providing images in near 'real-time' at a higher resolution. These images in turn will allow SEMA to detect deforestation at even earlier stages with the consequent issuing of preventive fines. In this way, SPOT will facilitate the realization of an improved version of the real-time law enforcement model also defended by IBAMA senior officials and INPE scientists.

In practice, however, and as with IBAMA, GIS is rarely used to carry out missions as soon as new deforestation is detected. SEMA rangers explained that they have to work under many different kinds of limitation, which means that it can take months before they are able to inspect a new deforestation site. The first limitation they pointed out is the sheer scale of the state of Mato Grosso and the lack of appropriate roads. One ranger, for instance, reported that it takes three days to reach regions in the

north of the state, such as Aripuaña, and depending on the condition of the roads may take even longer. The second limitation concerns the availability of human resources and equipment. The rangers explained that SEMA covers only two regions at the same time due to the lack of personnel and the limited number of GPS devices and computers. This means that at any given period SEMA has to leave the deforestation in the other four regions of the state unchartered.

Finally, and perhaps most crucially, SEMA rangers work under a strict regime as regards the provision of travel allowances. SEMA's fieldwork is an expensive and lengthy process. In order to reach the locations pinpointed by the GIS and carry out inspections, the rangers usually spend many days in the field, going from town to town in order to make the most of their time. Because of the extra costs, such as the hotels and meals during fieldwork, the rangers receive a daily allowance. This extra salary is also referred to as a kind of compensation for the hardship involved in carrying out the fieldwork. Therefore the rangers consider the allowances to be a key element of the fieldwork without which they would refuse to leave their offices. The provision of daily allowances and transportation for fieldwork has been a longstanding issue at IBAMA and SEMA. IBAMA has solved this issue in recent years by increasing the resources for this activity, but SEMA has taken the opposite route. A state decree approved in 2006 restricts the total number of fieldwork allowances to SEMA rangers (working as civil servants) to five-and- a-half days per month, and for the rangers working with short-term contracts to nine-and-a-half days. Because of these limitations, the forest rangers who were interviewed reported that in practice they can only devote one third of their time to law enforcement activities, and are relatively idle for the remainder of the time.

While the GIS is not used for the sort of 'real-time' law enforcement imagined by senior officials, it is apparent that this technology plays an important role in facilitating the coordination between the different professionals involved in planning and carrying out the missions. As with IBAMA, before each mission the law enforcement manager and GIS experts create maps of different scales for the areas to be inspected; this is achieved through using the data provided by DETER from INPE and SAD from IMAZON (an environmental NGO). The maps printed out on the largest scale are used by the team leader in the fieldwork to manage the work of the other team members; with these larger maps, the team leader is able to decide how to

divide the team into sub-teams in order to carry out day trips in the surrounding areas and inspect the specific deforestation points he has chosen (see Figure 26, on the left). In addition to the larger-scaled general maps, SEMA GIS experts also create maps on a smaller scale for each deforestation point (or set of nearby points). The forest rangers then use these maps jointly with GPS devices to locate individual points when traveling on the ground (see Figure 26, on the right). SEMA rangers also use a third type of map specifically to support the fieldwork carried out by helicopter, this map being on an intermediate scale. In addition to indicating the location of a dozen or so points of deforestation, these maps also show the fuel autonomy of the helicopter with a circle to help the pilots and rangers avoid accidents while covering as many points as possible.

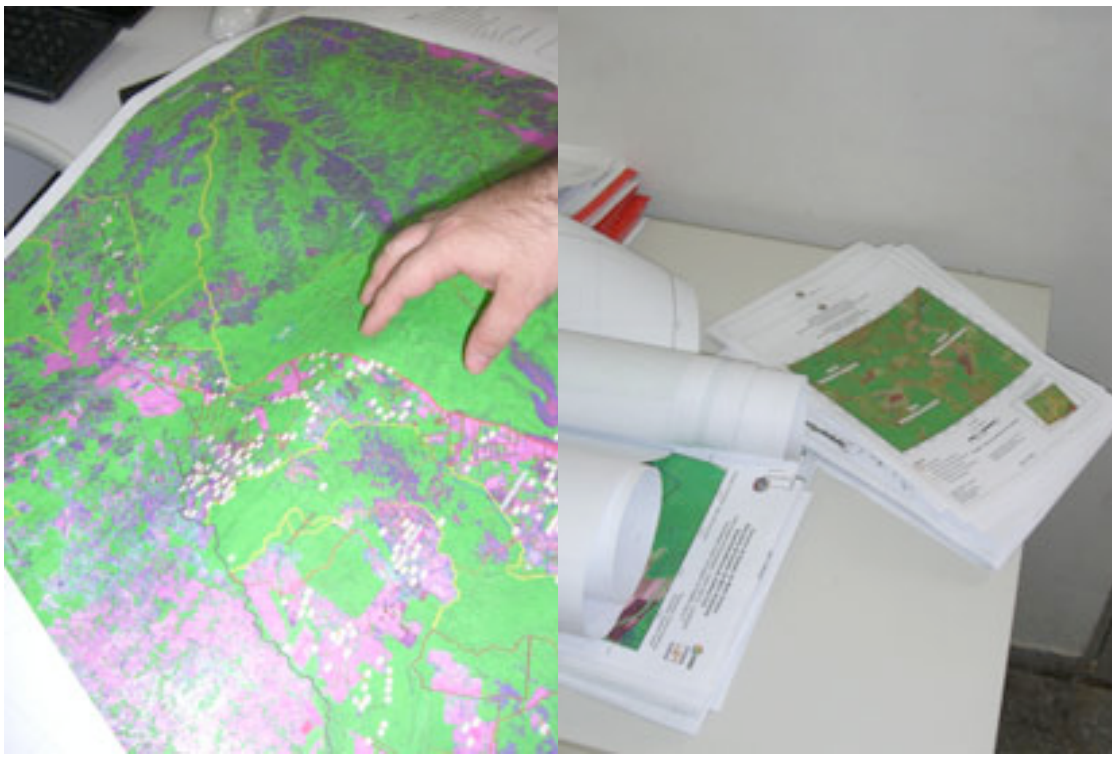

Figure 26 An example of SEMA's logistic map (left) and individual deforestation point maps (right) used by SEMA rangers during fieldwork

The rangers and managers reported that the benefit of using GIS for this purpose is twofold. On the one hand, by having a bird's eye view of the region and the task ahead, managers and team leaders are able to improve the rangers' efficiency on the ground through indicating the routes that cover more points in less time. On the other hand, controlling which locations the rangers must visit and knowing in advance what sort of deforestation they might find in that location allows the managers to reduce the risk of corruption.

Even though most of the SEMA officials interviewed praised the benefits of using DETER, a recent political crisis involving the system suggests an underlying love-hate relationship with the system. On the one hand, DETER helps its work by facilitating the joint work between the different groups operating within the agency. On the other hand, however, DETER deforestation data has also exposed SEMA's failure to tame deforestation in the region. In most instances, SEMA officials were keen to accept the data coming from DETER and to take appropriate action. However, following particular legal actions from the federal government against the interests of the state's agricultural sector, some underlying tensions between SEMA and INPE came to the fore. As indicated in Chapter 4, towards the end of 2007, INPE scientists took the polemic decision to publish the monthly deforestation assessments from DETER online in order to prompt the government to tackle the rising deforestation. As intended by INPE scientists, the federal government passed a decree restricting credit to farmers in the Amazon, and IBAMA launched *Arco de fogo* (fire arch), a major law enforcement operation focusing on the municipalities with the highest deforestation rates.

The new decree and the aggressive law enforcement operations by IBAMA caused considerable distress among the farmers from Mato Grosso. Even though most of the farmers were still able to bypass the credit restrictions by financing their crops with multinationals such as Bunge and Amaggi, the lack of access to loans with lower interest meant that for the first time in history farmers experienced direct financial loss due to an environmental law. For instance, a local farmer explained in an informal conversation that because of the decree in 2008 some soybean farmers had to sacrifice particular luxuries, such as the acquisition of a new sports utility vehicle that year (Field note #25/2008). Defending the interests of local farmers, Blario Maggi, the State Governor of Mato Grosso, launched a heavy attack (with the help of Reinhold Stephanes, the Minister of Agriculture) against the Ministry of the Environment and INPE (Sant'Anna, 2008). The attack on INPE could not have occurred without the assistance of SEMA's GIS experts. Therefore, in order to challenge INPE's data with scientific arguments, SEMA carried out a major operation, which according to many forest rangers was the biggest fieldwork ever undertaken by the state government. With the full financial support of the governor, SEMA rangers and other officials visited and took pictures of all the points signaled

by DETER as being deforestation. These pictures were then used to compile a report, with hundreds of pages arguing that INPE had mistakenly classified 90% of the points indicated by DETER as deforestation. In response, INPE formulated a counter-report stating that in fact only 10% of its initial classifications were wrong, and explaining that the confusion had emerged because DETER detects not only clear-cut deforestation but also other forms of severe forest degradation which are also prosecutable by the environmental law. Furthermore, as in the debates concerning INPE's data in the early 1990s, the institute was willing to compromise. In order to avoid future problems, INPE started to differentiate between the percentage of DETER's deforestation that was clear-cut and degraded forests. Since this change SEMA has not challenged INPE data again, which was probably also helped by the fact that since then INPE has published data showing decreasing deforestation rates in the region.

6.3.2 Writing up fines

After planning the missions and eventually reaching the areas pin-pointed by the GIS, SEMA forest rangers have to collect evidence and decide which legal measures to take. While many senior officials have affirmed that it is possible to issue fines remotely based solely on satellite images it emerged that this is not the case in practice. According to the rangers, while deforestation may be evident from the satellite images or from aerial photographs taken from helicopters, the authorship of the crime is not. Consequently, SEMA rangers also have to interview local farmers and other witnesses found in the area in order to find the person who has caused the deforestation.

In instances where the deforestation is in a limited area and the authorship is clear (i.e. when they catch the perpetrator in the act), the rangers may issue the fine on the spot. In these cases, the rangers use the GPS device to calculate the total area of deforestation, and from that the total amount of the fine. In particular, they register the distance between the extremes of the deforestation in the GPS device in order to form a simple geometric figure, and from this create an estimate of the size of the clearing by calculating manually the area of the figure (see Figure 27, on the left). In the cases, where the deforestation has a more complex pattern or involves different types of environmental crime, the rangers ask the GIS experts from the monitoring department

to create a map-image. In such a document, the GIS experts make an outline of the line between the virgin forest and the different types of clearing using the GPS coordinates provided by the rangers. In the case of Figure 27 (on the right), for instance, the rangers have differentiated the clearing caused by arson in the native forest (blue line) and in the pasture (white line), indicating in both cases the total area affected by the fire. In this way, the main source of evidence for the environmental crime becomes the GIS-based map and not the rangers' own eyewitness account of the area. When the fine is finally ready, it is sent to the farmer by post or handed to him in person if a postal delivery is not possible.

After the fine is issued, a copy is given to the farmer and another is sent to the department of the state-level court that deals with environmental crimes. From here another process begins involving the farmers' lawyers and the state attorneys concerning the analysis of these fines and other legal measures. The rangers explained that the GPS coordinates, pictures and, in some cases, satellite images of the farms they have inspected are key elements in the legal process. In particular, they indicate that the attorneys and lawyers are able to carry out their debates on the legal matters relating to the environmental crime based on these elements, and they can be sure that they are referring to a specific property even though they have never been to the region before.

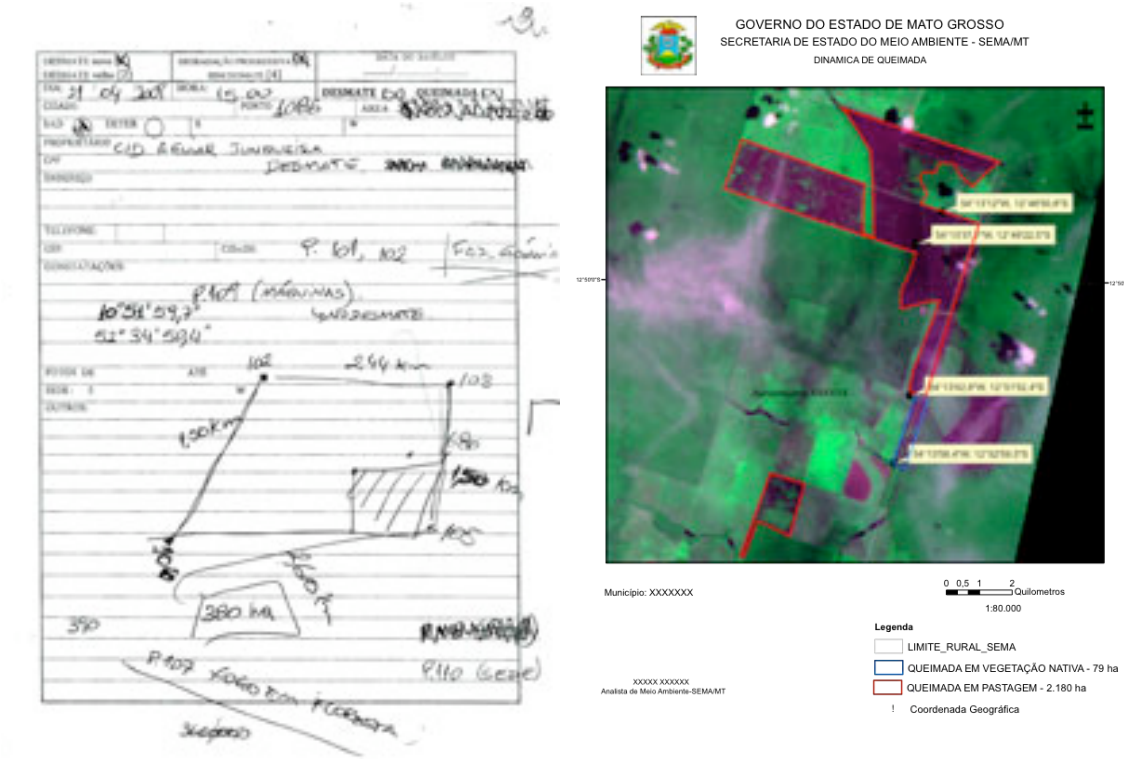

Figure 27 An example of a simple fine that uses the GPS to calculate the deforested area (left) and a complex fine issued by SEMA that uses satellite images and GIS (right)

Even though there are many similarities between SEMA and IBAMA, a closer look at the practices of SEMA rangers reveals that they tend to adopt a legal framework that is much softer with farmers than the one usually adopted by IBAMA. While both SEMA and IBAMA rangers use GIS to reach deforestation points, once they reach these points they adopt a different course of action. One of the main strategies adopted by IBAMA rangers is to attempt to generate as much cost to the farmer as possible. Based on the assumption that most fines are not paid, the rangers attempt to punish the farmers with legal measures that will bring about an immediate payment, such as the seizure of trucks, tractors and the embargo of farms. From interviews with SEMA rangers, however, it has emerged that the state agency tends to take the opposite approach. After finding an illegal clearing, the standard approach of SEMA rangers is to issue a notification ordering the farmer to register with SLAPR within 90 days. Even though this means that farmers will have to spend time and money going through a registration process which they would not have otherwise done, the simple registration at SLAPR does not mean that the farmer will improve upon his environmental practices. Furthermore, with the approval of *MT Legal* (explained below), farmers can now register with SLAPR without paying any fines for deforestation. Heavy measures, such as the seizure of equipment and an embargo on

the farm are only reserved for rare instances when SEMA rangers catch the farmers in the act of deforestation or when riparian forests are cleared.

At the root of this practice lie particular interpretations of environmental law. For example, according to the current environmental policy, forest rangers are obliged to place embargoes on properties only when they find deforestation in 'areas of special preservation'. As mentioned in Chapter 5, IBAMA rangers understand that the whole Amazon rainforest is an area of special preservation, citing for this purpose the national constitution which refers to the region as a 'national patrimony'. SEMA rangers, in contrast, have been instructed to consider only the 'areas of permanent protection' such as riparian forest and other vegetation near water springs as these are areas of special preservation. Hence, the ability of SEMA rangers to cause farmers financial damage has been severely restricted by senior officials. Because of this and other differences between the practices of SEMA and IBAMA, it was not surprising to hear from different interviewees that farmers often prefer to be fined by SEMA instead of IBAMA. A metaphor mentioned by both IBAMA and SEMA rangers summarizes this difference well. In their view, IBAMA constitutes the 'hard teacher that beats his students on the hand when they commit a misdeed', while SEMA 'is the soft teacher that pats a student on the shoulder and forgives him straightway' (Field note #15/2009).

6.4 SLAPR and environmental licenses

While the previous section has described the role of GIS in the issuing of fines, this section focuses on the role of SLAPR, a GIS developed by SEMA as regards the issuing of environmental licenses. SLAPR is the acronym in Portuguese for the Environmental Licensing System for Rural Properties. As the names suggests, the basis of the SLAPR system is a legal instrument called 'environmental licensing', namely the requirement of a formal authorization for the functioning of certain activities. SLAPR was conceived as a three-stage system (see Figure 28). In the licensing stage, the borders and land-use of each individual property are brought into the system. In this process, the farmers who have deforested more than the percentage allowed by the law or who have deforested in places where clearing is prohibited, such as riversides, may have to pay a fine and sign an agreement to reforest those areas. In the monitoring stage, each property is monitored using satellite-based remote

sensing and GIS technology in order to identify the increase or decrease in the forested area. Finally, in the enforcing stage, farmers within the system who do not obey the law and continue to deforest or use fire in their proprieties have their licenses suspended and pay a fine.

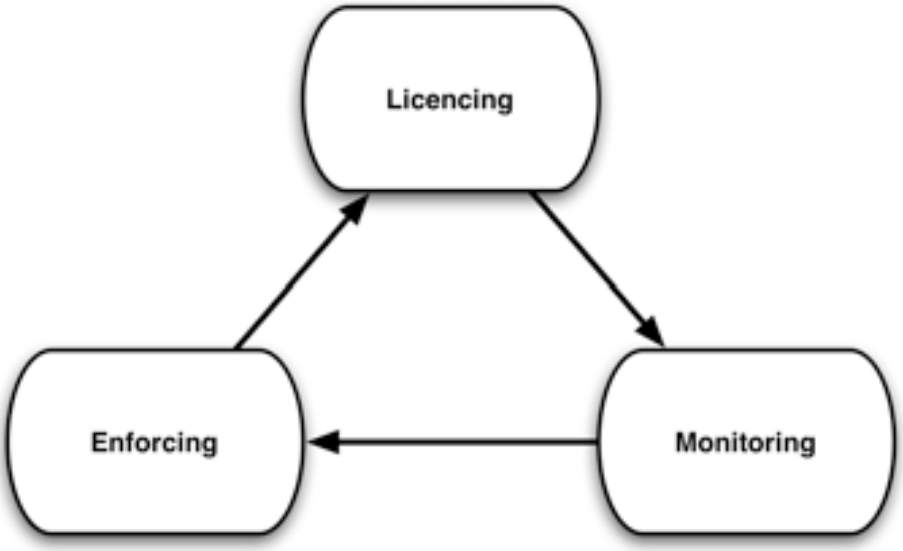

Figure 28 Principle behind the functioning of SLAPR (based on Lima et al., 2005a)

SLAPR, the first major GIS used by SEMA, was (and still is) widely acknowledged as an efficient way to control deforestation in the Amazon by researchers, funding agencies and policy-makers (Chomitz et al., 2005; Wertz-Kanounnikoff, 2005). For instance, Fearnside (2003), one of the main scientific authorities in the area (see Chapters 2 and 4), affirmed that SLAPR contributed to the reductions in deforestation in Mato Grosso and represented a new model that showed for the first time the government's ability to control deforestation. Funding agencies also provided considerable support to SLAPR. An example of this is when the World Bank, in addition to providing non-refundable loans, also presented SLAPR to different countries as an example of 'best practice' in the context of deforestation control. Similarly, the Pilot Program to Conserve the Brazilian Rain Forest (PPG7), a research program funded by the G7 countries, in addition to providing financial resources, also cited SLAPR as its main 'success story' (MMA, 2002: 28). Many senior officials from the federal government also openly support SLAPR. For instance, during an interview for this thesis, an ex-Minister of the Environment showed clear enthusiasm for the capabilities of GIS technology and reported that he regretted the fact that

during his time in office he was not able to expand the system to other parts of the Amazon (Interviewee #7/2007).

Even though some studies have indicated problems with SLAPR following the arrival of Bario Maggi in office (Azevedo, 2009; Lima et al., 2005a), faith in its efficiency has remained largely unshaken and even expanded since its creation. For instance, following the creation of SLAPR, the Ministry of the Environment officially adopted this system as the desired standard for the Amazon and started supporting the development of similar systems in other states. Furthermore, the implementation of systems similar to SLAPR used as a justification for the lessening of the environmental restrictions and the provision of benefits to farmers. One example of this is with *MT Legal* (State Law Nº 343/2008), a state program created in Mato Grosso that provides an amnesty on fines and allows farmers to compensate for their lack of forest in their lands by paying into a governmental fund. Similarly, the federal government created the program *Mais Ambiente* (more environment) at the end 2009, expanding the concessions allowed by *MT Legal* to all regions of Brazil (Decree Nº 7029/2009). Moreover, in parallel with the discussions of *Mais Ambiente* and *MT Legal*, the National Congress also approved a law and created the program *Terra Legal* (legal land) allowing the legalization of up to 1,500 hectares of public land illegally appropriated in the Amazon. This was done under the premise that by monitoring these properties with a GIS similar to SLAPR the government would ensure the environmental conservation of these areas.

Moreover, it was possible to observe that many senior officials from the Ministry of the Environment and SEMA still uphold high expectations in relation to SLAPR. They have pointed out that in contrast to PRODES which can only calculate the overall deforestation rates in the region SLAPR was designed to relate specific plots of land to specific landowners. In this way, SLAPR is believed to be able to control the behavior of individual farmers remotely. One of the officials from SEMA directly responsible for creating SLAPR explained the central role of GIS and satellite images in the new policy:

> The environmental law in the country concerns single properties. It is not about the Amazon, Mato Grosso or the municipality: it is about ONE property that must have 80% of the legal reserve. Now, if Brazilian law is saying what is subject to control is an individual property, I must know where it is located, otherwise I cannot control it. (Interviewee #73/2009)

The excerpt above suggests that SLAPR represents a major innovation in the way the environmental law in the Amazon is conceived and enforced. It also indicates that policy-makers from different parts of the government have very high expectations as regards the capability of GIS technology to control deforestation in the Amazon. In particular, for many senior officials, by capturing the borders of a certain property in the GIS, the control of deforestation can become almost automatic. In the words of a senior official from the federal government, "[with GIS], deforestation in these areas is going to have a name and surname. This fact certainly leads to a sensible increase in the governance capability of the environmental agencies in the states of the Amazon" (Personal communication #1/2010).

While senior officials often describe SLAPR as an efficient solution with which to control deforestation, a closer look at how SLAPR is used reveals a more complex scenario. In particular, it is possible to observe contradictions between official discourses and actual practices in relation to both the licensing of new properties for SLAPR and the monitoring and law enforcement of properties already within the system.

6.4.1 Licensing

According to the legislation of the state government of Mato Grosso, all farmers carrying out agricultural activities must register their properties in SLAPR. Within SEMA, this activity is carried out by the Forestry Management Department. Forestry management is by far the biggest and most well-resourced department within SEMA. By 2008, this department had 176 staff, a number 23% higher than the previous year and much higher than the average number of 20 staff for other departments (Micol et al., 2009). Forestry Management is also SEMA's department that is more closely watched by senior officials. The only performance indicators repeatedly mentioned by senior officials during their interviews refer to the number of applications assessed in a given year. For instance, in the context of *MT Legal* mentioned above, senior officials expect to increase the number of registered properties within SLAPR more than tenfold in one year alone (Barbant, 2009).

Despite the prevalence of official aims for the number of licenses to be issued in a given period, senior officials seem to grossly ignore the complexity and work

involved in registering a single farm at SLAPR. A closer observation of the practices behind SLAPR reveals that the inclusion of a single farm involves the creation of detailed map of the property and the provision of more than 10 different documents from almost as many different governmental bodies in order to prove the lawful ownership of the land. The licensing process then becomes even more complicated in cases where the farm has already deforested beyond its legal limit. In this case, in addition to all the maps and documents above, the engineer has to create a report explaining how the additional deforested area is going to be compensated for (i.e. through forest plantations, buying adjacent forested land or, paying into a fund).

In addition, it emerged from the interviews with bureaucrats and the observations of their work that they often have to work with farmers and external GIS experts. In theory, all communication between SEMA and the outside world should be carried out via official letters and through the training sessions on GIS. In practice, however, GIS experts and lawyers working on the behalf of farmers often call the bureaucrats in order to ask for information about the status of certain processes and to negotiate an interpretation of the law and related GIS assessments. For instance, a bureaucrat reported that until recently particular state assemblymen kept members of their staff within SEMA to work as mediators between the farmers and the bureaucrats, and to request that priority be given to particular applications from rich farmers and political allies. Because of this complexity, the licensing process takes 574 days on average to finish (Micol et al., 2009). Furthermore, despite the promises and ambitions of senior officials after six months of *MT Legal* (halfway through the program), only 870 properties were registered, this being less than 0.5% of the 140,000 expected. The following exception illustrates the complex set of practices SEMA bureaucrats have to enact in order to carry out their work:

> Despite this effort from the management to make work-flows more logic within each department, the huge number of processes scattered around the different desks, in some cases food on the tables and other non-work material gives an impression of a relaxed and relatively disorganized work site. […] From time to time, groups of employees comes by and talk informally to other groups […] Employees sit in groups of two (usually a more experienced member and a junior member) and discuss the interpretation of the law in relation to a specific licensing process. Additionally, the phone never stops ringing. Landowners, lawyers, geoprocessing technicians and even politicians often call SEMA's licensing department diectly to check the status of their process, or to ask if their processes can be speeded up. When asked about the telephone calls, a junior staff member explained: "The Secretary [of the Environment] has asked them [the deputies] to stop sending their people because it hinders our work. But in the deputy's assessor's [office] they are always calling us here to ask about the process… they really get on our nerves" (Field note #8/2008).

It is possible to notice a similar distance between the official discourse and the current practice in relation to the recruitment of farmers into SLAPR. Since the creation of SLAPR in 1999, SEMA has adopted different recruitment strategies for the system. In the first phase of SLAPR, SEMA actively invited farmers to join the system through inspection rallies. Here, SEMA rangers visited each property in turn issuing notifications, so that if the farmer did not register the property within 90 days, he would incur a fine. In this way, SEMA adopted a strategy similar to ordnance land surveys which cover specific regions in their entirety. However, different bureaucrats from SEMA reported that after the arrival of Blario Maggi in 2003, this strategy was discontinued and SEMA started to adopt a passive stance. Thus, in practice, the choice of whether to register or not was left to the farmers. Consequently, farmers now tend to join the system only when the benefit of joining SLAPR surpasses the high cost of the licensing process and the stricter governmental controls that follow. In this regard, many farmers reported in their interviews that the soybean sector is under increasing pressure to seek environmental regularization. This tendency was further reinforced following the publication of the Decree Nº 6.321/2007 denying bank credit access to properties outside SLAPR. However, in the case of cattle ranching and other activities which are less dependent on external credit and green certificates, this incentive is not as clear and farmers often prefer to remain outside the system. This suggests that SEMA is allowing farmers to balance the cost benefit of joining SLAPR, and that they consider it in practice as a sort of optional green certificate that provides access to financial credit at a lower interest rate.

There is also evidence that SEMA is allowing SLAPR to be used by farmers as a way of increasing deforestation. A GIS expert who worked on the creation of environmental licenses for SLAPR explained in an informal conversation that some farmers might only register the properties with remaining forest cover in SLAPR. In this way, large farmers can benefit from having deforestation authorization for one of their forested farms while their properties that have already been cleared remain invisible to SLAPR. Similarly, some farmers also reported that SLAPR is worthwhile mainly for the properties where there is still forest to be cleared, suggesting that in the farms already deforested it is better to do it illegally, so avoiding the control of the state. The extent of this problem was captured by Azevedo (2009) in her spatial analysis of the profile of the properties joining SLAPR between 1999 and 2006. This

analysis shows that farmers tend to deforest after their inclusion of properties in SLAPR, indicating that in many cases, farmers joined the system explicitly to obtain authorizations for legal deforestation. Furthermore, data at municipal level confirms that the farms within SLAPR are predominantly related to the soybean sector or have an extensive forest cover for which they can obtain an authorization for legal deforestation and logging. From this the study concluded that overall deforestation increased after the introduction of SLAPR, instead of being reduced as claimed by the promoters of SLAPR and other similar systems.

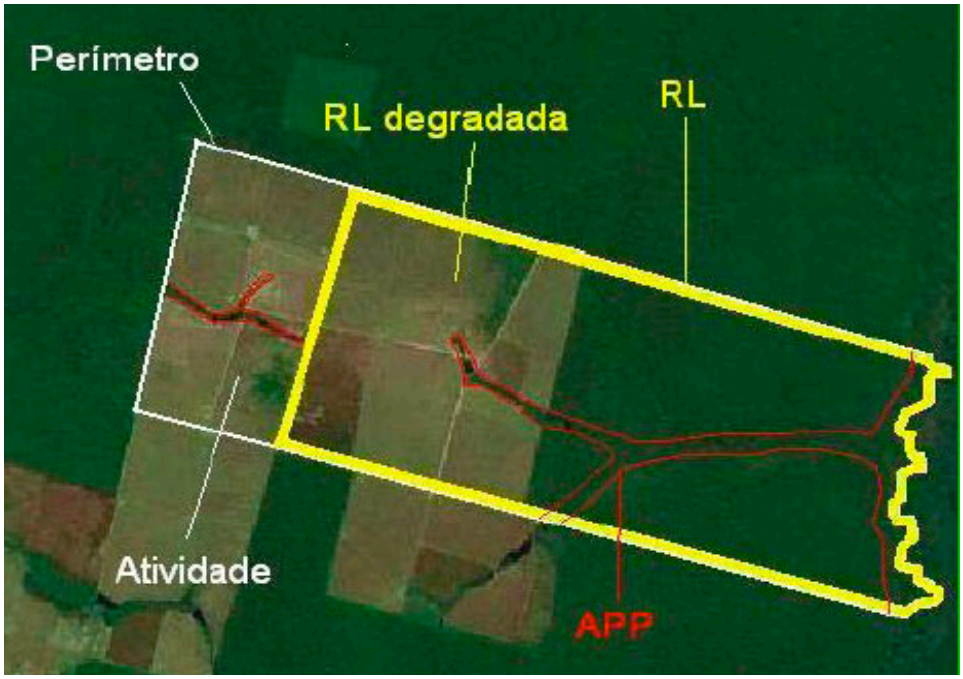

Figure 29 An example of a map annexed to a process for joining SLAPR

It was also possible to observe that the examination of registry applications by SEMA bureaucrats adopts practices that are beneficial to farmers. As mentioned above, in order to join SLAPR farmers have to hire a forestry or agricultural engineer with GIS skills to survey their property and procure the required documentation. This survey evaluates the state of the forestry cover of the property and obtains the geographical coordinates of the farm using a GPS. Following this, and using the coordinates to hand, the engineer obtains a satellite image of the property and draws its borders, watercourses as well as the forested and deforested areas using a GIS desktop application. Figure 29 provides an example of the maps created as part of the licensing process of SLAPR. The white line is the perimeter of the property, the yellow line is the minimum legal reserve (*RL*, or 80% of the property) and the red line

is the area of permanent preservation (*APP,* alongside the rivers). In this case, almost half the legal reserve of the property has been illegally deforested (*RL degradada*).

The licensing of properties also involves the close cooperation between agricultural engineers working on the behalf of farmers and bureaucrats. After carrying out the survey and collecting the relevant documents, the engineers send the full set of documents and maps to SEMA's forestry management department in printed and digital formats where it is assessed by SEMA bureaucrats. This analysis is heavily regulated by federal and state laws as well as by internal formal procedures. These regulations became particularly stringent following the corruption scandals in 2005 when more than 80 people were arrested, many of them bureaucrats from the Forestry Management Department. In their interviews senior officials from both the Ministry of the Environment and SEMA often made reference to the new regulations and improvements in the technology behind SLAPR which were intended as a warranty against corruption and to establish strict compliance with the law. In this way, senior officials suggested that for them the analysis process behind SLAPR is politically neutral and legally rigorous: an activity whose outcome can be ensured by following the regulations and using GIS technology correctly. However, a closer look at SEMA's work suggests that beneath the use of GIS and the related interpretation of the law, the state agency systematically favors the agricultural elite of the state. This bias in relation to the use of GIS has emerged in two main ways.

Figure 30 SEMA bureaucrats analyzing a property to be registered in SLAPR (left) and an environmental license with dubious classifications of pristine rainforest circled in yellow (right)

Firstly, SEMA bureaucrats tend to allow the GIS experts hired on the behalf of farmers to interpret satellite images in a biased way. While senior officials often regard satellite images as mirrors of reality, they are rarely used directly as raw data. As mentioned above and as seen in the previous chapter, for a satellite picture to become proof of deforestation, a GIS expert has to create a map-image, outlining the images of the rivers, pristine forest and deforested areas of the property. In this process, satellite images provide considerable room for different interpretations of what is forest and what is deforestation. The map-image of a SLAPR environmental license (shown on the right) in Figure 30 provides an example of this issue. In this map-image a GIS expert has drawn a line (in white) separating deforestation from pristine rainforest. The farm has three areas, however, and even though these are indicated as pristine forest, the prevalence of red tones on the satellite image indicates that the forest area might be severely degraded as a result of selective logging or the creation of new pastures.

Current and ex-officials from SEMA provided evidence of the prevalence of this practice. For instance, a GIS expert who held a senior management position at SEMA told me off the record that it is possible to "lie with satellite images [since] it is very difficult to see anything useful when the land use is fragmented". He went on to suggest that the blurriness of the satellite images in relation to the degraded or small forested areas, such as the ones adjacent to rivers, allows GIS experts to present a favorable representation of the farm in SLAPR (Interviewee #28/2008). On another occasion, I tried to confirm this matter when shadowing the work of SEMA bureaucrats analyzing satellite images. In my observation of their work, I found a dubious interpretation of a satellite image, and took the opportunity to question the bureaucrat about how he deals with the multiple interpretations of satellite images in addition to the potential bias towards farmers. He was clearly uncomfortable with the question and simply said that they rarely challenged the farmers' interpretations of the satellite images. Even though he avoided addressing the question directly, his reaction could be interpreted as confirmation of the prevalence of the practice indicated by the GIS expert mentioned above.

In addition to this, there is evidence that SEMA allows and even invites farmers to make use of multiple vegetation classification schemes in order to obtain a legal advantage during the licensing process. As mentioned in the previous chapters, the Brazilian Forestry Code establishes different percentages for the legal reserve depending on the biome where the property is located. In the case of the legal Amazon region, if the property is within the savanna biome, the farmer can obtain authorization to deforest up to 65% of his or her property, but if it is in the rainforest biome, only 20% can be deforested. The distinction between what is rainforest and what is savanna is extremely controversial, both scientifically and legally, especially in the areas where the two types of biome are in contact with each other. Following the demands of farmers living in regions where the savanna meets the rainforest, the state of Mato Grosso approved a state law creating the notion of 'transition forest' which allows deforestation of up to 50% (State Law 38/1995). In this way, all the farms near the savanna (which otherwise would be considered rainforest) were able to legally increase their deforested areas. This legislation raised concerns in the federal government, which saw the practice as an explicit attempt to distort the Forestry Code in favor of local farmers. Nonetheless, SEMA used this legislation as the basis for many of its environmental licenses issued through SLAPR until 2005, when a judicial ruling in a process initiated by the Ministry of the Environment decided that the idea of 'transition forest' was unlawful and the state law had to be revoked. The law was repealed but all the licenses issued using the old classification were maintained.

Even after the rejection the notion of 'transition forests', it was possible to observe the emergence of other ways in which farmers were able to achieve more advantageous classifications for individual properties within SLAPR. One of the main challenges in defining savanna and rainforest, as required by the Forestry Code, is drawing the imaginary line that divides the two biomes. The Brazilian Institute for Geography and Statistics (IBGE) has published a map to show this distinction on a scale of 1:1,000,000 which has been used as the *de facto* standard at federal level (see hatched shading in Figure 31). In addition to IBGE's classification, the project RADAM (mentioned in Chapter 4) also generated a second map with a much greater level of detail and on a scale of 1:25,000 in order to be used for planning and scientific purposes.

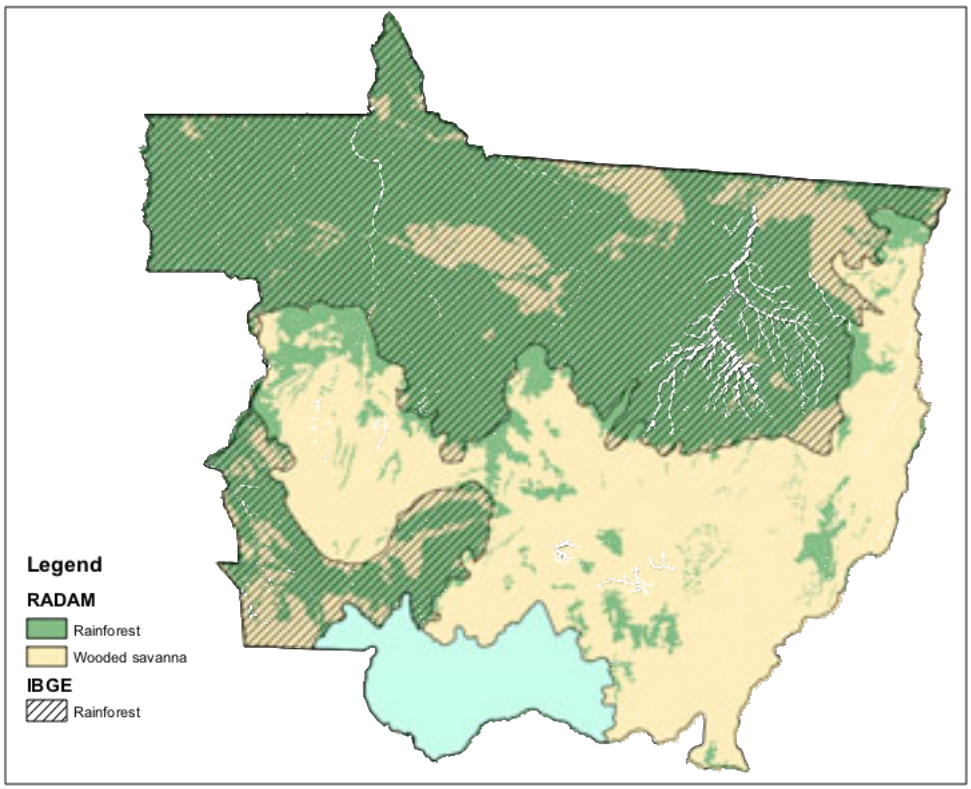

Figure 31 IBGE and RADAM classifications of the types of biome in the state of Mato Grosso

Different GIS experts and SEMA bureaucrats explained that the GIS experts working on the behalf of farmers started to use these two maps interchangeably, depending on the map that would 'place' the farm outside the rainforest (thereby increasing the deforestation area). They also explained that even in cases when the individual farm does not fall within an advantageous classification, the farmer can still hire an agricultural engineer or biologist to carry out a study in the farm which legally establishes that the local vegetation is not rainforest. However, some IBAMA rangers explained that these studies are often deceptive because the repeated burning of dense rainforest may result in the area giving the appearance of savanna after some years. When questioned about this issue in their interviews, senior SEMA officials claimed that they allow the use of RADAM's maps because those of IBGE were on too large a scale to be able to distinguish individual properties. Other officials explained that the law makes the distinction between the 'physiognomy' of vegetation and not the broad biome defined by maps. Hence, what is important for environmental law is the external aspect of the vegetation in a specific property and not the map. Because of this, the law can only obtain definitive answers after local inspections. Nonetheless, the above suggests that SEMA has implicitly allowed farmers with more financial

resources to obtain environmental licenses which enable them to deforest more land than their less well-off neighboring farmers.

6.4.2 Monitoring and punishing farmers

Following the registration of properties with SLAPR the next crucial stage is the monitoring of the farmers within SLAPR. However, despite the importance of this activity for the functioning of SLAPR, there is evidence that this is not being carried out as suggested by senior officials. As mentioned above, in order to obtain the environmental license and join SLAPR, the farmers who have deforested more than the percentage allowed by the law must compromise to reforest their properties. Since the full deforestation of a farm can take up to 30 years, and particularly in the initial stages cannot be observed from satellite images, the only way to check if the farmers are respecting their compromises is to carry out inspections *in situ*. At SEMA this work is the responsibility of a group of officials within the Department of Biodiversity. While senior officials were very vague when asked about this activity, according to a lower ranking official from this department, this type of control is being carried out very rarely (see also Micol et al., 2009: 17).

According to the official description of SLAPR, SEMA also monitors farmers using GIS in order to identify new deforestation in the properties within the system. This is done by comparing the Landsat satellite images of the whole state with the images of the same locations obtained in the previous year. Then, by superimposing the detected deforestation with the borders of the properties in SLAPR, the names of the farmers who have deforested emerge. If it is found that these properties have deforested more than the area authorized or have deforested in their legal reserves (hence illegally), SEMA can issue a fine and revoke the property's environmental license. This particular type of monitoring was one of the most publicized aspects of SLAPR and for most senior officials this type of remote control over the farmers justified SEMA's softer approach and related legal concessions.

The observation of SEMA practices suggests that there are also serious issues with this type of monitoring. Firstly, in order to facilitate such a procedure, it is necessary not only to analyze the satellite images and identify the new deforestation in the rainforest but also to do this in the savanna and wetlands in southern part of the state (which are not covered by INPE's GIS). From the interviews with officials from this

department as well as from other documents, it has emerged that SEMA has not been carrying out this activity on a yearly basis, as some senior officials have affirmed. For instance, between 2006 and 2007, SEMA did not undertake monitoring for new deforestation, having at its disposal only the data from 2005 (Azevedo, 2009: 222). Furthermore, even though in 2008 SEMA finally completed the monitoring for these two years, this problem occurred again and by the beginning of 2009 SEMA had still not initiated the monitoring of 2008. This meant that all the deforestation occurring in the southern portion of Mato Grosso remained invisible for at least two years, and thus was not controlled by SEMA.

More worryingly still is the evidence that even when the satellite monitoring data is available, SEMA does not always punish farmers as expected. This issue first emerged in an interview with a SEMA forest ranger who explained that following fieldwork inspections they apply fines not only for properties outside the system, but also to the ones inside SLAPR. This puzzled me since, in theory, SEMA does not need to actually visit farms within SLAPR in order to issue fines for large deforestation. However, when questioned about this, the ranger replied: "I don't know if applying fines which are only based on satellite pictures has a judicial validity; that is why we like to check the points with the helicopter" (Interviewee #73/2009). Therefore, in order to obtain further empirical confirmation of this issue, I attempted to replicate the same GIS-based practices necessary to identify illegal deforestation remotely. Firstly, I crossed the deforestation polygons detected by SEMA's *Dinâmica do Desmatamento* for the year 2007 with the legal reserves of the properties within SLAPR which were obtained from SEMA in 2009. Here it emerged that from the total deforestation that took place in the region in 2008, a substantial 7% has taken place within the legal reserves of the properties within SLAPR[5]. This amounts to 39,363 ha, or more than three times the area of the city of Manchester (for a similar result see Azevedo, 2009: 194). This analysis also showed that in most cases deforestation polygons were inferior to 10 ha, and were relatively small by Amazonian standards. Nonetheless, it appears that even some large deforested areas have remained uninspected. By crossing-checking the five largest clearings (i.e. ranging from 600

[5] These calculations were achieved using ArcGIS, the same GIS software application used by SEMA and IBAMA. The georeferred data was based on the geographical coordinates GCS South American 1969 and the area was calculated based on the Lambert conformal conic projection.

and 2,600 ha) with the list of fines issued by SEMA in 2007 and 2008 it emerged that in only one case did SEMA issue a fine, suggesting that the other four farmers continued to deforest with impunity. While it is still impossible to determine with certainty why SEMA is neglecting to monitor the properties within SLAPR as it should, the details above suggest that SLAPR is working to the advantage of the farmers. Hence, the farmers that decide to register with SLAPR have the economic benefits of being within the system, such as having loans with lower interest, while still avoiding the tough environmental controls promised by SEMA senior officials to the federal government.

Notwithstanding all the issues identified above, it emerged from the interviews with the IBAMA rangers that SEMA's environmental licenses are still accepted without problem by other groups, despite the practices of SEMA described above. As mentioned in the previous chapter, IBAMA asks farmers to show their SEMA environmental licenses in order to ascertain if any given deforestation is legal or not. Here, some rangers reported that they find it odd when some farms have 35% or 50% of legal reserve even though the properties appear to be clearly within the rainforest and thus should have 80% of legal reserve. However, they indicated that they rarely challenge SEMA's documents by examining, for instance, the evidence behind the licenses and their related classifications. Other rangers even reported that they tend to filter out the farms which have an environmental license from their law enforcement missions since these properties should be under the watch of SEMA. This suggests that SEMA's SLAPR and related environmental licenses are still largely regarded as trustworthy, and therefore are deemed politically neutral for legal purposes.

6.5 Political conflicts in SEMA

It is beyond the scope of this research to establish whether or not SEMA is interpreting environmental law and using GIS 'correctly' from a legal or scientific point of view. Nonetheless, it is possible to relate many of the positions adopted by SEMA to an ongoing political struggle taking place within the agency. Some senior officials from SEMA revealed in off the record conversations that they sometimes feel there is an ongoing conspiracy against Mato Grosso; the United States and Europe would lose important markets if Mato Grosso emerged as a 'global farm' and for this reason they conspire with the INPE and the Ministry of the Environment to

'invent' theories such as those linking deforestation to global warming. These officials also repeatedly indicated that Mato Grosso and other states in the Amazon are being unfairly accused of being environmental villains. They explained that both Europe and southern Brazil have deforested most of their lands, and therefore they cannot pretend to be well-behaved citizens and attack Mato Grosso. While SEMA senior officials did not explicitly refer to the issues mentioned above, they hinted that bending the rules and using GIS to benefit farmers was a way of correcting the tendency of the federal government to punish Mato Grosso unfairly.

Many SEMA officials at lower ranks, however, do not share the beliefs of their superiors. In particular, bureaucrats, forest rangers, managers, technicians and other civil servants complained that SEMA is 'too political' and not sufficiently 'technical'. Hence, in their view, the fact that senior officials have been appointed for mainly political reasons places SEMA in the hands of local farmers. From this they argued that if instead of political appointees, career civil servant experts in ecology were part of the leadership of SEMA the agency would be working for the benefit of the state's environment rather than local farmers. As evidence of that the lower ranking officials pointed out that the many limitations imposed by SEMA on their work has political motivations. For instance, in pondering on the limited provision of allowances, the lack of computers and GPS devices a SEMA ranger concluded: "I don't believe the state is interested in our work being 100% efficient" (Interviewee #58/2009). Other low ranking officials also indicated that they disagreed with the strategy of particular senior officials to challenge DETER's data. For them, even though INPE might have wrongly classified some areas as deforestation, the institute was right in pointing out the overall increase.

Even though the strategy of SEMA's senior officials to align themselves with the interests of the farmers is returned in terms of their political support for the state government, this stance is also creating internal and external problems. Internally, low ranking officials are showing growing frustration with the influence of politics within SEMA's internal affairs. For instance, an ecologist who has worked in SEMA for more than 10 years reported that she sometimes feels her hard work is in vain because the government is more interested in hearing the voice of FAMATO (a farming lobby) and local politicians than environmental experts. The same frustration emerged in a surprisingly frank conversation with a middle-ranking official from SEMA in the

context of a policy-making meeting. As part of my involvement in a project of the United Nations Development Program (UNDP), I explained to a group of officials and GIS experts from SEMA that the preliminary results of my research indicated that the farmers were using SLAPR for their own benefits. I therefore suggested that a comprehensive registering strategy for the new *MT Legal* was needed in other to ensure better deforestation control. At this point a middle-ranking official declared: "everybody knows that helping farmers get their green certificates is the whole point of SLAPR and MT Legal, not reducing deforestation". Since nobody denied her claim, this silently confirmed that she might be right in her assessment. Furthermore, it was clear from the expressions of consternation on the faces of the other four SEMA officials and a representative from the logging industry sitting in our discussion group that her statement reflected some ongoing tensions within SEMA (Field note #23/2009).

SEMA's political stance is also creating tensions between the agency and IBAMA. A point that emerged from the observation of SEMA's and IBAMA's practices is how disconnected these two agencies are. In particular, it emerged that issues such as the duplication of work (i.e. two fines for the same deforestation) and conflicts over the interpretation of legal texts are common. However, when some IBAMA officials were asked why they do not increase their cooperation with SEMA, they replied that it was impossible because they do not 'trust' SEMA. For instance, a local IBAMA manager explained that "in contrast to São Paulo's environmental state agency SEMA is not consolidated because its behavior clearly varies according to the political context" (Interviewee #40/2008). Another IBAMA local manager was even more explicit in his doubts about SEMA's honesty: "we do not communicate with SEMA. I have tried to make joint actions, but without success. I believe the reason for that is that the state level agencies give insider's information to farmers and jeopardize the missions" (Interviewee #41/2008). These and other statements from SEMA and IBAMA officials suggest that this political tension and the inability of some senior officials in the federal government to see how SLAPR is actually being used are hindering the ability of these two institutions to cooperate and improve the enforcement of environmental law in the region.

It should not come as a surprise that groups linked to different historic, economic and social contexts have developed opposing views about the Amazon and the role of the

government in it. Furthermore, in Brazil as in many other democracies, people are free to express their views and hold different beliefs. What is worrying about the situation found in SEMA and other parts of the government is that these groups rarely have the opportunity to debate their views openly or to eventually reach some form of consensus around basic issues. It is possible to identify different reasons for this. Firstly, with some rare exceptions (such as the meeting reported above) the policy towards the Amazon tends to be debated in politically homogeneous silos. Hence, it is normally the case that SEMA senior officials and Mato Grosso politicians, on the one hand, and officials from IBAMA and the Ministry of the Environment on the other, only meet among themselves and thereby avoid having their views aired by others outside these groups. Secondly, it is often the case that the members from one group see the voice from other political groups as being inherently illegitimate in other groups. The idea, reported by one SEMA official, that global warming is a hoax is an example of this. However, the opposite has also taken place since IBAMA officials and INPE officials rarely take the views from SEMA officials and local farmers seriously. Sometimes these groups even deny the relevance of the voice of other groups. For instance, while presenting elements of this research to a group of officials from the Ministry of the Environment in a seminar held in the United Nations headquarters in Brasília, a policy consultant questioned my emphasis on the views of local farmers, suggesting that these actors do not deserve attention but rather the full weight of the law (Field note #24/2009).

6.6 Summary and final remarks

This chapter explored the work practices of SEMA as regards the enforcement of the deforestation control policy in the Amazon. It emerged that senior officials from SEMA and the federal government have high expectations concerning the ability of GIS to control deforestation in the region. In particular, SLAPR is widely regarded as the best practice for deforestation control and it is considered that the use of this technology should be replicated in the other states of the Amazon. In fact, it was possible to observe that GIS has provided important opportunities for managers to coordinate forest rangers in the execution of law enforcement missions. It also facilitated the cooperation between bureaucrats, agricultural engineers, farmers and lawyers during the analysis of the SLAPR licenses.

A closer examination of SEMA's practices also revealed that the use of GIS by the state agency diverges from the accounts of senior officials in a variety of ways. As observed above, senior officials have suggested that GIS should be used to carry out 'real-time' law enforcement and to issue fines remotely, without the need to conduct inspections *in loco*. Furthermore, these officials proposed ambitious targets to increase the number of properties in SLAPR, suggesting that the analysis process conducted by SEMA bureaucrats could be done quickly and without difficulty. However, as with IBAMA, the interviews with forest rangers and the observation of the work of the bureaucrats revealed that the working conditions in the Amazon and the legal requirements faced by rangers and bureaucrats render the expectations of senior officials infeasible in practice.

More significantly, it has emerged that SEMA's law enforcement practices and the related use of GIS are deeply embedded in a political struggle within SEMA and between the state and federal government. In particular, it was noticeable that SEMA tends to benefit famers by: limiting the resources available to forest rangers with which they can carry out their work; adopting a 'softer' legal framework while prosecuting deforestation; allowing farmers to choose whether to register in SLAPR or not; and monitoring farmers within SLAPR irregularly. It is difficult to determine if these practices have emerged organically or are part of a master plan from SEMA senior officials aimed at obtaining the benefits of an 'environmentally friendly' state government while avoiding the imposition of heavy restrictions to the most important part of its economy. Regardless of the reasons for this, interviews with SEMA and IBAMA officials at different levels reveal that they see themselves as being part of a political struggle between those supporting the expansion of the agricultural frontier of the state and those concerned with the environmental consequences of deforestation. This suggests that the use of GIS within SEMA should not be viewed separately from the recent colonization history of Mato Grosso and the central role of big farmers in the political context of the state.

Chapter 7: Objectification, blinding and joint work across boundaries

7.1 Introduction

After spending one year in Brazil, and talking to and observing the practices of scientists, senior officials, rangers, bureaucrats, among other groups, I returned to Lancaster puzzled with what I had seen in the field. On the one hand, it became clear that GIS has brought major improvements to the way the Brazilian government controls deforestation in the Amazon. The literature contains many examples where claims of a 'successful' introduction of GIS were not matched by the observation of how the technology is actually used (e.g. Campbell et al., 1995). In the case of the Amazon, however, it was possible to observe that GIS technology is in fact being used intensively by groups ranging from policy-makers in Brasília down to forest rangers working in the Amazon. Furthermore, it became apparent that these different groups are increasingly relying on GIS in order to work together in the elaboration and enforcement of deforestation control policies in the region, especially in situations involving coordination and cooperation at a distance. Thus, it seems justified the consensus among the different parts of the government that GIS is a force for good and the use of which should be encouraged and expanded.

On the other hand, it also became apparent that there is a growing tension between the different groups working in the Amazon. A close examination of law enforcement in the Amazon revealed that this involves the crossing of many 'boundaries', namely, relations of difference and sameness across social groups. In particular, it emerged that the enforcement and formulation of policies towards the Amazon takes place within a set of: 1) occupational boundaries, these being the local bodies of knowledge of professional groups or 'communities of practice' such as senior officials, forest rangers and attorneys; 2) spatial boundaries, namely the different geographical locations from which these groups operate (i.e. Brasília, Cuiabá, São José dos Campos…); 3) political boundaries, these being the positioning of these groups within different agendas. Moreover, since many work practices are initiated within a specific set of boundaries (i.e. a scientist detecting deforestation at INPE), and concluded

within another (i.e. a ranger issuing a fine in the Amazon), the groups described above often have to face the daunting task of working across these boundaries and in territories that are unfamiliar to them. Furthermore, even though joint work across boundaries has become common, the groups involved find it increasingly difficult to work together effectively. Thus, while senior officials and scientists criticize forest rangers and bureaucrats for being inefficient, stubborn or even corrupt, the latter often complain that they feel undervalued by the higher levels of the government. Consequently, while deforestation in the Amazon has decreased in the past decades, the strikes from IBAMA rangers in 2009 and the increasing levels of deforestation at the end of 2010 suggest that if the current situation remains as it is the long-term preservation of the Amazon rainforest may be at risk.

The theoretical notions introduced in Chapter 2 provide an important base for exploring these contradictory findings. In particular, the notion of boundary objects helps to explain how GIS technology has offered important opportunities for working across spatial, occupational and political boundaries (Star and Griemeser, 1989; Star, 2010). Similarly, the discussion on the social implications of objectification and the limitations of instrumental forms of joint work provide the elements with which to analyze the tensions that may emerge from the shared use of GIS in the Amazon (Heckscher et al., 2006; Pickles, 1995b). Drawing upon these notions, the remainder of this chapter revisits the empirical material presented above in order to answer the three research questions established at the beginning of this thesis and the related contradictions. Specifically, the next section explores the history of the Amazon in order to understand the process that led the establishment of GIS as a boundary object. This initial step is important because it provides insights into the design of GIS and the historical roots of the tensions related to the joint work in the Amazon. The third section of the chapter deals more directly with the contradictory effect of GIS by analyzing IBAMA and SEMA practices. This section opens with a discussion about the ways in which GIS facilitates joint work and then analyzes the circumstances under which GIS may hinder it. Based on this discussion, the last section provides suggestions about how the government could improve its policy-making and law-enforcement practices in the Amazon.

7.2 The establishment of GIS in the Amazon

This section analyzes the historic trajectory of GIS in the Amazon in order to elucidate why GIS became a central boundary object while others artifacts failed to do so. By doing so, this section also intends to expose the root causes of some of the current issues facing the Brazilian government in the region. As a starting point to this analysis, it is important to highlight the remarkable diffusion of this technology over the last four decades. At first the use of GIS technology in Brazil was largely limited to scientists working at INPE and FAO and senior officials planning and monitoring colonization projects in the Amazon. From the 1980s onwards, however, an increasing number of 'green' scientists concerned with the ongoing deforestation of the Amazon started adopting this technology. Then, after a timid start during the 1990s, the use of GIS also became central to the lobbying strategies of environmental NGOs and other groups attempting to influence polices towards the Amazon. Simultaneously, the use of GIS also became commonplace in the law enforcement activities carried out by bureaucrats and forest rangers working in the Amazon (see Figure 32).

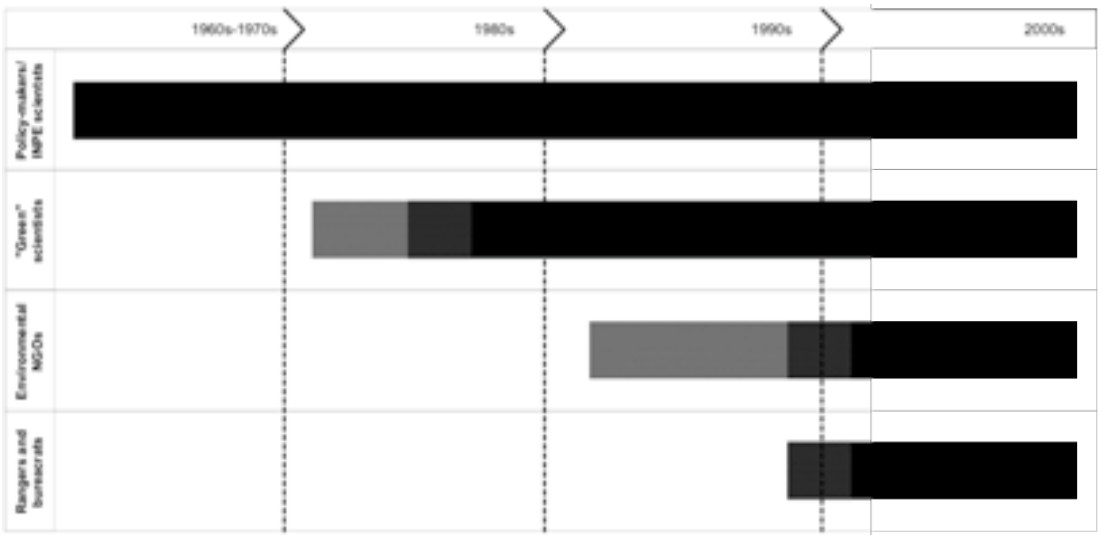

Figure 32 Diffusion of GIS in Brazil between the 1960s and the 2000s. Solid bars indicate established usage of GIS, while gray bars indicate initial usage

During the same period, the Brazilian government also oversaw the diffusion of other technologies, such as computers, the Internet and various types of information systems (e.g. accounting, web browsers, voice-over-ip). It is possible to note, however, that the diffusion of GIS has important similarities and differences from the diffusion of these other technological artifacts. On the one hand, their forms of

diffusion were similar because they involved the spread of technological artifacts in different social contexts and their tailoring to suit the local needs of the different groups using them. On the other hand, with GIS it is possible to observe not only the emergence of local uses within specific contexts but also shared uses across boundaries. Hence, GIS was used not only in local work practices, but also took the role of a boundary object, this being implicated in joint work practices involving multiple groups. It was possible to observe that the establishment of GIS as a boundary object was closely related to three aspects of the development and use of this technology: political flexibility, negotiation and epistemological affinity.

7.2.1 Political flexibility

The first aspect that helps to explain the establishment of GIS as a boundary object in the Amazon was the manner in which this technology adapted itself to different political contexts. Figure 32 lists the use of GIS by governmental officials, 'green' scientists, environmental NGOs, rangers and bureaucrats working in the Amazon. In addition to the more obvious differences between these groups in relation to their organizational affiliations (i.e. INPE, Ministry of Environment, IBAMA, etc…) and roles within the government (i.e. research, policy-making, law enforcement), it is also possible to note that these groups have also different work and information needs. For instance, in the 1970s the central government needed technology to help them plan the colonization of the Amazon, while in 1980s scientists required a technology capable of measuring the effects of deforestation in a holistic way.

It is important to note, however, that the information and work needs of these different groups were closely related to their political positions. For instance, the use of GIS in the 1970s to survey the natural resources of the Amazon and to monitor the execution of colonization projects in the Amazon was not only aimed at carrying out these activities more efficiently, but also at providing political support for the developmentalist agenda of the government in the region. Similarly, 'green' scientists and NGO activists used GIS in the 1980s not only to produce scientific publications but also to foster the conservationist agenda in the Amazon.

This close relation between information and work needs as well as political affiliations is still present in the Amazon. While IBAMA uses GIS to punish farmers as heavily as possible, SEMA adopts a softer stance requesting farmers to register at

SLAPR rather than applying heavy fines. The friendlier approach of SEMA can also be seen in the adoption of a passive stance towards the enforcement of the obligation of registering at SLAPR, the lack of constant GIS-based monitoring and the acceptance of biased interpretations of satellite images in addition to the use of GIS-based classification maps of vegetation physiognomy (i.e. rainforest *vs* savanna) more favorable to the farmers. Therefore, the use of GIS by SEMA tends to give the farmers the benefits of having an environmental license (i.e. access to markets and lower interest loans) while downplaying its negative sides (i.e. effective control at a distance, the payment of fines and embargoes).

Clearly, it was not always the case that the political intentions behind the adoption of GIS were realized in practice. GIS has been an unruly technology whose implications change as the social context in which it is used is transformed over time and space. Hence, for example, while the federal government initially developed PRODES to defend itself against criticism as regards its colonization policies, during the 1990s the deforestation figures provided by this GIS ended up supporting the formulation of environmental protection policies. This indicates that rather than GIS being a deterministic technology following the aims of its designers, it is often reshaped by an ever-changing social context. Nonetheless, it emerged from interviews with senior officials that GIS has often been understood as a technology that can be shaped without problem according to individual aims. For instance, some senior officials at SEMA recognized that SLAPR was developed with the intention of helping Mato Grosso's agricultural sector face the growing national and international pressure for the preservation of the rainforest. This suggest thats some groups not only adopted GIS to suit their own work needs, but often carried this out by considering GIS as a potential political resource for their own agendas. In this way, GIS appeared to them as an interesting technology from a political point of view, despite how it was being used by opposing groups.

As pointed out in Chapter 2, the literature analyzing the relationship between social contexts and GIS implementations highlights that GIS, like other technological artifacts, should be understood as being interpretively flexible (Pinch et al., 1984; Sahay et al., 1996). Through developing this idea further, it is possible to say that GIS in the Amazon has been politically flexible, that is, able to be reconfigured to support the political agendas of different or even opposing groups. Here, the relationship

between political flexibility and the acceptance of GIS across boundaries also suggests the importance of observing not only the information and work needs, but also the way the groups tailor the technology in order to suit their political needs across different parts of the Amazon.

7.2.2 Negotiation

The second aspect that helps to explain the establishment of GIS as a boundary object concerns the willingness of the groups using this technology to negotiate common uses across boundaries. The history of GIS in the Amazon revealed that there have been conflicts concerning the 'correct' use of GIS at different moments in the last decades. At the end of the 1980s when INPE and FAO insisted that deforestation was low and used GIS data as irrefutable proof of this, scientists such as Fearnside and Mahar used the same GIS data to argue that the opposite was so and to show that in fact deforestation was increasing at an exponential rate. At the same time, INPE was also the target of criticism from different scientists for not including in its total deforestation estimates the clearing that took place before the 1970s. Similarly, in 2008 some SEMA officials challenged the deforestation data produced by INPE maintaining that the functioning of DETER was not consistent and presented many false positives.

In both cases, however, the groups involved in the conflict were willing to negotiate joint technical solutions. In relation to the conflict at the end of the 1980s, after a few years of reluctance, INPE scientists started to produce joint research articles with their former critics and developed a new official GIS-based deforestation estimate that included portions of old deforestation. A similar result also emerged from the more recent conflicts. After a few months of debate INPE made clear in its official methodology that DETER detected not only 'clear cut' deforestation (i.e. the traditional classification) but also 'forest degradation' at different stages. From this, INPE started to differentiate in its monthly deforestation rates the proportion of these two types of deforestation in order to prevent its data from being wrongly interpreted by policy-makers. Moreover, in the end of these negotiation processes there was the emergence of a settlement whereby these different groups (re)started using INPE's GIS as a 'taken-for-granted mirror' of the Amazon, namely, a trusted common ground for the creation of policies and enforcement strategies. It is difficult to determine what

would have happened if INPE scientists had ignored these groups and refused to negotiate, but it is likely that GIS would have continued to be the focus of conflict between the groups, rather than a common starting point for joint work practices. In other words, it is likely that the lack of negotiation would have prevented the emergence of GIS as a boundary object with a shared use across boundaries.

These finding reflect other studies that point to the role of negotiation in the diffusion of GIS (Elwood, 2008; Georgiadou et al., 2005) as well as the establishment of boundary objects (Harvey et al., 1998; Levina et al., 2005). However, a point that distinguishes the history of GIS in the Amazon from other cases is the temporary and incomplete character of the process of negotiation that it entailed. Here, the negotiations were incomplete since in both the cases reported above INPE ignored some important demands from both Fearnside (e.g. the recognition of deforestation rates as exponential) and SEMA (e.g. to stop publishing DETER's data). Furthermore, even though INPE's data is publicly acclaimed as being reliable and is used by a wide variety of groups, privately some members of these groups have cast some doubts on this status. For instance, particular SEMA senior officials privately reported their suspicions that INPE may periodically overestimate deforestation rates from which the environmentalist agenda may explicitly benefit. The negotiation process was also temporary since the settlements reached in the early 1990s did not prevent SEMA from raising similar issues in 2008. This suggests that the importance of negotiation when establishing GIS as a boundary object in the Amazon resides more in the openness of different groups to negotiate and reach temporary agreements than in the achievement of a stable consensus for specific uses of GIS. Therefore, in line with Star (2010), this finding confirms that the establishment of GIS as a boundary object in the Amazon did not require consensus in order to be accepted across boundaries – something that would be impossible given the stark political differences found in the region.

7.2.3 Epistemological affinity

The third aspect that helps to explain the establishment of GIS as a boundary object in the Amazon concerns the affinity between the values embedded in this technology and the historical values behind the formation of the Brazilian government. Due to its origins in disciplines such as computer science and quantitative geography GIS is

closely related to the positivist epistemological stance. Hence, GIS technology not only represents the world, as a hand-written map would do, but also accomplishes this feat in a way that is generally considered scientifically rigorous and thus neutral and accurate. At different points in the history of the Amazon it was possible to observe that this aspect of GIS was a key point of attraction for the establishment of this technology.

By examining the historical *longue durée* of the Amazon it was possible to notice how French positivist ideals and other related high-modernist ideals have had a strong influence on the formation of the Brazilian government. These ideals were particularly central to the military regime given its emphasis on the need to govern the country in a rational and corrupt-free way. The introduction of GIS in the Amazon was specifically intended to realize these intentions. In particular, through the use of detailed maps with the locations of natural resources, which were provided by RADAM and other GIS-based projects, the military rulers were able to trace roads, decide the location of rural settlements and establish other colonization projects in a way that fulfilled their expectations of how proper planning should be done. Furthermore, thanks to the deforestation estimates for the whole of the Amazon and for the individually subsidized projects provided by GIS, the military were able to obtain hard evidence to demonstrate that their plans were being carried out as intended, so avoiding the need for local inspections by potentially corrupt officials.

The values embedded in GIS also help to explain why the calls to save the rainforest based on this technology were only taken seriously by the Brazilian government from the 1980s onwards. The first demands to save the rainforest (that emerged in the 1970s) were based on anthropological accounts and studies in biology focusing only on a specific patch of forest or population. The limited scope of these studies in addition to the diffidence towards studies produced by social scientists may help to explain why these types of projects failed to act as a bridge between the government and other groups worried with the consequences of deforestation. When the scientists and activists concerned with the Amazon embraced GIS in the 1980s and 1990s it was possible to observe a sensible increase in their influence in policy-making. Hence, even though this process was marked by conflicts surrounding the scientific rigor of some deforestation estimates from the INPE and competing institutions, the central government nonetheless found it much more difficult to dismiss as ‘exaggerated’ the

evidence provided by GIS in the same way as with other types of accounts. This can be explained when taking into consideration the fact that by criticizing GIS the government would also be indirectly criticizing its own historical allegiance to the positivist epistemology.

Many studies concerning GIS have highlighted how the values embedded in this technology may be at odds with the social context of developing countries, and in this way contribute to its failure (Barrett et al., 2001; Miscione, 2007; Pickles, 2004; Puri, 2007; Walsham et al., 1999). In contrast, the findings presented above suggest that the presence of an epistemological affinity between GIS technology and the expectations of the Brazilian government as well as many other groups involved in the formulation and enforcement of governmental policies in the region. This does not mean, however, that the social context of the Amazon is similar to the ones found in the USA and Europe, the places where GIS was initially conceived. Brazil, as India and other developing countries, is host a wide variety of populations, many of which contain local bodies of knowledge that are substantially different from the perspectives embedded in GIS (Miscione, 2007). Thus the difference in Brazil in relation to these places seems to lie in the force that historically established positivist values have had at the higher levels of the government and its ability to outmatch local alternatives such as local references of space. This conclusion also suggests that the establishment of GIS as a boundary object in the Amazon not only involved the more recent events following the introduction of this technology in the 1970s, but also the broader historical context in which it was inserted.

At this point it is possible to come back to the first research question that motivated this thesis. The accounts from officials and the current literature on GIS often imply that the establishment of this technology as common ground for policy-making and law enforcement in the Amazon is due to its technical superiority. In particular GIS is described as a cost-effective way to monitor the whole Amazon, a feat that would be impossible to achieve on the ground (Câmara et al., 2009; Fuller, 2006; Macedo, 2007). While this point is certainly valid, the technical side of GIS alone cannot explain the enthusiastic embracing of this technology in Brazil when this did not occur with other types of artifacts.

Here, it was possible to observe that the emergence of GIS as a boundary object occurred in relation to a combination of aspects which go beyond the immediate use of GIS. The political flexibility of GIS can be regarded as the main aspect of this technology which allowed its widespread use across a wide variety of groups and political agendas. However, this tailoring of GIS often creates conflicts, since groups across the political spectrum are expected to jointly use particular aspects of GIS, such as the deforestation data provided by PRODES. In this context, it was possible to observe how the negotiated aspect of the establishment of GIS played an important role in allowing the resolution of particular political tensions emerging from the different uses of this system. At the same time, the epistemological affinity between GIS and most groups involved in the formulation and enforcement of policies towards the Amazon has contributed to the maintenance of cohesion around the use of this technology in Brazil as well as a predisposition to accept it across boundaries. The discussion of how GIS became a boundary object in the Amazon not only illuminate the history of the region but also contains elements that help to explain the current dynamics of this technology. Consequently, it is to this aspect that we now turn our attention in the next section.

7.3 GIS and joint work in the Amazon

This section endeavors to answer the second research question of the thesis, namely how IBAMA rangers and SEMA bureaucrats and rangers in Mato Grosso use GIS to enforce the deforestation control policy towards the Amazon. As mentioned above, the enforcement of environmental policy involves a set of practices taking place across political, occupational and spatial boundaries. Here, a useful way to conceptualize the current role of GIS in the Amazon is to consider it as a boundary object that facilitates or hinders joint work across these boundaries. Thus, it is important to understand which aspects of the use of GIS allow this technology to assume the role of a boundary object and what the implications of this process for joint work practices are.

This section argues that the process of objectification is crucial for understanding of the current role of GIS as a boundary object in practice in the Amazon. As explained in Chapter 2, objectification is the process whereby complex social phenomena (e.g. the colonization of the Amazon, environmental behavior), physical environment (e.g.

patches of rainforest) and subjects (e.g. farmers, native Indians, forest rangers) are transformed into data objects stored in the GIS. Therefore, for instance, the farmer and his farm are objectified into a GIS-based fine with artificial lines dividing pristine forest from deforestation and the 'legal' from the 'illegal'. In a similar way, the ongoing colonization of the Amazon are transformed into deforestation rates and 'points of deforestation' on the computer screens of senior officials and forest rangers. To explain how this process is related to joint work the next subsection analyzes how GIS has facilitated the emergence of particular forms of cooperation and coordination, and in this way brought about joint work across boundaries. The second subsection considers the negative side of this process, highlighting the negative effects relating to an overemphasis on GIS. Following this, the final subsection discusses these opposing sides together in order to address the second research question of this thesis.

7.3.1 Objectification and boundary crossing

Objectification is intimately related to a process of simplification. It would be infeasible to develop a form of GIS able to capture all aspects of the Amazon social space. Therefore, to make the Amazon 'fit' into the GIS, particular aspects of the region are selected for objectification while others are ignored. As will be seen in the next subsection, this process has important drawbacks. Nonetheless, it is important to recognize that the process of objectification has also enabled important forms of joint work across boundaries in the Amazon. In particular, the findings of this study suggest that the GIS-induced objectification has provided opportunities for coordination and cooperation across occupational, spatial and political spheres in at least three ways.

Scalability and occupational boundaries

The first way GIS facilitates joint work across boundaries is by allowing the creation of objectifications of the Amazon at different scales. From the case study, it is possible to observe the existence of different occupational boundaries dividing the groups involved in the formulation and enforcement of the policy in the Amazon. These include, for instance, forest rangers, bureaucrats, scientists, attorneys and senior officials. Even though these professionals may work in the same location and are affiliated to the same organization, they work in a labor regime where they only perform the practices relating to their communities. Thus, attorneys and GIS experts

working within the same environmental agency draw upon very distinctive knowledge bodies (i.e. legislation *vs* remote sensing methodologies), disciplines (i.e. law *vs* quantitative geography) and enact different practices (i.e. analyzing documents *vs* interpreting satellite images).

Another important difference between the occupational groups operating in the Amazon is the scale of their work. For example, while senior officials in Brasília operate mainly on a national scale, local IBAMA rangers often deal with single properties while issuing fines. For this reason, these groups also need to work with representations of the Amazon at different scales, such as deforestation rates of the whole Amazon and a map showing a single clearing. Moreover, since these different groups need to cross boundaries to perform their work, they require objectifications that can also be traceable to each other in order to maintain a single identity, that is, to be considered as a specific part of the same whole (i.e. the Amazon). This issue is particularly evident in the situations where one group has to coordinate the work of another group. In these instances, it is essential that the two groups are able to share an objectification of the Amazon, and from this, to agree on broad objectives. Following this, these objectifications also need to be disaggregated on a smaller scale so that subordinates are able to understand what they are expected to do, and the superiors are able to monitor if their broad aims are being realized as planned.

The process of objectification relating to the use of GIS has provided important opportunities to deal with the challenges involved in working across these occupational boundaries. GIS such as PRODES and DETER objectifies deforestation as a set of points and polygons which can be easily compared with one another. For example, after being captured by a GIS, two different deforestation patches are objectified into comparable polygons independently of the date, location and local social context where it took place. For this reason, different deforestation patches can be summed up, divided and superimposed with other GIS-based data in a malleable way in order to create, for instance, aggregates valid for the whole Amazon or for a specific municipality.

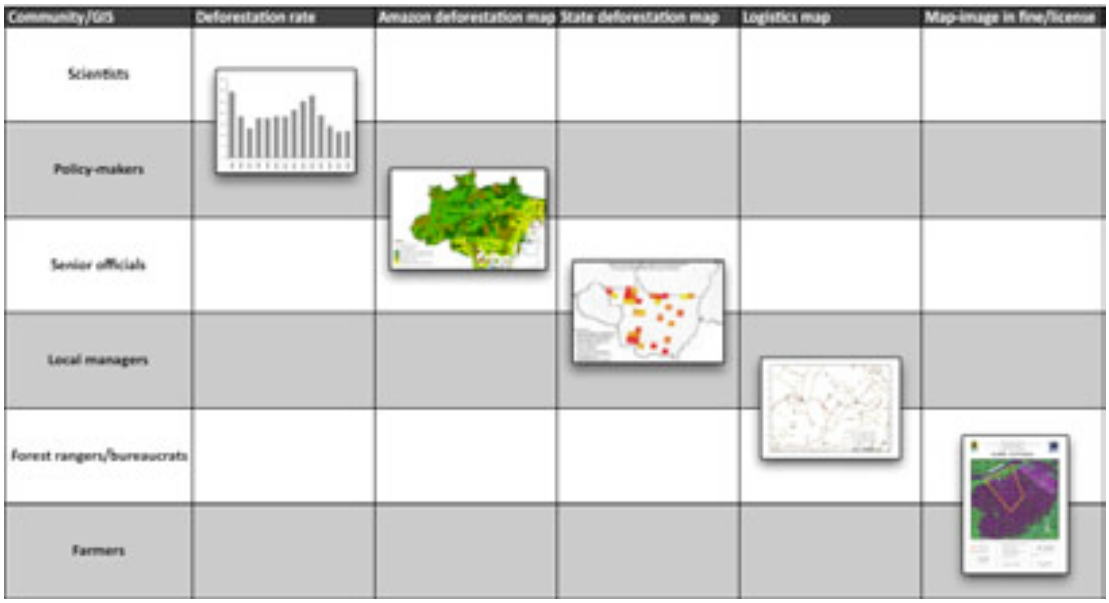

Figure 33 The (dis)aggregation of deforestation across occupational boundaries at IBAMA

Figure 33 shows how the process of objectification entailed by GIS facilitates coordination by linking the work of IBAMA on different scales. At the top, senior officials use GIS-based deforestation rates for the whole Amazon in order to set priorities and formulate tougher environmental laws, such as the increase in the legal reserve from 50% to 80%. These maps, in turn, are disaggregated to represent the deforestation of a specific state of the Amazon and used by local managers to negotiate financial and human resources with senior officials in order to carry out missions. IBAMA local managers also disaggregate, manipulate and superimpose other geospatial data from the GIS-based deforestation data in order to create the logistic maps which are used to manage the work of forest rangers and ensure compliance with specific targets. Finally, forest rangers further disaggregate the logistic maps into single deforestation points, these then being used to identify *in situ* the farm to be inspected and to create map-images in order to assess the compliance of farmers with the environmental law set by senior officials in Brasília. Moreover, while these objectifications are aggregated or disaggregated they maintain a link between the different scales of action, providing opportunities for the groups involved to make reference to and coordinate each others' work.

Star (2010) referred this phenomenon as the dynamic between ill and well-structured uses of boundary objects, a transition that is also related to the 'coordinating mechanisms' reported by Bowker and Star (1999). What is interesting to note here,

however, is that it is difficult to imagine this sort of dynamic without taking into consideration the process of objectification promoted by GIS. For instance, sentient perception and qualitative accounts of a burnt clearing in the rainforest are very difficult to compare and combine in order to form representations valid for the whole Amazon. Similarly, qualitative accounts based on the 'olhometro' are difficult to break down to a smaller scale, such as the exact number of hectares or the species of burnt trees, which are often needed for the work of forest rangers and SEMA bureaucrats. This suggests that the role of GIS as a boundary object in the Amazon cannot be disassociated from ability of this technology and its related practices to aggregate/disaggregate objectifications of the Amazon as to fit different information and work needs.

Mobility and spatial boundaries

The second way GIS has contributed to joint work is by offering a shared informatic structure that renders policies, fines and licenses more mobile. One of the most striking aspects of the case study (and one of the main difficulties in researching it) are the spatial boundaries, namely the vast geographical distances that separate the different groups involved in the formulation and enforcement of the policy towards the Amazon (see Figure 34). The presence of these spatial boundaries implies that these groups often have to work together in situations of absence, broadening in this way the gap between occupational groups. However, since policy-making, law enforcement and the analysis of legal documents tend to take place in places often thousands of kilometers from each other, it is crucial for the government to find ways to work effectively across these spatial boundaries.

Figure 34 Location of some of the groups formulating and enforcing the environmental policy in the Amazon: 1) scientists in São José dos Campos; 2) senior officials in Brasília; and 3) forest rangers and bureaucrats in the Amazon region

An example of the amount of travelling involved in the enforcement of environmental law can be seen in relation to the work of SEMA and IBAMA forest rangers and bureaucrats. In order to issue a fine, a forest ranger has to go *in situ* to collect evidence and convince the farmers to provide key information. On their return to their offices the rangers issue the fines and send them to the farmers and their lawyers as well as to attorneys and senior officials who usually work in Cuiabá, Brasília or other locations far from the site where the clearing took place. It is through this continuous movement of documents that different groups cooperate in order to ensure the validity of the fines. The issuing of environmental licenses by SEMA also involves cooperation at a distance between different groups. Firstly, GIS experts and agronomists have to inspect the farm where an application has been made for a license in order to create a series of documents and GIS-based maps as required by law. Then these documents have to be sent to SEMA so that the bureaucrats there can analyze them, negotiate interpretations with colleagues and lawyers and eventually issue the environmental license.

One of the main obstacles related to the movement of these documents is the maintenance of similar interpretations across vast distances. In particular, the farmer, GIS expert, attorney and SEMA bureaucrat and IBAMA rangers have to agree that the legal documents in question and the information contained in them all refer to a specific farm. Before the introduction of GIS the lawyers and attorneys had to rely exclusively on paper-based documents. These were deemed problematic since they only used local references such as the name of the municipalities (which in many cases may be as large as Belgium), roads and other local names (e.g. 'near the river bend' or 'after the rubber tree'). In other words, forest rangers used relational references of space which depended on the knowledge of particular elements of the landscape as seen by someone living in the region. Similarly, the size of deforestation in the fines was usually calculated using the *olhometro*, that is, the measuring of size in an approximate way based only on sight and experience.

Even though the people living in the Amazon use these local representations of location and area on an everyday basis, they are deemed unsatisfactory by the lawyers and attorneys working at a distance. This issue relates to two factors. Firstly, lawyers and attorneys, in most instances, live far from the rainforest and consequently are not socialized to the local navigation practices (i.e. do not know the region 'on the ground'). This means, that even if an attorney from Brasília is able to travel to the Amazon and read the local references in a fine or license, he might not be able to identify what it means exactly since the ability to identify a certain tree species or some other characteristic of the natural landscape requires social practices that are only available to those living in the region. Secondly, and most crucially, local references were deemed to be ambiguous and thus not able to maintain a single identity across boundaries. Landscape features (i.e. 'tall tree'), road names, and even some city names often have duplicates in the Amazon. This means that farmers' lawyers can easily argue, for instance, that a fine for illegal deforestation was not specific enough or did not concern his client's farm. Similarly, attorneys might regard environmental licenses issued using local references as not being sufficiently specific to ensure that, for instance, the 'right' farm is receiving an official authorization for deforestation and not a piece of land grabbed within an indigenous reserve or other prohibited area.

In this context it has become apparent that the use of GIS has played a key role in facilitating cooperation between these groups across spatial boundaries. Specifically, a closer look at the informatic structure behind GIS reveals that forest rangers and bureaucrats from SEMA and IBAMA use this technology to objectify all the locations on the planet in terms of longitude/latitude - a single Cartesian grid that is recognized as a global scientific standard. Further to this, GIS is used to provide precise area measurements in hectares, this being a standard metrical unit that is also adopted by Brazilian environmental law in order to calculate the value of fines. In this way, the GIS informatic structure enables rangers and bureaucrats to create fines and environmental licenses which (in practice) are believed to be independent from the knowledge of the local context being objectified, and consequently can even be read at great distances while maintaining the identity of the location.

It is important to note, however, that the emergence of common interpretations across spatial boundaries depend not only on the informatic structure of GIS but also on the existence of the shared practices involved in coding and decoding the GIS-based references found in these legal documents. In particular, it was possible to observe that the practices required for the basic use of GIS are much more widespread throughout the Brazilian government than the local spatial practices mentioned above. Many forest rangers have degrees in disciplines such as biology, forestry and agronomy which offer some training in the use of GIS. Furthermore, IBAMA also provides training on GIS to some of its personnel, while SEMA also gives GIS training to agronomists and other professionals working on the behalf of farmers, thereby contributing to the widespread use of this technology. In addition to that, it was possible to observe that lawyers and other professionals with higher education can usually understand the basic principles of map reading and latitude/longitude despite the lack of specific training on GIS technology. As a result of this, fines using location references and sizes objectified through GIS are much more likely to be decipherable by forest rangers, senior officials, attorneys and farmers (with the help of hired lawyers and GIS experts) than descriptions that rely on local knowledge.

These findings confirm the central importance of informatic structures and shared practices in the functioning of boundary objects. In particular, even though the content of boundary objects (i.e. what kind of information they have) has often been glossed over, it is clear from the examples above that not taking into consideration the

way GIS objectifies size and location would make it difficult to explain the role of this technology in facilitating joint work in the Amazon (Star, 2010; Trompette et al., 2009). Furthermore, by expanding on recent discussions regarding the functioning of GIS in practice, it is possible to observe that the existence (or in this case, pre-existence) of shared decoding practices was important for the maintenance of a stable meaning of documents across spatial boundaries in the Amazon (Kitchin et al., 2007; Levina et al., 2005); this is an issue that also helps to explain why GIS failed to become established in other countries where these practices are not as widespread (Barrett et al., 2001).

Trustworthiness and political boundaries

The third way GIS-based objectification facilitates joint work across boundaries is by creating documents that are able to cross political boundaries in the Amazon. These boundaries represent the agenda and affiliations of individuals or groups which influence their practices and tendency to trust other groups. As mentioned above, it is possible to observe a major separating line dividing the groups operating in the region. On the one side, there are the groups defending (more or less overtly) the rural development of the Amazon. These include the military governments between the 1960s and 1980s but also some SEMA senior officials and politicians in Brasília. On the other side, there are the groups that defend the environmental preservation of the Amazon rainforest. These include, for instance, politicians from the green party, attorneys and forest rangers, environmental activists and scientists concerned with the global effects of deforestation. It is important to note that this boundary cannot always be mapped directly to formal organizations or occupational boundaries. For instance, SEMA rangers seemed to be much closer to their IBAMA counterparts in relation to the need to reduce deforestation than their own superiors within the state agency.

Political differences and mistrust can be an important obstacle to the joint work practices across boundaries that are required to elaborate and enforce deforestation control policies in the Amazon. As seen above, there is considerable mistrust between the groups operating in the Amazon. Consequently the officials often feel uncomfortable expressing their views or sharing their experiences with people from different political positions. For instance, IBAMA officials repeatedly mentioned that they do not trust SEMA because of its links with local farmers. At the same time,

SEMA officials have also shed doubt on the political neutrality of INPE and IBAMA and find it difficult working with them.

In the forms of joint work involving coordination, mistrust does not appear to be a major obstacle. For instance, even though SEMA rangers might not agree with the political position of their superiors, they are compelled to follow orders and abide by their directives. But this is not the case for instances involving cooperation between groups since this form of joint work does not rely on direct hierarchical relations between the groups involved. As a result, the different groups cooperating with one another have much more room to assess the value of the work done across political boundaries, and in some instances may even refuse to work together. For instance, when farmers' lawyers, attorneys and rangers cooperate in the analysis and judgment of a fine for illegal deforestation they cannot impose the acceptance of the outcome of their work because of their specific hierarchical positions. Therefore, these groups must try to create a situation of trust and reciprocity, even if this only takes place superficially and provisionally.

The case study suggests that GIS has helped surmount political boundaries by allowing the creation of objectifications that are deemed trustworthy. In contrast to the old paper-based fines, the documents completed with the assistance of GIS are rarely challenged in court in relation to their materiality (i.e. the existence of the fact) or the presence of bias (i.e. attempted blackmail by a corrupt ranger). GIS has also played a similar role in relation to SEMA's environmental licenses. Even though IBAMA rangers consider SEMA to be politically motivated, they rarely challenge the environmental licenses produced by SLAPR. Such trust in GIS can be partially attributed to the epistemological affinity between the values embedded in GIS technology and the practices and historical role of positivism and high-modernism in the formation of the Brazilian state. Indeed, it is partly because of the prevalence of the positivist epistemology that GIS is able to provide the illusion of transparency required for working across political boundaries.

In addition to the broader historical factors that emerged in the historical analysis of the Amazon, it was possible to observe that GIS has also helped to overcome political boundaries in a performative way. It emerged from a closer observation of the rangers' practices that GIS is central to the constitution of fines. To this end, they

often state that their fines are "based on the satellite map-image", and not on their own testimony of the fact. A similar dynamic is also present in the formulation of environmental policies. For instance, 'green' scientists and other lobbying groups were able to play a more central role in policy-making only from the moment when they were able to form an argument based on GIS (and not their own opinions or perceptions) that demonstrates that deforestation was a large-scale phenomenon with consequences for the global environment. This suggests that these groups use GIS in order to attempt to performatively erase the traces of 'subjectivity' (i.e. human agency) from the arguments they produce. In this context it is possible to argue that the objectification promoted by GIS has a transformative character. When rangers, bureaucrats, scientists and policy-makers are able to successfully erase their own agencies from the outcome of their work, what emerges transcends the status of mere 'opinion' and becomes a solid 'fact'. Thus, these documents gain legitimacy and are better able to cross the political boundaries involved in the forms of cooperation found in the Amazon.

The findings reported above in relation to the Amazon are by no means unique to this setting. As pointed out by different studies, the building of trust is one of the key elements of joint work involving cooperating between different groups (Alter et al., 1993; Heckscher et al., 2006; Powell, 1990). What is interesting to notice about the Amazons, however, is that here trust was achieved not through the means of intensive communication and reciprocity as in the cases reported in the literature, but mostly through the ability of GIS practices to create apparently neutral objectifications (Bowker et al., 1999; Daston, 1992; Garfinkel, 1967; Neyland, 2007). This suggests that the achievement of trust through historical (i.e. positivist roots) and performative (i.e. the erasing of an agency) dynamics should be considered as a key element in the functioning of GIS as a boundary object in the Amazon alongside flexibility, shared practices and informatic structures. This also suggests the importance of understanding the practices and history of GIS in the Amazon in order to evaluate its role as a boundary object in the region.

Overall it is possible to conclude that the objectification process promoted by GIS has provided pragmatic opportunities for joint work. Even though GIS has not contributed to a reduction in the knowledge gap between the different groups operating in the Amazon, the process of objectification promoted by GIS has provided opportunities

for working across boundaries in ways that were not possible when these practices were centered on paper-based documents and sentient accounts. It has frequently been the case that this joint work has only been superficial, since the mutual understanding obtained through GIS has been limited to simple information such the location, size and ownership of a clearing. Moreover, GIS is mainly implicated in facilitating the achievement of instrumental goals, such as cooperation around the analysis of legal documents and the coordination of law enforcement missions. Nonetheless, the scalability, mobility and trustworthiness provided by the use of GIS as a boundary object has facilitated the surmounting of occupational, spatial and political boundaries in some pragmatic instances. At the same time, however, an overemphasis on GIS seems to be behind the growing tensions between groups. The next subsection examines these tensions in greater detail in order to clarify the relationship between the current failings of the government and the role of GIS as a boundary object.

7.3.2 Boundary-blinding

It was argued above that by objectifying particular aspects of territories, practices, people and events into digital data, GIS has acted as a boundary object, so providing opportunities for cooperation and coordination between groups operating across occupational, spatial and political boundaries in the Amazon. An important question in this context is what happens with the aspects of reality that are not selected for objectification and what the negative consequences of this neglect are. This section proposes the notion of boundary-blinding to describe the ways in which an overemphasis on GIS has prevented particular groups from understanding the social reality across boundaries and hindered joint work relations operating in the Amazon. According to this idea, emphasis will be given to how GIS is helping to promote the invisibility of social reality in specific dimensions: the blinding of practices, work outcomes and political motives.

Blinding practices

It was possible to observe that senior officials and scientists frequently fail to appreciate the work carried out across boundaries by forest rangers and bureaucrats. As seen in the previous section, the ability of GIS to make certain practices invisible can contribute to the creation of more trustworthy documents which can be used to overcome political boundaries in joint work practices. However, it was possible to

observe that in many other instances the neglect of practice can be problematic. Specifically, a large number of emerging tensions and the current failings of the Brazilian government in relation to the control of deforestation in the Amazon can be traced to the blinding of practices, that is to say, the inability of the government to understand the practices taking place across boundaries.

Here, in particular, the blinding of practices can be related to both the broader organizational structure of the Brazilian government and the specific role of GIS in it. It is possible to observe the presence of a strict division of labor in the Amazon, and not only between agencies but also within the departments operating in the same sphere. In line with the Taylorist conception of work, it is possible to observe a separation between the groups that develop technology and formulate policies, and the groups who apply them in the Amazon. This separation occurs on different dimensions; it is geographical, since the decision-making process tends to take place in Brasília and São José dos Campos, while the enforcement of the policies and the use of technological artifacts take place in the Amazon. This division is often also occupational as important decisions are often left to high-ranking officials, scientists and consultants, most of whom have masters and PhDs in subjects such as geography, biology and forestry, while those who put these decisions into practice are low ranking rangers and bureaucrats who in some cases have not been through higher education.

Underlying these more visible separating lines, the blinding of practices is also related to the legitimacy and perceived relevance of different professionals. On the one hand, INPE scientists and senior officials tend to enjoy a high-status within the government and are considered to be knowledgeable due to their formal education and ability to draw upon legal and scientific vocabularies to express their views. IBAMA and SEMA rangers and bureaucrats, in contrast, have historically been regarded as inefficient, stubborn and corrupt. Thus, on the premises that the practices low ranking officials are inherently ‘wrong’, scientists and senior officials often deem unnecessary to engage with them. Therefore, the groups that actually use GIS and enforce the law rarely have the opportunity to influence their design or to contribute to their improvement.

It was possible to observe that GIS and the related process of objectification also play a decisive role in the blinding of practices. Senior officials and scientists tend not only to ignore the voices of forest rangers and bureaucrats, but also replace them with visions related to the technical aspects of GIS. Hence, senior officials and scientists increasingly base their understanding of law enforcement in the Amazon on the capabilities of GIS technologies rather than the actual practices and limitations of the rangers and bureaucrats. This issue is evident prevalent on the view that deforestation control can take place in 'real-time' . As seen above, INPE, IBAMA and SEMA are spending considerable sums in the acquisition of satellite images with higher spatial (i.e. more quality) and temporal resolutions (i.e. more frequent snapshots) in order to create GIS able to provide data as near to the 'real-time' as possible. When it comes to the description of the way these systems are used in law enforcement, senior officials and scientists suggested that they expect SEMA and IBAMA forest rangers to also work on a 'real-time' basis, and launch operations that are able to interrupt ongoing deforestation and arrest the perpetrators in the act as soon as new deforestation data appears on the computer screen.

However, despite the prevalence of the description of law enforcement as taking place in real-time, a closer look at the actual practices of forest rangers reveals a different situation. Given the logistical challenges involved in getting to the location of deforestation, the scarce amount of human resources and the quantity of work involved in issuing fines, it is often not possible for the rangers to go after single deforestation points as soon as they are detected by the latest GIS technology. Instead, local managers usually have to wait a few months until the total number of deforestation points makes it worthwhile sending a team of forest rangers to the region. Therefore, it is often the case that deforestation is prosecuted only many months after being detected. In addition to this, many more points are not even investigated. For example, only 17% of the deforestation detected by INPE between 2004 and 2008 actually led to a fine by IBAMA. This suggests that the notion of deforestation control in 'real-time' is not only infeasible in practice but also that SEMA and IBAMA rangers cannot cope with the current volume of deforestation data already taking place.

In some cases, the emphasis on the technical capabilities of GIS has been so intense that it come to completely replace the need for human agency in the enforcement of

the environmental law in the minds of the scientists and senior officials. One of the main justifications behind the development of SLAPR by SEMA is the ability of this GIS to capture the full name and location of farmers in the Amazon. In particular, some senior officials reported that with the help of GIS the government is able to exert remote control over farmers by monitoring and issuing fines from a distance. In this way they suggested that the sole detection of deforestation through GIS would be sufficient to enforce the law in the region, leaving aside the need for the work of forest rangers and bureaucrats in the region. However, a closer look at the actual practices behind SLAPR has shown that its function is far from being autonomous. Rather, the registry of new properties within SLAPR involves inspections, the creation of GIS-based maps and the careful analysis of all the documents by SEMA bureaucrats in a laborious process that can take many months or even years. Furthermore, the detection of new deforestation and its enforcement within SLAPR involves not only SEMA scientists but also forest rangers who have to go to the point indicated by the GIS in order to find the perpetrator of the crime. In this way, senior officials often wrongly conflate deforestation as detected by the GIS to deforestation under control.

Even though some form of blinding of practice should be expected in any complex organization, the extent to which this is taking place in the Amazon is hindering joint work practices in different ways. Firstly by ignoring who enforces the law and how it is done, senior officials are more likely to create policies that are infeasible in practice. The case of real-time and deforestation control at a distance is a clear example of this issue, and is by no means an isolated case. As reported by different forest rangers, policy-makers often approve new regulations which cannot be implemented in practice owing to their complexity and resource demands. Consequently, IBAMA and SEMA rangers and bureaucrats are often blamed for not fully implementing the environmental law, even though the government does not provide the conditions for this to take place or create laws that are proportionate to their resources. This, in turn, creates tensions between the different groups which have to work together in order to protect the Amazon.

Secondly, by wrongly transferring the agency of law enforcement to the GIS, some senior officials are also undermining the conditions for the actual protection of the rainforest. While the emphasis on GIS technology is leading the government to invest

large sums in the construction of advanced and often underutilized GIS, the occupational groups that actually enforce the law are largely neglected and undervalued. Specifically, even though IBAMA has improved the provision of vehicles and daily allowances for the execution of missions in recent years, forest rangers still complain about their low salaries and the lack of training in GIS and legal matters. In addition to this, forest rangers frequently lament the fact that they are often blamed for not enforcing the law 'correctly' but rarely have the chance to improve the situation by negotiating solutions with attorneys and senior officials. Similarly, many SEMA rangers seemed frustrated with their work, complaining that senior officials provide inadequate daily allowances, computers and GPS devices for them to carry out their work at full capacity. In both cases, it appears that if the government continues to neglect the importance of bureaucrats and forest rangers, strikes and decreases in productivity are likely to occur.

The examples reported above bear a close resemblance to the neglect of the work of 'street level bureaucrats' reported by Lipsky (1980), the invisibility of work and workers discussed by Star and Strauss (1999) and the implications of the distance between canonical and non-canonical practices reported by Brown and Duguid (1991). Here, as in the cases reported by the literature, forest rangers and bureaucrats are increasingly treated as nonpersons: actors with illegitimate voices who, like asylum interns or domestic workers, have their individuality, personality and even presence ignored. Notwithstanding this, the findings presented above suggest that the boundary-blinding is not only being fostered by the lack of legitimacy of certain groups, but also by the presence of a strong version of technological determinism among scientists and senior officials (Brown et al., 2000; Grint et al., 1997; Nardi et al., 1999). Consequently, the work of bureaucrats and rangers is being objectified or even replaced by the GIS, leading to a situation whereby the development of new technologies is seen as the main driver of social action and change in the Amazon.

Blinding outcomes

The second way boundary-blinding is hindering joint work in the Amazon is by preventing senior officials from adequately understanding the outcomes of the work of forest rangers and bureaucrats. At different times it was possible to observe that senior officials increasingly rely on the abstract indicators provided by GIS in order to evaluate the law enforcement activities and policies in the Amazon. Following the

establishment of INPE's GIS in the 1990s, the total deforestation figures released by the institute largely became the main basis for the creation of new policies, and in many cases were also used to evaluate the efficiency of these policies. For instance, it was the hike in deforestation rate in 2004 detected by PRODES that led the government to create PPCDAm, a new plan to control deforestation. Five years later it was also based on the outcomes of this GIS objectifications that senior officials from the Ministry of the Environment concluded that PPCDAm was a success. GIS-based objectifications also play a similar role of in the coordination of law enforcement practices. Hence, senior officials from the two institutions are keen to highlight the total number of fines and environmental licenses produced in a given period while discussing the effectiveness of their agency in the environmental protection of the Amazon.

As seen above, the objectification of work with the help of GIS has been helpful in allowing the coordination of different joint work practices. However, it is important to notice that these objectifications constitute a very selective image of the Amazon. In particular, such objectifications are often restricted to aspects of the Amazon that are quantifiable, spatially located and detectable from outer space. This leaves out the picture aspects of the Amazonian reality that are immeasurable, diffused or that require more than a quick glance in order to be captured. Hence, by relying exclusively on these figures, senior officials often remain blinded to the outcome of the rangers' and bureaucrats' practices, in addition to the related meaning of GIS figures and their actual implication for the environmental protection of the Amazon. The negative effects of the blinding of outcomes can be observed both in relation to the formulation of broad policies and the manner in which senior officials manage the work of rangers and bureaucrats.

It was possible to observe that the blinding of outcomes precludes the formulation of better environmental policies. Specifically, the use of GIS as the only window on the region reduces the complex social diversity of the Amazon into two archetypes: the forest peoples as noble savages defending Mother Nature in a disinterested way and the farmers as greedy and heartless criminals destroying the World's lungs. These archetypes are not only too simplistic but also misleading. It was possible to observe (even if only superficially) that the behavior of both forest dwellers and farmers has been changing over the last decades. Today farmers are much more likely to accept an

agreement with the environmental sector of the government than a few years ago, since many have understood that green credentials are becoming increasingly important to national and international buyers. At the same time, forest dwellers are increasingly seeking Western-like life-styles that are more akin to the farmers they are supposed to oppose. Therefore, as a consequence of these increasingly unrealistic understandings of the inhabitants of the Amazon, policy-makers are not able to meet the demands of the local inhabitants and cannot devise more efficient deforestation control policies.

The blinding of outcomes also has important implications for the way senior officials and scientists understand and manage the work of forest rangers and bureaucrats. In order to produce documents that are legally valid, forest rangers from SEMA and IBAMA have to engage with a complex and constantly changing set of laws. Furthermore, the amount of work necessary to produce a single fine can vary considerably depending on the distance of the deforestation from the local office, the level of danger involved in the operation, the willingness of the farmer to help and the complexity of individual cases. Additionally, not all forest rangers are able to issue fines and licenses with the same level of mastery, and some may even fail when they come under the scrutiny of lawyers and attorneys. Despite these differences, when it comes to evaluating the productivity of a given local office all fines and licenses are treated as if they are the same, this being an aggregated figure of the total number of documents issued in a given period. As a result of this, senior officials are often unable to observe the relationship between these indicators and the actual punishment of crimes of illegal deforestation. This issue helps to explain why only a small percentage of fines are ever paid and many farmers do not respect their agreements to recover the native forests following the registration at SLAPR. Moreover, by emphasizing the quantity rather than the quality of the fines, senior officials tend to disregard the need for an improved legal and GIS training for the rangers and bureaucrats. While this issue is related to the problem of the invisibility of the agency (mentioned above), it also has consequences for the final outcome of fines and licenses since better-trained officials would be able to create documents that would have a higher chance of leading to the actual punishment of perpetrators of environmental crimes.

The relation between GIS and the blinding of outcomes in the Amazon should not come as a surprise. Studies exploring the implications of GIS and other technologies have already explored at length the inability of abstract symbols and related positivist epistemologies to capture the richness of social life (Kallinikos, 1995; Pickles, 1995a; Scott, 1998; Taylor et al., 1995). More specific to the public sector, these findings also confirm the problems generated by a growing emphasis on targets and indicators (Blackler, 2006; Chapman, 2004; Lipsky, 1980; Miller, 2003). However, what is particularly significant here is that, as in the case of the blinding of practices, the blinding of outcomes is preventing the different groups working in the Amazon (including the local population) from understanding each other's demands and therefore is also preventing the creation of more effective polices, technologies and law enforcement strategies.

Blinding motives

Finally, the overemphasis on GIS is also contributing to the blinding of the political motivations behind the use of GIS. As seen above, GIS has proved to be a flexible technology, being adaptable to the specific political agenda of its users. Even though all the GIS applications in operation in the Amazon have similar origins in the work of INPE and other large research institutes, such as NASA, it is possible to observe that its use has varied radically across political boundaries. Nevertheless, despite the close link between political motives and the use of GIS, most scientists and senior officials suggested in their interviews that they see GIS as a neutral technology able to deterministically reduce deforestation. The clearest example of this can be found in relation to the use of GIS at SEMA. Many senior officials in Brasília (including Ministers of the Environment) consider SLAPR and similar GIS as the 'best practice' for the control of deforestation in the Amazon. For this reason, they often implied in their interviews that the issuing of more environmental licenses was the equivalent of better-protected forests. However, this is not always necessarily the case. For instance, the environmental licenses issued by SEMA in Mato Grosso have often been used as a way of legitimizing the deforestation already in place (without concrete actions to recover the area), or have been used to obtain authorization for further deforestation. The lack of consideration for the double-edged nature of environmental licenses by senior officials in Brasília implies that they often give their full support to a policy that may ultimately go against their own political agenda.

As with the blinding of practices, the blinding of motives can be traced to both the ways in which different parts of the government relate to each other and the role of GIS in it. In relation to the former issue, it was possible to observe a tendency within the government to compartmentalize the different debates concerning the Amazon. At national level, even though the environmental and farm policies are strongly interrelated, the policy-makers of these two areas rarely talk to each other, let alone contribute directly to each other's decisions. A similar issue can also be seen at regional level, where despite the overlap between IBAMA and SEMA, these two bodies rarely collaborate in order to find joint solutions. In addition to this, even when some voices get across political boundaries they are often considered 'politically' biased and are pushed to the sideline. This issue can be seen, for instance, when SEMA officials reported 'off the record' that they consider global warming to be a hoax aimed at undermining the economic growth of Mato Grosso, or when policy-makers complained that my presentation at the United Nations was giving too much emphasis to the views of local farmers.

It can be seen that the other two types of boundary-blinding mentioned above, and the related process of objectification also play a significant role in blinding the political motives behind specific uses of GIS. Specifically, by remaining blind to the agency behind the use of GIS, the supporters of this technology tend to believe that there are no intermediaries between their intentions and the actual outcomes of GIS. In this way, they fail to recognize the ways in which the use of GIS diverges from their initial designs and may even go against their original intentions. In addition to this, by remaining blind to the outcomes of the use of GIS, the expectations in relation to the implications of GIS remain unchallenged, even after its contradictory effects have begun to emerge on the ground.

These findings confirm and expand insights into the relationship between the use of GIS (and the related positivistic representations of space) and the illusion of transparency (Harley, 1989; Lefebvre, 1991; Pickles, 2004). This perception of GIS as a transparent technology helps to explain the inability (and unwillingness) of the groups in the Amazon to see the motives, practices and motives of the other groups using GIS across boundaries. In addition to this, it seems that boundary-blinding also relates to a lack of appreciation about the ways in which the social implications of technology depend on the social context in which they are implemented (Pinch et al.,

1984; Walsham, 1993): a lack of awareness that also prevents the government from realizing how technology may go against its original intentions (Orlikowski, 2000; Suchman et al., 1999). Hence, it would appear that the inability of the government to critically evaluate GIS technology in the Amazon emerges from an intoxicating combination of technological determinism and the illusion of transparency. This suggests that if the boundary-blinding provoked by GIS remains untackled in the long run it could undermine the very joint work practices that this technology is intended to improve.

7.3.3 The contradictory effects of GIS in the Amazon

After analyzing how GIS has helped and hindered joint work practices, it is now possible to answer the second research question concerning how GIS is implicated in the way different groups attempt to control deforestation in Mato Grosso. The analysis presented above suggests that it was not undeservedly that GIS became a central element to policy-making and law enforcement in Brazil. As argued in subsection 7.3.1, GIS and the related process of objectification facilitated joint work, providing as it did mobility, scalability and trustworthiness to representations of the Amazon and the work of the different groups involved. However, in subsection 7.3.2 it was argued that objectification also had negative implications for the government. In particular it was shown that GIS contributes to boundary-blinding, this being a phenomenon that prevents senior officials and scientists from understanding practices, outcomes and political motivations across boundaries. It was also possible to see that the ways in which GIS helps and hinders joint work is closely related to both the current practices observed in the Amazon, and the historical phenomena discussed in subsection 7.2, such as the political flexibility and the positivist values embedded in both GIS and the constitution of the Brazilian government.

It is important to note, however, that the roles of GIS as an aid and obstacle for joint work in the Amazon cannot be disassociated from each other. While it is easy to romanticize a pre-technological past when people talked to each other instead of exchanging digital tokens, the case suggests that the government is better equipped to deal with the challenges posed by the issue of deforestation with GIS than without it. Given the number and complexity of the many spatial, temporal, occupational and political boundaries involved in elaborating and enforcing the environmental law, it

would be infeasible to simply substitute GIS with a sentient engagement with the whole Amazon. Furthermore, complex organizations such as the Brazilian government need to work in a regime organized in accordance with a division of labor. It would be impracticable, for instance, to have a Minister of the Environment who personally carried out the complex chain of practices linking broad policies to specific patches of forest in the Amazon. In this context, it is anticipated that the work of each group needs to be, to a certain extent, 'black-boxed' and thus invisible to the individuals outside those boundaries. This suggests the presence of a dilemma. On the one hand, GIS is needed to deal with complex and geographically distributed work, but, on the other hand, the overemphasis on GIS for this role is also undermining the same work it is intended to support and improve. The recognition of this dilemma implies that rather than attacking GIS for its negative implications or blindly praising it for its benefits, the different parts of the Brazilian government should find ways in order to deal with the contradictory effects of GIS in practice.

The analysis presented above suggests that up to now the Brazilian government has dealt very poorly with the paradoxical effects of GIS. As already seen, the forms of coordination and cooperation that emerged following the establishment of GIS as a boundary object were mostly instrumental and superficial; they were instrumental because the joint work practices have often been based on a command-and-control structure whereby workers across boundaries are only seen as a means for achieving some predetermined goal, such as inspecting particular sites of deforestation as indicated by a manager (see unidirectional arrows in Figure 35). The instrumental aspect of joint work is also evident in the instances where rangers, bureaucrats and attorneys as well as other different groups have to cooperate. In these instances, even though there is a bidirectional flow of information and work outcomes, the groups involved rarely reflect on their own practices or negotiate shared solutions, usually restricting themselves to the instrumental use of the work outcome of other groups (see bidirectional arrows in Figure 35). The forms of joint work supported by GIS in the Amazon were also superficial because (in most cases) the level of common understanding were largely limited to the establishment of a given location, size and type of deforestation in addition to other objectified aspects of the Amazon and of the work of the rangers. Furthermore, as indicated by the central position of GIS in Figure 35, following the emergence of GIS as a boundary object, this technology was

implicated in most interactions between these groups, suppressing in this way other forms of interaction.

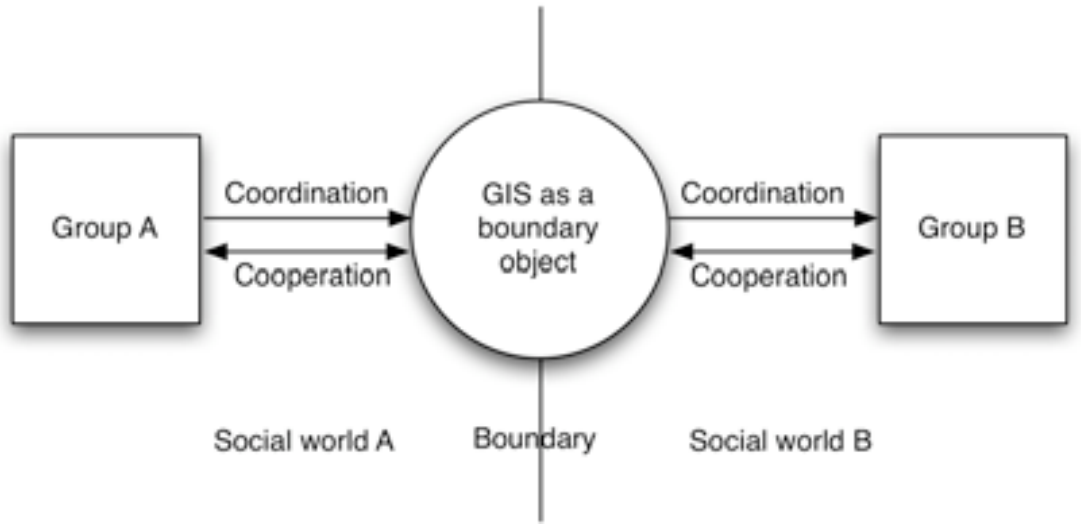

Figure 35 Instrumental forms of joint work and GIS as a boundary object in the Amazon

The instrumental forms of joint work described above may be suitable for homogeneous, stable environments, such as mature industrial plants with a slow pace of innovation and change (Adler et al., 2006; Donaldson, 2001). Similarly, superficial forms of cooperation may also be sufficient for endeavors where the different groups involved can maintain a high degree of independence, such as with the exchange of money for specimens or the collection of scientific data by amateur naturalists (Star and Griesemer, 1989). However, many authors argued that superficial and merely instrumental forms of joint work are unsuitable for complex and highly interdependent organizational contexts, such as the one found in the Amazon (Adler et al., 2006; Chapman, 2004; Spinuzzi, 2008). In particular, due to the constant changes faced by the Brazilian government, its officials cannot simply 'stick to the rules' but must attempt to find new solutions for the emerging and shared problems (Engestrom et al., 1997; Spinuzzi, 2008). Furthermore, given the many boundaries implicated in joint work, the different groups involved also need to find ways to go beyond their own preconceptions and learn how to engage with the workers from the other groups (Boland et al., 1995; Brown et al., 1991).

This suggests that the negative effects of boundary-blinding and the related shortcomings of current policy-making and law enforcement practices should be understood as being closely related to the forms of joint work currently being

supported by GIS. In other words, the boundary-blinding related to the role of GIS as a boundary object is a reflection of the inability of the government to go beyond instrumental forms of joint work and adopt more collaborative approaches. However, this suggestion does not imply that the government should replace its hierarchies and power relations with egalitarianism and brotherhood. Rather, what is being argued here is that the management of the many boundaries involved in the formulation and enforcement of deforestation control polices in the Amazon demand more engagement than currently acknowledged by the government. The next section concludes this chapter by providing some suggestions on how the government could foster collaboration and improve its practices.

7.4 Fostering collaboration across boundaries

This section draws together some elements from the analysis above as well as the insights from the literature in order to discuss the organizational and policy implications of this study. In this way, this section endeavors to address the third and last research question, namely how the government could improve its deforestation control policies and practices in the Amazon. It is beyond the scope of this thesis to provide definitive solutions for the issues identified above. Nonetheless, it is possible (and critical given the importance of the topic) to suggest some directions that the government could take in order to foster collaboration at different levels. Starting at the policy-level and going towards the organizational-level these directions are: from dissimulation to negotiation, from imposition to co-construction and from casting blame to mending breakdowns.

7.4.1 From dissimulation to negotiation

The inability of the government to foster collaboration between its many parts as well as between itself and the local population has created many issues at policy-level. Among these, one that is particularly damaging is the inability of the government to foster negotiation between the groups holding different political positions. As argued above, the overemphasis on GIS and the related process of objectification is leading to the blinding of the political motivations behind technologies and policies. In this way, the people involved rarely have the chance to hear in detail the arguments from those in opposing political positions, thereby reinforcing their own perspectives as the only alternative to the future of the Amazon.

The lack of collaboration in policy-making is also preventing the government from creating policies that can aggregate the interests of different groups. As shown above, there has been a tug-of-war for decades between those defending the environmental protection of the Amazon and those wanting to promote its economic development. In this process, what is seen as a victory for one group is a drawback to others, and what is fair policy for one group is a conspiracy for others. An example of this is how the decree limiting access to credit to unlawful farmers was seen as a major improvement by IBAMA and a betrayal by some SEMA officials. At the same time, while SEMA sees its softer approach towards farmers as a way of bring them onto the side of the law, IBAMA refers to these actions as proof of SEMA's political bias. Consequently, the governance of the Amazon faces a serious problem in terms of representation: policy decisions are habitually seen as being one-sided and the different social groups involved often disregard or even subvert the policies proposed across boundaries.

There are no easy fixes to this problem. The move towards collaboration and negotiation cannot be brought about from the outside, but has to be an internal movement connecting the protagonists of the different groups in the Amazon. Here, it is possible to suggest two activities that the government can undertake in order to foster collaboration: the breaking down of silos and the embracing of shared vocabularies. As mentioned above, policy creation has been dominated by silo-like structures whereby the decision-makers involved at one level (i.e. state, federal) and in one area (i.e. farming, forestry, Indigenous populations) of the government rarely have the chance to talk to each other. In this context, it is important to start breaking apart these silos by inviting decision makers from different forums to contribute to the debates taking place across boundaries. Of course, placing different people in the same room does not ensure that they will participate or that the difference voices will be heard. Furthermore, as pointed out by a variety of authors, the adoption of democratic processes does not eliminate the role of politics and power play in policy-making (Cooke et al., 2001; Stone, 1988; Zografos et al., 2008). Nonetheless, putting groups with different perspectives face-to-face and allowing their views to be expressed in a more direct way may expose hidden tensions and lead to the challenging of 'taken-for-granted' notions and eventually more expansive forms of learning, namely, a joint search for solutions that goes beyond particular worldviews and the more immediate instrumental aims of the groups involved (Engestrom, 2001).

There have been a few instances where the different groups operating in the Amazon were able to interact across these silos. This occurred, for instance, when scientists and SEMA criticized INPE's data at the end of the 1980s and 2000s. As argued above, it was partially because of these negotiation processes that GIS became established as a boundary object in the Amazon. In addition, there have also been instances where there has been an explicit attempt to create policies by involving a broader set of actors. Following an internal study that pointed out the lack of involvement of state-level environmental agencies in the formulation of deforestation control policies, in 2009 the Ministry of the Environment decided to transfer the responsibility of creating the second version of the PPCDAm to the separate states. I was present at one of the first policy-making meetings under this new scheme which took place at SEMA's headquarters. On this occasion, I observe that some IBAMA officials were also present, alongside two observers from the United Nations (one of them being myself) and two visitors representing the farmers and loggers. From the interaction between these different groups it was possible to observe, for instance, that some political positions that were taken for granted by particular groups (i.e. the legal reserve of 80%) were still perceived as being unacceptable by the other groups. Even though these examples provided some indication of the willingness of the government to change its silo-like structure, the forms of negotiation that have emerged so far have been largely incipient and superficial since the surfacing tensions were treated more as embarrassments that needed to be glossed over than as issues to be dealt explicitly. Similarly, the negotiations relating to GIS were mainly restricted to its technical aspects, leaving largely uncharted the political positions behind the use of the technology. In this way, the trust in GIS as a technology was kept largely outside these debates and senior officials continued to view GIS as a reflection of their own epistemological assumptions.

The second activity that may contribute to a move towards negotiation is the creation of shared vocabularies aimed at translating the concerns of the different political positions into one another (Collins et al., 2007). Presently, most of the arguments in favor of the preservation of the Amazon tend to be based on disciplines related to the natural sciences, such as the relationship between deforestation and climate change and the need to preserve biodiversity (e.g. Schroeder et al., 1995). However, the majority of arguments in favor of the development of the Amazon (and indirectly

leading to the extension of crop fields and the reduction of forested areas) are based on mainstream economic concepts, such as the importance of income growth and high returns on investments (e.g. Pereira, 1971). Consequently, it is often difficult for these two groups to understand the content and relevance of the arguments coming from opposite sides of the political spectrum.

Notwithstanding this, the emergence of new fields within conservation biology and economics suggest that there have been some advances towards the creation of shared vocabularies. In particular, in the last decade, established conservation biologists proposed notions such as environmental services and carbon credits which give an economic value to protectionist actions (Brasil, 2009a; Kaimowitz, 2008; Nepstad et al., 2008). In this way, there has been a gradual recognition that 'political will' and 'environmental consciousness' may not be enough to 'keep the trees standing', as explained by an ex-Minister of the Environment during an interview (Interviewee #59/2009). At the same time, the use of the term 'sustainable development' in policy-making also indicates the recognition of the existence of environmental issues related to the process of economic growth (Daly, 2007; United Nations, 1992). Here, however, different authors have pointed out that the notion of sustainable development has been used more as a rhetoric device than as a way of transforming policy-making (Peet et al., 1996; Zhouri et al., 2005). Furthermore, even though the Brazilian government has adopted the notion of environmental services in order to argue for the creation of funds for the preservation of the Amazon, many questions still remain open (see next chapter).

The challenges already faced by activities mentioned above suggest that the shift towards negotiation will involve some deep changes. In particular, it suggests that by simply changing the way in which the government organizes its policy-making forums and the way the different groups defend their positions may not ensure that a constructive process of negotiation will emerge. Thus, the move towards collaboration in policy-making is likely to also involve challenging the Brazilian tendency to avoid direct confrontation (Amado et al., 1991), the lack self-recognition regarding political positions and the creation of shared understandings on what constitutes development in Brazil (Carneiro, 2005; Hayes et al., 2011).

7.4.2 From imposition to co-construction

The second level where collaborative approaches are sorely needed concerns the design of laws and technological artifacts that are effective in practice. One of the consequences of boundary-blinding relating to the use of GIS is the tendency of senior officials and scientists to create new laws and technologies largely based on the potential of these artifacts rather than on the social reality in which they should be used. Clearly, scientists should continue to explore and expand the potential for remote sensing and GIS technology, and senior officials should continue to devise new legal means with which to achieve policy aims. However, the disconnection between notions such as 'real-time' deforestation control and the actual work conditions of forest rangers in the Amazon is problematic, since, as argued above, this leads to the creation of policies and technologies which are not feasible in practice, and thus fail to reach their goals. In addition to this, the tendency to evaluate the outcome of policies and technologies in a detached way is preventing the government from evaluating the outcomes of its actions. Therefore, even though some laws and technologies are failing to provide the desired outcomes, the government is not currently able to realize the existence of particular issues. As with the discussion of broad policies, this situation relates to the lack of collaboration between different sectors of the government. More specifically, it is closely related to the tendency of the government to enforce a strict division of labor between those who create policies and technologies and those who use them in practice. In this context, it is important to try to bridge these dividing lines and move towards a situation whereby laws and technologies are co-constructured by the different groups involved rather than imposed from the top.

This move towards co-construction involves changes at different levels of the government (Chapman, 2004; Lipsky, 1980). First of all, senior officials and scientists should recognize the role of low ranking officials as key determinants of the outcome of their policies. That is, they should acknowledge that their law enforcement strategies and technologies only take effect in the ground when enacted and tailored by low ranking officials according to their local contexts. A consequence of this recognition would be that senior officials and scientists could attempt to involve forest rangers and bureaucrats in the earlier stages of the creation of new laws and technologies. The government would then be able to take into consideration not only

the concerns of the specialist jurists and blue-sky GIS researchers, but also the pragmatic work needs of the groups that eventually will have to embrace these artifacts in their daily practices (Harris et al., 1995; Schuler et al., 1993). These participatory approaches, in turn, would also be an important occasion for the recognition of differences between perspectives and for connecting the different bodies of knowledge involved in controlling deforestation in the Amazon (Boland et al., 1995; Tsoukas, 1996).

The Brazilian government should also attempt to find new ways to evaluate the outcomes of its laws and technologies in the Amazon. There is no question that GIS technology is an essential research instrument with which to understand deforestation. Nonetheless, scientists and policy-makers dealing with this issue should attempt to go beyond this dominant paradigm and also adopt qualitative research methods such as ethnography and semi-structured interviews (Alves, 2008; Carmenta, 2010; Harwell, 2000; Reid et al., 2006). In this way the government may be able to obtain a better appreciation of the organizational and social dynamics taking place in the Amazon which usually remains invisible to GIS. In this way, they will be able to develop a clearer understanding of the implications of their laws and technologies and improve their practices. However, for this to happen, the government should give more space to arguments stemming from other perspectives, such as the one offered by this doctoral research, and from a broader set of actors, such as the rangers and bureaucrats themselves (Puri, 2007).

Even though this move towards co-construction is important in different ways, there are indications that it will not be unproblematic in the Brazilian context. As mentioned above, the formation of the Brazilian government is closely related to positivist and high-modernist values. Although these values have contributed to the establishment of GIS as a boundary object, they have also become an obstacle to the adoption of participatory approaches. In particular, the division of labor (mentioned above) between the creators and the users of policies and technologies is linked to the belief that formal education (PhDs, Master's degrees, etc…) is enough to ensure the design of good laws and technologies. In this context, lower ranking officials are in an advantageous position not only because they are seen as being inherently inefficient, stubborn or even corrupt but also because they frequently lack educational qualifications. At the same time, given the emphasis on positivist research methods,

qualitative studies such as the one offered here, still have to convince many policy-makers of their validity and scientific rigor. This suggests that the successful adoption of participatory approaches depends on a combination of the provision of opportunities for participation and the challenging of deep seated assumptions concerning the ability of low ranking officials and alternative epistemologies to provide relevant knowledge for the design and evaluation of law enforcement strategies and technologies.

7.4.3 From blaming to mending breakdowns

Finally, the Brazilian government should attempt to foster collaboration on an operational level. Even if the government is eventually able develop laws and technologies in a collaborative way, it is unlikely that their enactment at operational level will always take place smoothly. Moreover, given the size, complexity, geographical dispersion and dynamism of the Brazilian government in the Amazon, breakdowns are likely to occur (Chapman, 2004; Spinuzzi, 2008). These breakdowns include, for instance, the misinterpretation of new environmental laws by a bureaucrats, disagreements between rangers and attorneys on whether a given fine is valid or not and the conflicts between managers and senior officials concerning the planning of a law enforcement operation. However, given the blinding of practices and outcomes discussed above, these issues are rarely recognized and acted upon. Instead, the government tends to adopt a strategy which the economist Albert Hirschman has termed the 'failure complex', namely, the tendency to either deny the existence of any issues or to blame the current situation for being incorrigible and to impose radical reforms from the top (Bianchi, 2007; Hirschman, 1971). This suggests that the Brazilian government should develop the ability to learn from past failures and fix breakdowns as they appear. In other words, the Brazilian government should change from being a static system that is only able to impose drastic measures from the top, to a learning system that can continuously improve its practices through a collaborative process involving different groups (Argyris et al., 1978; Wenger, 2000).

In order to develop the capability to collaboratively mend breakdowns the government should foster the ability to: open black-boxes, negotiate pragmatic solutions and create the conditions for quick learning. As mentioned above, GIS technology has brought important benefits to the management of the law enforcement

activities in the Amazon by creating scalable representations and creating black-boxes which reduce the interaction between groups to a predetermined set of inputs (e.g. detected deforestation, new laws) and outputs (e.g. fines for illegal deforestation, reductions in deforestation rates). At the same time however, the solidification of these black-boxes is contributing to the blinding of practices and outcomes as reported above, and the related inability of the government to improve law enforcement practices in the region. Therefore, in order to tackle this issue, senior officials and scientists should find new ways of identifying the issues. This could involve, for example, periodic trips to the Amazon, interviews with forest rangers, and workshops involving the different groups. In this way the different groups involved would be able to get to know the Amazon and become acquainted with the work that has been achieved across boundaries through more engaged means that the ones offered by GIS objectifications alone.

After the breakdowns have been identified, senior officials and scientists need to learn how to negotiate pragmatic solutions. In this process, senior officials and scientists should not only identify what is wrong with the work carried out by others but also embark on a joint reflective effort about their own and other practices (Spinuzzi, 2008). Therefore, rather than imposing a ready-made solution for breakdowns, senior officials and scientists should be prepared to negotiate alternatives with their subordinates and reach agreements in a collaborative way. In this way, the mending of breakdowns would be a bidirectional process involving mutual learning and change (Engestrom, 2001). In developing this ability, senior officials would be able, for instance, to investigate why particular laws are not being enforced by the forest rangers as expected, rather than simply creating new laws and blaming the rangers for being ineffective. Similarly, attorneys would be able to negotiate directly with the rangers specific interpretations of the law (reflecting the latter's work conditions), instead of writing official letters accusing them of a lack of legal rigor and making infeasible demands.

However, for this to happen, not only must senior officials and scientists engage more closely with the work of the rangers and bureaucrats, but the latter must also learn to voice their own concerns. For this purpose, these groups should firstly, be able to embark on 'perspective-making', that is, recognize their own role within the organization and solidify the body of knowledge that they have developed (Boland et

al., 1995). This perspective-making could involve, for instance, the recognition that the work of bureaucrats and rangers involves not only the following of pre-established rules, but also complex interactions with farmers, lawyers, senior officials and GIS experts. Based on such self-understanding, rangers and bureaucrats would then be able to make more compelling arguments in the negotiation of shared solutions for the breakdowns they face.

Finally, and most importantly, all the groups involved should develop the ability to learn and adapt quickly to new situations and demands. To this end, the government should encourage and support liaisons, namely the actors able to participate in a legitimate way in different groups in addition to brokerage solutions, innovations and knowledge (Levina et al., 2005; Wenger, 2000). In this way, when breakdowns occur, the government can rely on the pre-existing links cross-cutting the organization in order to identify the relevant actors and negotiate solutions. Further to this, the government should provide more formal training on aspects of the work carried out across boundaries. This would involve, for instance, the provision of basic training on GIS for attorneys and bureaucrats, as well as training on environmental legislation for GIS experts. The aim of this training strategy is not to blur the division of labor within the Brazilian government so that, paraphrasing Marx and Engels (1845/1970: 54), an official could be a ranger in the morning, a GIS expert in the afternoon and an attorney at night. Rather, as with the broad political negotiations mentioned above, this strategy aims to foster the diffusion of area specific vocabularies (e.g. polygons, temporal resolutions, legal reserves, materiality) which could provide opportunities for the emergence of a better understanding of the practices and perspectives across boundaries. In this, way, when breakdowns occur, the negotiation between the different parts involved would involve fewer misunderstandings and frustrations.

As with the move from dissimulation to negotiation and from imposition to co-construction, the government will have to face different challenges in order to learn how to mend breakdowns in a constructive way. Initially, in order to recognize breakdowns and to solve them locally the government will need to challenge the notion that specific technologies and policies are deterministic solutions to deforestation. As shown above, there is a strong sense among scientists and senior officials that the development of GIS applications with a better resolution and closer to the real-time will lead to reductions in deforestation. In order to actively identify

and mend the breakdowns emerging from the use of these systems, the government will need to accept that these systems may fail and cause negative implications. In addition to this, senior officials will also need to reflect on their tendency to silence dissident voices and accept failure as part a natural part of its activities (Chapman, 2004). At present, it is very difficult to get forest rangers, bureaucrats or even local managers to voice their concerns and make requests to their superiors since they fear that they may be punished for doing so. This suggests that in order to develop the ability to actively mend breakdowns, the different groups involved will need to learn how to indicate issues and solve them in a more constructive way.

Notwithstanding this, the three directions outlined above do not preclude the important role of GIS. Different studies have reported that GIS and other technologies may foster collaboration by acting as a boundary object, and there is no reason to believe that this finding may not be applicable to the Amazon as well (Barrett et al., 2010; Boland et al., 1995; Harvey, 1997; Hayes, 2001; Levina et al., 2005). In the case of the Amazon, the GIS-based deforestation data provided by INPE may be an important basis for political negotiation by allowing the discussion of compromises as regards the proportions of the region that should be protected or farmed. Similarly, GIS could be a starting point for the co-construction of policies and technologies by allowing, for instance, the use of participative mapping in order to integrate suggestions from different scales (i.e. local, regional and national) and epistemologies (Puri, 2007; Sieber, 2006). Finally, the data provided by GIS might act as a starting point to identify the presence of breakdowns within the government. Calculations, such as the proportion of deforestation plots detected by INPE which eventually become a fine and the length of time required for the analysis of an environmental license are good indicators that forest rangers and bureaucrats currently do not have the resources necessary to enforce the law. However, for GIS to become a boundary object able to foster collaboration in the Amazon the groups involved should be willing to go beyond its objectifications and attempt to understand the root source of the problems. This suggests that the eventual role of GIS in collaboration cannot be disassociated from the emergence of collaborative practices that involve learning, mutual understanding and openness towards forms of knowledge found across boundaries.

Chapter 8: Conclusion

8.1 Introduction

Having presented and discussed the findings of this research, it is now possible to summarize some of the potential contributions that emerged from the thesis and to provide suggestions for future research. With this in mind, the next section indicates the empirical contributions which specifically relate to the understanding of GIS in the Amazon. Closely connected to this, the third section shows the practical contributions of my activities in the Amazon as a researcher. The fourth section then presents the insights this thesis has offered to the notion of boundary objects. Finally, the last section of this chapter concludes the thesis by suggesting some topics for further research.

8.2 Empirical contributions

The empirical data and related discussion proposed above could contribute to the debates concerning the Amazon in different ways. Firstly, as seen in Chapter 1, there is considerable amount of literature about the process that led to the formation of the current environmental policy in the Amazon (e.g. Hecht et al., 1989; Lemos et al., 2008; Mello, 2006). Yet, the overall impression provided by the current literature is that scientists are detached observers of the region who provide sound evidence for the political debates between the various groups, without necessarily being influenced by these dynamics (for exceptions see Lahsen, 2009; Schor, 2008). This thesis went beyond the current literature by emphasizing how different groups (including scientists) actively reframed scientific evidence in order to reinforce their own political positions. In this way, this research highlights the importance of understanding the role of politics in the production of scientific evidence, and in particular how the reframing of GIS data has been one of the key elements in shaping the policy towards the Amazon in the last few decades.

Secondly, this thesis has also contributed to the debate on the establishment of GIS in the Amazon. Different studies in the current literature tend to relate the diffusion of GIS in Brazil to its technical qualities, such as precision and low data collection costs

per square kilometer when compared to ground-based methods (e.g. Fearnside, 2003; Fonseca et al., 2009; Fuller, 2006). While it is clear that the technical features of GIS are important, it is also possible to observe that the positivist roots of the Brazilian government help to explain why this technology came to dominate the provision of data for the Amazon. Furthermore, this study found that the establishment of GIS was an active process involving the negotiation of shared uses of GIS between scientists, members of NGOs and governmental officials. Hence, the thesis suggests that the establishment of GIS in the Amazon, rather than being a straightforward process, was shaped by long-term historical factors, conflicts and reconfigurations.

Thirdly and most importantly, by showing how the deforestation control policy is actually enforced in the Amazon, this study has also challenged the stereotypical and technological deterministic views currently found in the literature about the region (Abler, 1993; Esty et al., 2005: 425; Fuller, 2006; Wise et al., 2008). In particular, it emerged from a close examination of work practices that in order for a deforestation point as detected by the GIS to become a fine or an environmental license, rangers and attorneys have to enact a set of complex and often neglected joint work practices. The neglect of these practices, in turn, is leading to growing tensions between the different groups in the Amazon since the government is currently unable to negotiate policies, co-construct laws and technologies and mend the breakdowns that are inherent in complex organizations such as the Brazilian government. Moreover, the findings of this thesis pose a serious challenge to the notion that GIS deterministically leads to reductions in deforestation. In particular, the findings presented above suggest a close link between the political context in which GIS is used and the outcomes generated by this technology. Therefore, it was suggested that even though it is clear that GIS has improved many practices in the Amazon, the current overemphasis on this technology can also contribute to increases in deforestation.

In short, this thesis has contributed to the empirical literature on the Amazon by showing the importance of attending to the history and practices of actors such as scientists, forest rangers and bureaucrats, who so far have been largely ignored. Here, the particular set of methods adopted by this research certainly cannot match the ability of GIS-based deforestation assessments to generate findings valid for the whole Amazon (e.g. Aguiar et al., 2007; Soares-Filho et al., 2010). Similarly, the findings of this research cannot be compared with the in-depth ethnographical

accounts of the culture of indigenous populations living in the region (e.g. Lévi-Strauss, 1955/1988; Lima et al., 2005b). Furthermore, given the time and access restrictions it was not possible to give due attention to all relevant aspects of the Amazon (for the limitations of this research see Section 3.6). Nonetheless, this thesis suggests that in addition to Amazon-wide and population-specific accounts, the literature urgently needs more studies that consider phenomena at organizational level across multiple sites in order to reveal the challenges involved in ensuring the long-term preservation of the rainforest.

8.3 Practical contributions

In Chapter 1 it was stated that this thesis aims at not only generating knowledge about the role of GIS in the Amazon, but also contributing somehow to the long-term preservation of the rainforest. An assessment of the impact of any intellectual work upon a complex organization such as the Brazilian government is a difficult task. Given the myriad of actors trying to influence the government, it is often impossible to trace direct cause-effect relationships. Furthermore, organization change often involves 'muddles, misunderstandings, false starts, conflicts and loose endings' which makes it difficult to understand whether certain changes are superficial and temporary or deep and long lasting (Blackler, 2006: 1845; Engestrom, 2001). Nonetheless, there is evidence that the suggestions stemming from this research were able to influence to some extent the actions of a number of important actors in the Amazon. Here, it is possible to identify practical contributions at three different levels.

At a broader policy level, this study attempted to promote the negotiation between the groups defending the environmental preservation of the Amazon and the groups with economic interests in the region via a law proposal. This contribution was possible thanks to a deputy from the Green Party whose family has been close to mine for many years. Following a series of informal conversation with this congressman about the initial findings of my research, he asked me to draft a legal proposal aimed at improving the current environmental policy in the Amazon. Under his supervision and with the help of the legal team of the Brazilian congress, I drafted a law proposal for the creation of a mechanism that binds the amount of money the federal government transfers to state governments to the yearly deforestation rates in their territories. Hence, this legislation proposes the creation of an intra-governmental

carbon credit scheme that would be able to benefit the states willing to preserve the Amazon. More significantly, and in line with the aim of moving from dissimulation to negotiation mentioned in the previous chapter, in the section of the proposal that justifies the new law, I pointed out that are:

> [M]ainly the states of the Legal Amazon that pay the costs for the land-use restrictions imposed by the Forestry Code […] Therefore, there is an economic interest behind the neglect of the federal environmental policy. [This law creates a] mechanism that financially compensates the states that are willing to align themselves to the country's environmental policy, this being geared towards the environmental preservation of the Amazon rainforest. (PLP-435/2008: 6)

The different commissions relating to this matter have already approved the law proposal, which is currently waiting to be voted on by the plenary session of the Chamber of Deputies. However, even if this law is not voted for or fails to be approved, it is significant that a deputy from the Green Party (and his colleagues who analyzed the law proposal) were willing to subscribe to the idea that the federal and state governments live within different political and economic contexts and that it is important to create policies that acknowledge and attempt offset these differences.

This research has also tried to convince senior officials and scientists about the importance of moving from the imposition to the co-construction of policies and technologies by holding seminars in INPE, IBAMA and at the UN headquarters in Brasilia. Here, the suggestions were received very differently in these sites. As mentioned above, many INPE scientists disagreed with the argument that they should attend more closely to the practices of forest rangers and other groups that use their GIS. Rather, they defended the idea that INPE is a research institute and must be concerned with improvements of the technical aspects of the technology, not how it is used. Similarly, at the UN headquarters, some policy-makers from the Ministry of the Environment disagreed with my suggestion that they should attend to the practices of farmers in order to develop better policies. At IBAMA, in contrast, my arguments were received more sympathetically. One IBAMA manager even praised me as a 'virtuoso for being able to come to us and talk about our practices' in a constructive way (Field note #24/2010) despite their disagreement with some of some of the points made in the presentation. Even if it was not possible to identify a direct outcome from these seminars, the fact that some influential senior officials and scientists have agreed, contested or discussed the ideas stemming from this research provides an

indication that a reflection or even a change process may be under way (Engestrom, 2001).

There is also evidence that this research could have influenced particular law enforcement practices. As pointed out in the analysis of SEMA's practices, the farmers from Mato Grosso are currently benefiting from the passive registration strategy adopted by the state-level agency. This means in practical terms that farmers can register for the GIS-based licensing system only when they can obtain benefits such as authorizations for deforestation and access to cheaper bank credit. After I indicated this issue in the seminar and the final report related to the consultancy that I gave to the United Nations, the official responsible for advising the government on how to carry out major GIS-based licensing included in his draft a specific rule to tackle this matter. In particular, the document states that government contractors would only be paid if they managed to cover the majority of properties in a given municipality. In this way, the federal government created a direct incentive for a comprehensive registration of properties within GIS, restricting in turn the instrumental use of these systems.

It was also possible to relate this study to a potential change in how SEMA mends its breakdowns. Following an invitation from a UN official, I was able to participate in a policy-making meeting that took place at SEMA where it was possible to make suggestions and to discuss with SEMA officials how to improve Mato Grosso's deforestation control strategies. Even though some points that I made were ignored or contested, I was able to convince particular officials about the importance of exchanging experiences with rangers and bureaucrats. In particular, I reported on the difficulties that these groups face in order to enforce the current law to the director of legal affairs at SEMA and some of his colleagues. He firstly proposed to create more regulations in order to tackle the issue, but following my argument that knowledge sharing requires engagement from both parties, he agreed to include my suggestion in the blueprint of SEMA's deforestation control policy. Specifically, under the section dealing with the 'improvement of environmental law enforcement' it was included a 'training and exchange program' aimed at providing training in environmental legislation and fostering integration between forest rangers and attorneys (SEMA, 2009: 53).

It is still too early to relate any of the practical contributions mentioned above to improvements in the way the government uses GIS to formulate and enforce its policies in the region, let alone broader aims such as ensuring the long-term preservation of the Amazon. Nonetheless, these small changes and the positive response of some actors to the ideas stemming from this thesis provide a message of hope. This suggests that studies in the social sciences, such as this one, not only provide a deeper understanding of the Amazon but also may become instruments of change which could contribute to the adoption of more collaborative forms of joint work and lead to improvements in governmental practices in the region.

8.4 Theoretical contributions

As mentioned in Chapter 1, this doctoral research is mainly aimed at providing empirical and practical contributions to the Amazon. However, by drawing upon different bodies of literature and discussing them in relation to the role of GIS in the Amazon, other insights also emerged that might be relevant to ongoing debates concerning the notion of boundary objects. In particular, it is possible to relate the findings of this thesis to: the understanding of the establishment of boundary objects, the role of objectification in the functioning of boundary objects and the conceptualization of this notion in relation to different forms of joint work.

The establishment of boundary objects

The findings of this study offer particular insights into the social dynamics behind the establishment of boundary objects by emphasizing the role of political flexibility, contested negotiations and pre-existing practices. Specifically, the study suggests that the ability to embed political interests in artifacts plays an important role in the establishment of boundary objects. The current discussion surrounding the establishment of boundary objects tends to focus on the functional flexibility of objects, namely their being flexible enough to suit the information and work needs of the different groups involved in joint work (Bowker et al., 1999; Star, 2010; Star et al., 1989). In addition to this functional flexibility, the findings of this research also suggest that the political flexibility of these objects plays a significant role. Here, the possibility to tailor objects to support specific (and even opposing) political agendas appears to be a key attracting point for the acceptance of artifacts across boundaries.

This thesis also provides insights into the role of social practices in the establishment of boundary objects. Some studies argued that the establishment of a boundary object is closely related to the negotiation and emergence of a joint field of practices (Harvey et al., 1998; Levina et al., 2005). The thesis confirms this assessment by showing how GIS has been the target of a negotiation process involving concessions from different groups and the emergence in some instances of a mutually agreed shared use of GIS. At the same time, however, the outcome in this study showed that these negotiations were much more partial and contested than the examples provided by the literature. This finding suggests the importance of negotiating practices as a way of mitigating the tensions related to the political flexibility of GIS, even if the outcomes of these negotiations are only provisional and do not lead to a consensus.

The findings above suggest that the emergence of boundary objects may also be related to the presence of key, pre-existing practices and values. Specifically, it was shown above that the widespread use of GIS technology in the Amazon was partially enabled by presence of map-reading and basic mathematics skills as well as by the affinity between the values embedded in GIS and the positivist roots of the Brazilian government. This explains, for instance, why GIS became more diffused in Brazil than in other developing countries, such as India (Barrett et al., 2001; Walsham et al., 1999). From this, it is also possible to propose that the emergence of a new field of practice necessary for the establishment of a boundary object should be understood as a process involving the appropriation of elements (i.e. values, practices, visions of the future, etc…) which may act as allies in this endeavor.

Both points taken together call for the importance of examining the history as well as the practices of artifacts in order to understand why certain artifacts become boundary objects while others fail to do so. Different authors have already highlighted the importance of understanding the practices behind boundary objects. Hence, this study can be understood as answering and confirming the relevance of these calls (Barrett et al., 2010; Levina et al., 2005; Trompette et al., 2009). However, very little has been said about the relationship between history and boundary objects to date. In particular, even though the original study from Star and Griesemer (1989) is essentially a historiography, this method has been largely neglected by the literature that followed. By endeavoring to study the history behind the establishment of GIS in the Amazon, this study suggests that the study of boundary objects could benefit from attending to

both the recent events regarding the introduction of artifacts and the broader historical context in which they are used. In this way, this study indicates the relevance of the *longue durée* of social contexts (Flyvbjerg, 1998; Giddens, 1986) as well as the biography of technological artifacts (Williams et al., 2009) in order to understand boundary objects.

Boundary objects and objectification

The case study also gives insights into the role of objectification in the functioning of boundary objects. As the name suggests, the notion of boundary objects is closely related to the process of objectification. For instance, referring to the original case study of Star and Griesemer (1989), it is possible to argue that the state of California, animals and habitats have to be objectified into maps, specimens and inscriptions in a field note for these elements to function as boundary objects. Here, even though the literature on GIS and technology more generally contains studies dealing with objectification, these discussions have not yet been properly related to the notion of boundary objects (Kallinikos, 1995; Lefebvre, 1991; Pickles, 1995b). Hence, by empirically examining the relationship between objectification and boundary objects, this study provides particular insights into ongoing debates in the literature.

Moreover, recent literature reviews on the notion of boundary objects showed that much of the literature following the original article of Star and Griesemer's (1989) pay little attention to the dynamics that make some artifacts act as a boundary object (Barrett et al., 2010; Levina et al., 2005; Trompette et al., 2009; Zeiss et al., 2009). Within this, an aspect from the 1989 article that was seldom explored by the literature is the relation between the informatic structure and the dynamic between ill and well-structured uses of boundary objects (Star, 2010; Trompette et al., 2009). This study contribute to this debate by showing empirically how different groups used GIS to objectify particular aspects of the Amazonian reality and their own, and how this process helps joint work across boundaries. In particular, it showed how the objectification of locations into latitude and longitude and of complex territories into polygons allowed groups operating at different scales to work together while still being able to refer to each other's work unambiguously. Hence, this study has shown empirically how the specific informatic structure of GIS contributes to the dynamic between ill and well-structured uses while maintaining a single identity – one of the crucial aspects of joint work across occupational and spatial boundaries.

In addition to explaining the functioning of boundary objects across locations and professional groups, this study has also highlighted the role of objectification in the use of boundary objects across political boundaries. Here, various authors have already discussed the idea that objectification leads to the creation of more trustworthy statements (i.e. objective facts) in legal and scientific practices (Bowker et al., 1999; Daston, 1992; Garfinkel, 1967; Lefebvre, 1991; Neyland, 2007; Pickles, 2004), while other authors have highlighted the importance of trust in the cooperation spanning across boundaries (Alter et al., 1993; Heckscher et al., 2006; Powell, 1990). Notwithstanding this, very little has been said about the role of objectification to achieve trust in boundary objects, and the implication of this to joint work. Hence, by showing how trust was achieved in historical (i.e. positivist roots) and performative (i.e. erasing of agency) ways, the study suggests that this dynamic should be considered as an important element in the functioning of boundary objects in practice; this is particularly the case for situations involving stark political conflicts across boundaries.

Further to this, the study also provides insights into the recent debates on the potentially contradictory character of boundary objects. The current literature is dominated by accounts which highlight how artifacts may facilitate joint work practices and, in some cases, may even be the basis for knowledge sharing across boundaries (Boland et al., 1995; Harvey et al., 1998; Zeiss et al., 2009). More recently, however, some authors have shown how, depending on the practices and social context in which boundary objects are used, they may have negative effects and even hinder collaboration (Barrett et al., 2010; Barrett et al., 2007; Carlile, 2002; Levina et al., 2005). Therefore, expanding on this literature, the thesis has highlighted how the overemphasis on GIS for joint work may also lead to boundary-blinding, the inability of some actors to understand the practices, outcomes and motives across boundaries and from that to collaborate effectively. By emphasizing the ways in which boundary objects contribute to boundary blinding this study also suggests that boundary objects may hinder joint work in ways that are not directly related to power play or other political issues which have been already explored by studies dealing with the negative effects of boundary objects.

Finally, the thesis holds that in some cases the role of a boundary object as both an aid and an obstacle to joint work cannot be separated from each other. The current

literature on boundary objects highlights the fact that the outcome of boundary objects either helps or hinders collaboration at any given time and in any context, precluding the possibility of hybrids or more fuzzy situations. Furthermore, the social dynamics indicated as the elements hindering collaboration (e.g. politics, stereotyping) seem to be unrelated to the dynamics providing opportunities for collaboration across boundaries (e.g. flexibility, single identities, shared practice). The findings of this thesis suggest, however, that the same process of objectification which helps joint work by providing mobility, scalability and trustworthiness also creates tensions through fostering boundary-blinding. Hence, the thesis suggests it is important to observe the extent to which the tensions created by objectification are being tackled in order to understand the outcome of boundary objects in practice.

(Re)conceptualizing boundary objects

This thesis also contains findings that might be useful for the debate concerning how boundary objects should be conceptualized. On the one hand, the notion of boundary objects tend to be seen in organizations and management studies (OMS), mainly as a way to conceptualize the role of artifacts in fostering collaboration and knowledge sharing. Here, when a boundary object fails to yield these positive dynamics, it is said to be either hindering joint work or it is no longer a boundary object in practice. On the other hand, Zeiss and Groenewegen (2009: 92), arguing from a science and technology studies (STS) perspective maintained that many OMS scholars have largely misunderstood the original intentions of Star and Griesemer (1989). In particular, the authors pointed out that the original notion focused on cooperation and that by relating the notion of boundary objects to collaboration/knowledge sharing, the OMS literature 'contravened certain STS sensibilities' (*ibid*: 92).

The particular interpretation of the notion of boundary objects adopted by this thesis suggests a potential way out of this deadlock. It should be noticed that the original paper of Star and Griesemer (1989) was mainly directed towards explaining how artifacts may be involved in the way different people work together outside a strongly aligned actor-network. Thus, it could be argued that the authors intended to describe how different people might work together in non-coercive contexts, without further specifying what these contexts might be. Hence, the linkage between boundary objects and knowledge sharing or collaboration can be seen as a fruitful extension of the original notion, rather than a betrayal of the intentions of Star and Griesemer

(1989). At the same time, however, it should be stressed that Star and Griesemer (1989), as well as other studies in the STS literature, also use the notion to describe instances of joint work that do not necessarily fit with the engaged and transformative forms of collaboration featured in the OMS literature. This suggests that at its core, the notion of boundary objects does not imply any specific form of joint work, but rather a wide variety of social interactions, ranging from the superficial exchange of money to engaged forms of perspective-taking.

While, at a first glance, this (re)conceptualization of the notion of boundary objects may seem to be too generic or ambiguous, this thesis provides some empirical evidence to demonstrate that this is not the case. In particular, the research has shown empirically that the dynamics between ill and well-structured uses, informatic structures and interpretive flexibility may help to explain not only collaboration but also cooperation and coordination. Additionally, by separating the notion of boundary objects from a specific type of joint work, the thesis has also pointed to potentially fruitful theoretical connections. There is a rich literature that comments on how joint work may involve particular levels of engagement, these ranging from instrumental coordination to transformative collaboration (Collins et al., 2007; Engestrom et al., 1997; Heckscher, 2007), and how different organizational contexts demand different forms of joint work in order to function effectively (Adler et al., 2006; Chapman, 2004; Spinuzzi, 2008). Based on these bodies of literature, this thesis has shown that the inability of the government to tackle boundary-blinding in the Amazon is related to a lack of collaboration between groups and that this issue is further aggravated by the complex and distributed character of the Brazilian government. In this way, the thesis suggests that the outcomes stemming from the use of boundary objects (e.g. increased knowledge sharing) should be the topic of empirical investigations which are attentive to the types of joint practices and organizational contexts involved rather than being a taken-for-granted aspect of the notion of boundary objects.

8.5 Suggestions for future research

As well as illuminating particular outstanding questions related to the role of GIS in the Amazon and exploring the functioning of boundary objects, this thesis has also touched upon some topics that could constitute the basis for future research. It was suggested above that the Brazilian government should go beyond the instrumental

forms of joint work and attempt to foster collaboration in different ways in order to counter the boundary-blinding promoted by the overemphasis on GIS. However, these are hypotheses that still need to be tested empirically in the Amazon. In particular, it would be important to carry out longitudinal research aimed at: observing how objects relate to different forms of joint work, how objects transform boundaries (rather than simply travel between them) and the challenges relating to the transition towards collaboration. Moreover, in addition to observing these phenomena passively, it would be important to take a more active role in influencing the direction of change. Given the constant political changes at both IBAMA and SEMA, a research of this kind will only be possible with the institutional support of a relatively neutral yet influential organization, such as the UNDP in Brazil. Only with continuous support would such research be able to be simultaneously provocative to bring change, while being protected against the political conflicts that it is likely to trigger.

In future research it would also be important to go beyond the law enforcement work of IBAMA and SEMA in Mato Grosso, and attempt to understand the role of GIS in the broader initiatives aimed at tackling climate change. In recent years, diplomats, scientists, environmentalists and politicians have discussed ways of mitigating climate change at global level. One of the most emphasized solutions emerging from these debates is the attribution of a financial value to the emission of greenhouse gases, also known as carbon credits. The idea behind carbon credits is that by creating a market it will be possible to reduce greenhouse emissions at global level at the lowest cost. With this purpose in mind, in 2008 the United Nations initiated negotiations for the creation of UN-REDD, a program aimed at reducing the emissions from deforestation and forest degradation in exchange for carbon credits, which according to specialists, is the most cost-effective way of cutting greenhouse gas emissions (IPAM, 2008; Nepstad et al., 2008; Stern, 2007: 537). In this way, countries like Brazil could receive funds from other countries in exchange for substantial reductions in their historical deforestation levels, or incur debts should deforestation increase. Furthermore, a mechanism of this kind would allow countries such as Germany to off-set some of the emissions relating to highly productive industries (in terms of economic output per ton of carbon emissions) by paying compensations for the economic losses incurred from the avoidance of activities with low productivity such as extensive cattle ranching in tropical forests.

GIS technology has been at the heart of UN-REDD since the very inception of the program. In the official reports and academic studies discussing the design of this mechanism GIS technology is often depicted as the main way to measure carbon emissions, to estimate the emissions' base line and from this to calculate the carbon credits or debts of each country (Kaimowitz, 2008; Kintisch, 2007; Leeuw et al., 2010). Hence, the future of UN-REDD is closely linked to the successful establishment of GIS spanning even more contexts than the ones depicted in this thesis. At global level, it will be necessary to have a series of GIS-based national monitoring systems which are trusted by the international community. Meanwhile, at a national level, the different administrative spheres will have to agree upon the same set of GIS methodologies and systems in order to avoid endless conflicts over resource distributions. Finally, at local level GIS will need to provide the link between the people living in the Amazon and the carbon credit market.

Notwithstanding this, the establishment of UN-REDD is likely to be more challenging than presently envisioned by scientists and policy-makers. In particular, while current carbon stock measuring methodologies focus on achieving increasing levels of precision (including in some cases detailed measurements in the ground), practical issues such as the need to cover vast territories and the lack of resources for the acquisition of expensive equipment as well as the hiring of specialized personnel have not yet been properly taken into account (Brown, 2002; Kintisch, 2007; Nepstad et al., 2009: 1350; Schroeder et al., 1995). Furthermore, many scientists fail to recognize that the establishment of a GIS-based system for the monitoring of carbon in forests is going to involve not only technical but also political skills (Lahsen, 2009). For instance, one of the main points that prevented the approval of a binding climate change regime during the United Nations Conference held in Copenhagen in 2009 was the lack of agreement on whether carbon monitoring (which includes emissions from deforestation) should take place at national level (as defended by the Chinese) or global level (as desired by the USA)(Lee, 2009). This suggests that to date scientists seem to ignore the political and practical dimensions of the role of GIS in UN-REDD.

There are also some important unanswered questions concerning how the carbon credits are going to be shared and distributed at local level. On the one hand, many farmers and local politicians suggested in their interviews that they expect to benefit from the creation of a carbon credit market. Some farmers even reported that they are

already protecting some of their forests based on the assumption that these may yield financial gains in the future. However, on the other hand, influential scientists and policy-makers suggested in their interviews that the carbon credit must mainly go to native Indians, rubber tappers and other groups that historically have had sustainable lifestyles. For instance, one of the leading scientists in the discussion of UN-REDD in Brazil and in the IPCC (the UN scientific panel on climate change) very strongly affirmed in his interview that the program will not pay cattle rangers for any deforestation they have avoided since this group is unworthy of help (Interviewee #36, 2008).

This all suggests that UN-REDD may be inclined to repeat some of the mistakes that led to the current shortcomings of the deforestation control policy in the Brazilian Amazon. Therefore it would be important to research UN-REDD from a perspective similar to the one adopted in this thesis. Specifically, it would be valuable to investigate the role of negotiation, political flexibility and the epistemological affinity in the future establishment of GIS as a boundary object in UN-REDD. Furthermore, it would also be crucial to observe how scientists, policy-makers and local populations use GIS to work together and to identify eventual boundary-bindings and growing tensions. Finally, it would also be necessary to try to influence the dynamics between the groups involved in order to avoid the tendency of creating technologies and policies that are infeasible in practice. In this way, research on this topic could contribute to the emergence of a mechanism that is more likely to help in the tackling of global warming.

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