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Beyond SDI: Integrating Science and Communities to Create Environmental Policies for the Sustainability of the Amazon*

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Abstract

This paper will explore ways to go beyond the traditional SDI (spatial data infrastructures) in the direction of the Digital Earth, with the objective of supporting environmental policies that will lead to sustainability. We use the Amazon region as a starting point for the discussion. Environmental policy making for a place such as the Amazon has to take into account that phenomena occur and are modeled in various geographic scales, ranging from microbiology to planetary climate impacts. There are also multiple and sometimes conflicting views on the same reality, including the many scientific disciplines, governmental and non-governmental views, and the view of the local populations. Currently, the combination of technologies, people, and policies that defines an SDI is probably the best approximation we have to solve these problems, but some important elements are missing. A broader SDI would be an enabler for understanding space, not only delivering general-purpose maps, but disseminating spatial data to support policies for sustainable development. We think it is necessary to go beyond SDI to integrate science and communities in the effort of creating, enforcing, assessing, and revising environmental policies. We discuss the limitations of current SDIs with regards to data and information flow, semantics, and community building. We also review the information needs and modeling challenges for SDIs when used as a support for environmental policy making.

Keywords: SDI, environmental policy making, Digital Earth, Amazon, Sustainability

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1 INTRODUCTION

Environmental policy making requires a substantial amount of information, ranging from the scientific point of view (in many disciplines) to the experience of the local population. Scientists constantly gather data, perform analyses, and generate information and recommendations for policy makers. Wide access to that information is required, so that not only policy makers can decide on more solid grounds, but also the targets of policies can understand the reasons behind governmental action. Clear indicators of progress must be in place, so that the effectiveness of policies can be assessed. People in general must also be allowed to participate in a more direct and active manner, getting to know facts about the region, expressing themselves, and contributing to find solutions. In this scenario, it is evident that information must flow and connect as many people as possible.

In many aspects, this kind of arrangement exceeds the current concept of a traditional SDI (spatial data infrastructures). Such an SDI would be different from the traditional approaches, in which SDIs operate mainly as automated map distribution systems (Masser 2005). In the approach we are aiming for, a broader SDI would be an enabler for understanding space. The SDI would not only deliver general-purpose maps, but disseminate spatial data to support sustainable development policies. We think it is necessary to go beyond SDI to integrate science and communities in the effort of creating, enforcing, assessing, and revising environmental policies.

This paper will explore ways to go beyond traditional SDI in the direction of the Digital Earth (Craglia, Goodchild *et al.* 2008). This poses new research challenges for geoinformatics and other fields of knowledge. We chose the sustainability of the Amazon as a prime example of the breadth of scope and of the width of the reach of problems that must be faced in the next years[1].

The Amazon rainforest covers, in Brazil alone, an area of over 4 million km^2. This extensive territory, about the size of the 27 countries of the European Union put together, was only occupied along the rivers and coastal areas until the 1950s. In the next two decades, the Brazilian military government funded initiatives to populate the region and to integrate it with the rest of the country. After the 1990s, occupation continued to grow intensively, this time driven more by economic interests than by Federal government subsidizing (Becker 2005). Due to the intensive pace of human occupation in the last decades, about 16% of the

[1] Many of the research questions and answers presented here evolved from discussions held at a workshop on SDI for the Amazon, organized by the authors in December 2008 (http://www.personal.psu.edu/fuf1/SDI_for_the_Amazon/Workshop%20SDI%20for%20the%20Amazon.html).

original forest have been removed, and current deforestation rates are still high. The annual rate of deforestation in the present decade averages at about 19,000 km^2, even though there are large variations throughout the period (INPE 2008).

The Amazon rainforest region currently houses more than 20 million people, who require access to health, education, and economic well-being. Multiple actors and institutional arrangements shape the different change vectors in the region, and originate from distinct socioeconomic, biophysical, and political contexts. As a result, deforestation rates and patterns of land use also vary in space and time (Alves 2002). Most of the Amazon's economy is driven by activities such as logging, mining, cattle ranching, and soybean farming, which frequently involve illegal deforestation to obtain prime land. Locals currently regard the forest as being "*worth more dead than alive*".

The institutional arrangements in the Amazon provide the key to this situation, which caused land change in the region in the last 40 years. These arrangements define how natural resources are controlled and owned, thus defining the rules and norms of their use. Moving away from the current situation requires changing the economic and social organization of the region. The Amazon needs a new set of policies and social organizations so that sustainable practices are supported and promoted, and predatory land use is inhibited; maybe more than that, many current practices must become economically uninteresting. In other words, the forest must be seen as being *more valuable alive than dead*.

But in order to be able to create and maintain policies for a sustainable Amazon, we need an organized spatial information system from which the required data may be obtained. The availability of environmental, biodiversity, socioeconomic, and land information data at the appropriate resolutions will allow researchers and policy makers to find ways of making the forest worth more alive than dead. In this sense, we refer to such an information system as "SDI for a sustainable Amazon".

This paper is organized as follows. Section 2 presents the definition of sustainability science, along with general questions that orient research in that direction. Section 3 discusses SDI limitations for the objectives of this paper, first looking at the flow of data and information, then covering semantics issues. From this, we propose an SDI enhancement agenda, towards a new generation of Digital Earth tools and resources. Section 4 presents some additional challenges, regarding specifically the Amazon. Finally, Section 5 presents our conclusions.

2 SUSTAINABILITY SCIENCE

The Amazon is a prime example of the complexity and diversity of the challenges involved in sustainability research. The science areas necessary to address sustainability are so many that only a solid interdisciplinary approach can succeed. One of the attempts to understand sustainability in an interdisciplinary way is what is called today *Sustainability science* (Kates, Clark *et al.* 2001). Sustainability science purports to understand, integrate, and model nature and society. Since most of the interventions on the environment are human choices, we need modeling tools that capture the representation of the world as seen and modified by human beings.

Sustainability science focuses “on the dynamic interactions between nature and society, with equal attention to how social change shapes the environment and how environmental change shapes society” (Clark and Dickson 2003). The main questions that Sustainability Science wants to answer are:

- “How can those dynamic interactions be better incorporated into emerging models and conceptualizations that integrate the Earth system, social development, and sustainability?

- How are long-term trends in environment and development reshaping nature-society interactions?

- What factors determine the limits of resilience and sources of vulnerability for such interactive systems?

- What systems of incentive structures can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories?

- How can science and technology be more effectively harnessed to address sustainability goals?” (Clark 2007)

When applied to the Amazon, with its huge size, diversity of environmental conditions and multiplicity of actors, with points of view ranging from the political to the scientific to the common citizen, Clark’s questions pose enormous requirements for information science and technology, and for GIScience in particular. Currently, the combination of technologies, people, and policies that defines an SDI is probably the best approximation we have in that direction. However, some elements are missing from the SDI general schema, as we will point out in the next sections.

3 SDI LIMITATIONS

The set of technologies that support SDI is noteworthy for its interoperability potential. Interoperability allows joining several different data-providing organizations, without interfering with their technological choices, production processes, or internal culture. In fact, providing interoperable access to data is only a first step for SDIs, since there are initiatives towards creating information services (Schut and Whiteside 2005) and service chains (Kiehle, Heier *et al.* 2007), in a path that leads to *loosely-coupled geographic information systems*. However, several limitations come to mind as we think about the next step, i.e., on how the wide availability of spatial data and information can actually make a difference for complex problem-solving situations, involving multiple actors, with different (and often conflicting) world views.

Therefore, even though the current framework for SDI technology, based mostly on OGC standardized components and Web services (Lisboa Filho 1997; INSPIRE 2002), represents a departure from the days of offline data exchange, there is much more to be done. There is a definite call for more interaction, to support cooperation, discussions, and community building. People must be motivated to contribute and to participate, and better tools for data discovery must be developed, especially considering semantic aspects, since interdisciplinarity is a necessity. We will conduct the discussions in the remainder of the article considering three actors (*citizens*, *scientists* and *policy makers*), and observing how they are expected to interact towards the creation of environmental policies that will lead to a sustainable Amazon.

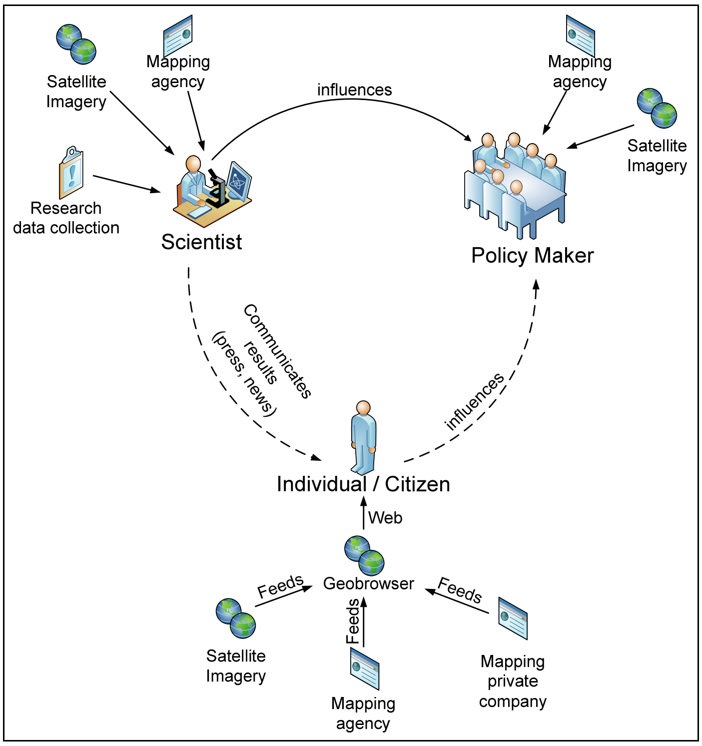
There are also concerns on privacy and security in SDIs, which are not easily answerable. Scientists usually impose restrictions on the access to data they produce – if it was so hard and costly to collect the data, why should I make them easily available to others? Furthermore, some scientists may consider their data to be sensitive, in terms of possible commercial applications or misuse. As a result, much spatial data is currently published only as PDF files or in other formats that preclude a direct use by the legitimately interested scientist or citizen. Raw data must usually be requested directly to the scientist or institution that generated them, following a protocol that can include an agreement on co-authorship in future publications, for instance. An SDI for the Amazon should consider these aspects, along with the diversity of data potentially available, in order to be able to foster actual cooperation in a practical and efficient manner (Amaral 2008).

3.1 Data and Information Flow

Consider the pre-SDI setting presented in Figure 1, in which traditional data sources for each involved actor are represented. Notice that, even though there are some common sources, information generated by each actor hardly ever gets to the other actors, since there are significant semantic gaps among them.

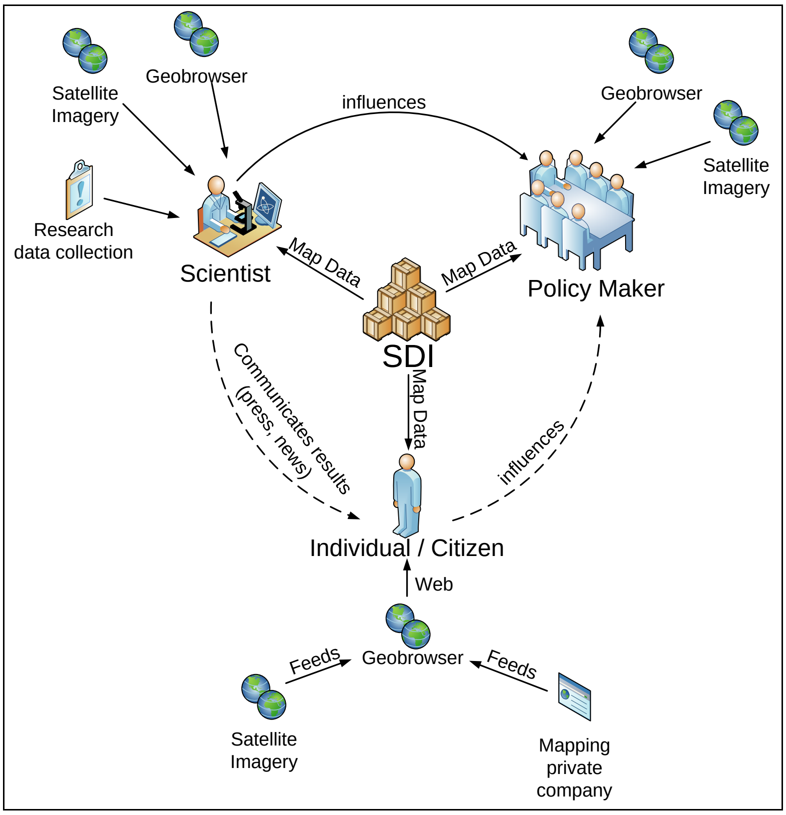
For instance, scientists use satellite imagery to determine last year's deforestation rate. The results of lots of man-hours of intensive and highly specialized labor reach the press as a single number. The concerned citizen who lives in the Amazon learns about it in the news, but there is no easy way in which he can verify how much forest was lost close to his town, considering the large volume of data and the need for specialized software – even if the scientists made their raw data and reports widely available. His potential reaction to the advancing threat to the forest is stifled simultaneously by lack of information he can understand, at his semantic and cultural level. Further along, the potential participation of this citizen in the assessment of any kind of deforestation limitation policy is lost. Policy makers are then motivated by the repercussion of that single deforestation number in the press, since community response to environmental degradation is unlikely in the absence of information. Any policies they devise to fight illegal deforestation actions in a region also remain unknown for the public at large, since it is also difficult to propagate information on all but the most general decisions. Furthermore, the potential for citizen reports and denouncements on environmental violations is nullified, since citizens do not get to know the policies in place.

Figure 1 – Pre-SDI setting



The emergence of SDI has an impact on the effort required to share data (Figure 2), but does not ensure that the actors involved actually make good use of it, or that integrated information triggers better responses for the challenges at hand. In fact, SDI is becoming rapidly associated to governmental actions, mostly involving official mapping agencies and similar traditional data providers. As such, the participation of actors such as scientists and citizens in the enrichment of SDIs becomes limited. Nevertheless, SDI is a common ground among actors: although many data sources compose an SDI, from the point of view of users it provides a single, standardized way to get necessary data, regardless of the intended use.

Figure 2 – SDI setting



Volunteered geographic information (VGI) is one of the most promising research areas for social networking on the Web nowadays, and we think there is the need to integrate simple contributions, from large numbers of people, to detailed and sophisticated data, provided by governments and academia, in a single and inclusive Web-based environment.

The question on the relevance of individual participation is well illustrated by some results from the Globo Amazonia[2] project. Developed by Brazil's leading TV network, Globo Amazonia has been conceived as a portal in which people can get to know more about environmental issues in the Amazon. A section of the portal shows forest fires and deforestation instances on a map, using INPE (Brazil´s National Institute for Space Research) data over Google Maps images, and allows people to manifest themselves, issuing geographically related protests. Some people felt motivated beyond that, and the site's administrators started receiving actual reports on deforestation from local citizens by e-mail. Some of these reports were followed up by TV crews, which then raised the issue to national coverage and caused an official response by the environmental authorities.

Even though people did not actually help in the identification of forest fires in most cases, it is possible to see the potential for the involvement of the public in environmental issues. The portal has received over 41 million manifestations in less than three months since its creation in September 2008. Some users have logged in more than 4,000 protests in that period, while some degraded areas attracted more than 10,000 protests. An application that works from the Orkut social network was installed by over 450,000 users, but non-Orkut users can manifest themselves directly at the portal. Looking at Orkut data, it is possible to see that contributors live in every part of the country, so protests are not restricted to inhabitants of the Amazon.

Such a huge popular feedback has motivated political response, including speeches in the Brazilian Senate, and public statements by governmental institutions on the importance of the public opinion in the matter as a motivator for monitoring actions. Following up on the matter, the portal has promoted a call for questions to be addressed to the governor of Mato Grosso State, probably the leader in recent deforestation incidents, resulting in a 100-question interview, which was published in the portal as a blog.

We observe that there is much more that citizens could do, from their homes, simply by connecting to the Web and exercising their interest in a cause they perceive as worthwhile (Moore 2007). People could be motivated to actually monitor series of satellite images to visually search for new degradations, or to report on the destination of forest-related goods in major cities. Of course, some quality assessment is required on volunteered data, so that bogus contributions can be filtered out. Such mechanisms are currently being used in a variety of "wiki-mapping" sites, such as Wikimapia and OpenStreetMap, and include reputation assignment and filtering by other users.

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[2] http://www.globoamazonia.com

3.2 Semantics

Semantic gaps also contribute to keep actors apart in the SDI setting (Figure 2), since the world views interfere with modeling and data collection at the semantic level. Definitely, semantic-based search is a requirement for an SDI that intends to support sustainability research (Craglia, Goodchild et al. 2008; Davis Jr., Fonseca et al. 2009 (to appear)). The various scientific viewpoints involved in the environmental issues require better ways to navigate among the sets of concepts, or *ontologies*, that characterize each community.

The construction of ontologies by information scientists is an attempt to overcome the Tower of Babel-Newspeak dilemma (Fonseca and Martin 2005) by providing a common dictionary of terms and definitions within a taxonomical (i.e., relationship) framework for knowledge representation that can be shared by different information-systems communities. However, theories of being, of what exists, are not defined by a common vocabulary, rather they are dependent upon particular perspectives and ways of understanding the world in which we are immersed. What exists is dependent upon our *cultural schemas* (Saab 2008; Saab and Fonseca 2008). Some cultural schemas can benefit from the data richness of an SDI, but can become overloaded with excessively detailed information. There should be ways to filter and to translate concepts, ideas and details that have been explored in a scientific setting to make them accessible to the common citizen, especially to people that are somehow involved in the problem.

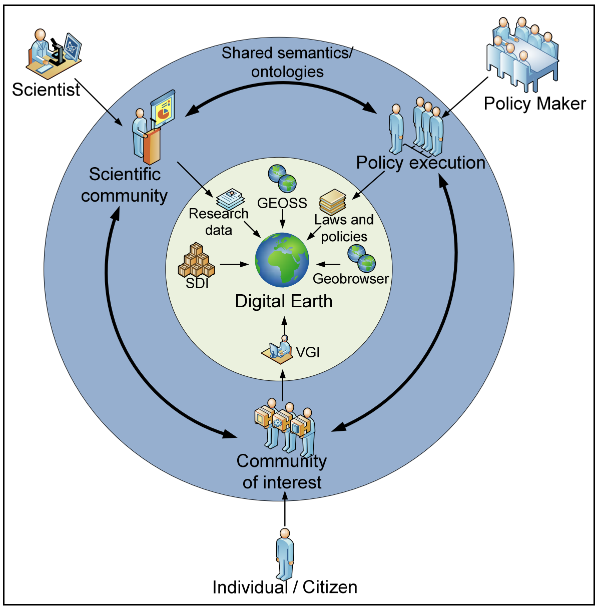
For instance, there is a challenge in making scientific information that exists in a sustainability-related SDI available to students worldwide, as part of an effort to increase environmental conscience and awareness in children. The challenges on teaching Science for K-12 students are widely reported. Different ways of approaching the problem have been tried and many of them suggest a more intense use of Web Technologies. The Web 2.0 brought new tools, called *mashups*, which facilitate the creation of applications that rapidly integrate different sources of information in an efficient and interesting way. K-12 students are becoming more and more familiar with social networking tools such as Facebook and My Space, with the creation and use of videos online in web sites such as YouTube, and with mapping services such as Google Maps. Such tools can be used to give access to professional and scientific data. How can this access be made smooth and easy-to-use as mashups are? Imagine a scenario in which an 11th grade student is doing a report on Global Change impacts on her hometown. She can start grabbing data from her local TV station and from Google Maps and then linking these data to the National Map and getting NOAA data to complement her report. Finally, she can post it on Facebook. We envision the use of ontologies that combine scientific rigor with the informality that is so dear to K-12 students, so that they can have access to scientific data in a seamless way. These ontologies should be able to recognize, accept and express the various cultural aspects involved in this process. Cultural schemas are seen as a special kind of ontologies, used to represent and integrate the different types of knowledge involved in this problem.

3.3 Towards Community Building

The kind of sharing that motivates the creation of SDIs can be extended towards the establishment of *communities of practice*, in which the central theme or subject is approached in various levels of detail and complexity. In our Amazon setting, there is clearly the need to improve information dissemination not only among members of the same group (scientists, policy makers, citizens), but among groups. The recent phenomenon of online communities of social interaction on the Web demonstrates that this kind of integration is possible, and highly desirable as a means to motivate people to participate and contribute to solve real problems.

In our point of view, the center of a community of practice for a subject as wide as the sustainability of the Amazon should be built along the lines of the Digital Earth paradigm (Craglia, Goodchild et al. 2008), which consists on a very wide array of data and information sources, ranging from the governmental mapping agency cartographic data (as in most SDIs), to data collected in research projects, associated to academic publications (Figure 3).

Figure 3 – Digital Earth setting



It should also range from structured data sources, such as remote sensing products (represented in the figure under GEOSS, the Global Earth Observation System of Systems), to simplified and less structured sources such as volunteered geographic information about themes of interest for the community. Geobrowsers can play the role of integrators for popular contributions, and should be enhanced by scientific data and elements from official policies.

Along with data and information sources, a “digital Amazon” environment should be equipped with most of today’s Web 2.0, social interaction, and geospatial Web tools and techniques. We list below some of them, and illustrate their utility for the purposes we presented.

Wikis. In their role as open knowledge bases, wikis can be an important tool to organize established facts and notions about the subjects related to sustainability.

Geotagging. Seen as volunteer contribution sources, geotagging is a kind of wiki where the user can assign names to places. This is important as a means to improve geographic knowledge sharing, and as a complement to “official” data sources, such as gazetteers, to be found within the scope of SDIs.

Blogs. Certain people are recognized as authorities in their fields or have distinguished roles in their communities, and blogs serve as a way for those people to disseminate new ideas and initiatives, and to motivate younger people to participate. Microblogging also seems to be well suited to large communities, while requiring less personal time from the blogger.

Forums. Over the Internet, forums are one of the most traditional tools for multi-participant offline discussions. Their capacity for archiving past discussions, combined with blogs and content distribution services, allows people to get progressively aware of the current interests and subjects.

Content management and distribution. New information and contributions keep being produced and published all the time. Content distribution services allow people to subscribe to certain subjects in several data sources, and get alerts when something of possible interest has been posted. This notion can be further enhanced by allowing the users to subscribe to data sources indicating places of interest, not only subjects or keywords, so that whenever something is posted on or about some location, the user is informed. GeoRSS[3] has been proposed as a way to include location references in RSS (Really Simple Syndication)

[3] http:// georss.org

feeds, but this idea goes in a different direction, monitoring geographic data sources for modifications or contributions.

Many more existing Web interaction tools can be envisioned at this time for the purposes we describe here, such as personal location, location-enabled interaction, reputation systems, and recommendation networks. Of course, in many cases adaptations and evolutions may be necessary or convenient. Furthermore, we expect that a new generation of semantic integration tools and techniques will be able to enrich community building, by providing actors with some level of semantic support, such as translation of concepts, automatic links to educational resources, and discovery of services or applications.

4 CHALLENGES

4.1 Information Needs for the Amazon

Even though much data on the Amazon is constantly being generated, from sources ranging from imaging satellites to data collection expeditions, there are still many gaps, either caused by difficulties that characterize the region, or originated by requirements posed by new theories and recent studies of the region.

As a first step, we need to understand how the forest ecosystems work. Experiments such as LBA (Large Scale Biosphere and Geosphere Experiment in Amazonia) (Avissar, Silva Dias et al. 2002) have set up data collection campaigns (in situ and airborne) that produced new perspectives on the functioning of the rain forest. For instance, they provided new insights into the role of aerosols emitted from forest fires in the hydrological balance. Heavy smoke from forest fires in the Amazon was observed to reduce cloud droplet size and so delay the onset of precipitation (Ometto, Nobre et al. 2005). The LBA results indicate the need to broaden the data collection sites in the Amazon.

Additionally, there is a gap of information on biodiversity in the region. Although it is recognized that the Amazon is one of the world’s biodiversity hot-spots, estimates of the number of species yet to be discovered there vary enormously. Hopkins (2007) considers the biodiversity of the Amazon Basin is considerably underestimated and that there may be up to 50,000 plant species yet to be discovered. To bring the biodiversity of the Amazon fully into light, major investments are required in data collection campaigns and on ecological modeling.

Socioeconomic data for the region also has substantial gaps. Although the basis of the land tenure system in the Amazon is legally established, land registry is unreliable or non-existent in many cases. The occupation process was chaotic in some places, with settlers and poachers occupying public land in an unruly fashion. The local land registries are notoriously prone to corruption. Thus, there is a gap of reliable land registry information, which would allow identification of the land's ownership and thus bring forward the legal responsible for deforestation and other illegal practices (Fearnside 2001). Detailed socioeconomic data is also needed to establish a statistical relationship between social and economic indicators and sustainable (or unsustainable) practices (Aguiar, Câmara et al. 2007). For example, is the evolution of beef prices in international markets correlated with deforestation? Did the social situation of communities that adhered to sounder environmental practices improve?

Finally, spatial data associated with land management is also lacking. The existing maps about soils, geology, terrain, and vegetation types have a very coarse spatial scale, which does not allow for adequate land planning and zoning. Although INPE publishes yearly maps of deforested data that are regarded as reliable (Kintisch 2007), the final destination of the deforested area is not known. When an area is deforested, the first motivation may be logging, then the land is converted into pasture, and then may be abandoned or converted to large-scale agriculture. We need reliable information about the trajectories of land use to understand how land is appropriated in the region.

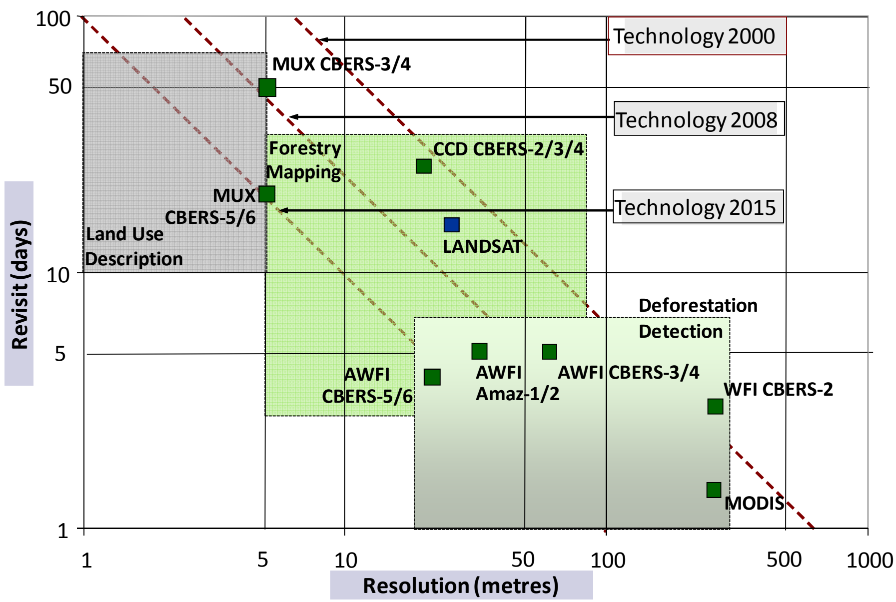
Knowing what data is available is one of the most important challenges for an SDI of the Amazon. Metadata-based catalogs are the SDI response to such a need, but creating metadata can be quite tedious and time consuming, due to the large amount of specialized yet manual labor required. There is a definite need for more automation in metadata creation, as well as for semantic search tools to be associated with metadata collections.

As to policies, new legislation was created in late November 2008, establishing the Brazilian National Spatial Data Infrastructure (*Infraestrutura Nacional de Dados Espaciais*, INDE) with a mostly institutional view, based on official/governmental data sources (Vieira, Lunardi et al. 2008). The upcoming creation of INDE immediately raises concerns as to its opening to contributions from other potential data providers, including academia, NGOs, and volunteers. At the very least, the same technological framework that is apparently going to be used in the creation of INDE (mostly OGC Web services in the traditional SDI architecture) can be used to foster other "unofficial" SDIs.

In the point of view of systematic cartography, the Amazon has still large uncharted areas, and the Brazilian mapping authorities (IBGE and the Army's geographic service) are currently developing efforts to cover such areas (Vieira, Lunardi et al. 2008). On the other hand, there are plenty of data in the form of satellite imagery, from INPE and other sources, which cover the entire region, including the uncharted areas.

Geosensing technology, especially satellite-based remote sensing, is expected to increase currently available resolutions, while reducing revisiting time (Figure 4). This evolution is in part motivated by the need to fight deforestation and forest fires. The immediate consequences would be much larger volumes of data, frequently renewed, which can be used in other applications. This is also the case of scientific data which are not available on the Web; the possibility of putting such data sets to other uses should motivate scientists to make them available.

Figure 4 – Evolution of resolution and revisit time of optical satellites for tropical forests monitoring



We think it is unreasonable to expect that systematic cartography can keep up with spatial data needs, especially in cases such as the Amazon. However, this point has been the subject of much debate recently. While cartography advocates stand for a more traditional approach, with an SDI based on a broad agreement on its data contents, others envision a multitude of apparently disconnected data sets, each of which with its own intended uses, but with possible applications in other areas as well. The first approach implies a stronger presence of official data providers in the definition of what should be available, while the second expects users to proactively discover the data they need, in a broader definition of the SDI concept. This redefinition of SDIs is based on the strong need for data availability, requiring simple and practical Web-based resources. We understand that, in such an SDI, a user should be able to assess data provenance, and to make an informed choice between official and other data sources.

There seems to be a consensus around the idea that the data needs for sustainability science are so broad that the right way to answer this question is to facilitate access to whatever data is available (Davis Jr., Fonseca et al. 2009 (to appear)). There are certainly large amounts of valuable data collected for many scientific projects in the Amazon which are currently inaccessible, or worse, whose existence is practically unknown for potential users. Today, even basic mapping data can be hard to locate and acquire.

4.2 Modeling

Modeling the Amazon is quite complex because of a number of distinctive characteristics of the region and its problems. First, phenomena occur and are modeled in various geographic scales, ranging from microbiology in specific locations to planetary climate impacts. Even though there is a general understanding about the semantic variation of phenomena across multiple geographic scales, our current tools and techniques are still primitive in comparison with the breadth of this challenge. Second, there are multiple views on the reality of the Amazon, including many scientific disciplines and the view of the local populations. These views are sometimes complementary, and sometimes conflicting, each one based on a particular set of concepts. Third, the complexity and level of detail of activities such as data collection and analysis range from large volumes of scientific data down to news and descriptions suited to the cultural level of local populations.

Davis Jr. et al. (2009 (to appear)) suggest some ways to understand the implications of putting society and nature together in a single model. Using a philosophical point of view they use Kant's view of man as phenomena (belonging to nature, being completely causally determined) and as noumena (human being as being free, as a thing in itself) to frame the discussion on how to build models that include both views. The issues in the integration of opposing views, such as society and nature, in a model, sometimes called the Tower of Babel problem. A common solution to this problem is the Newspeak solution (Fonseca and Martin 2005; Fonseca and Martin 2008), which is achieved through the imposition of a common ontology to which users are required to conform if they wish to participate at all. Looking for an integration of society and nature in modeling, Fonseca and Martin suggests that Gadamer's notion of Play coupled with self-organization concepts can be used as a way to balance, within a single model, two contrary positions. They think that a dialogue of clashing views can be held together without devolving into chaos, in which a contradiction implies all propositions, usually thought to be the consequence of bringing together inconsistent positions. This solution points beyond the either/or that is central to the Tower of Babel/Newspeak dilemma and may lead to environmental models that incorporate conflicting views.

Regarding public policies to the environment, the big question is on how can we use the knowledge that we acquired with the previous processes to develop policies to act upon the dynamic interactions of nature and society. It is necessary to communicate the results from knowledge discovery to policy makers. They also need access to the data and to well-explained versions of the models. In case of global policies, we need also to make any cultural assumptions behind the data and the models explicit.

How can we take actions to preserve the environment now and keep growing economically in the long run? We need to create different ways of modeling, implement and study these models (possibly using simulation techniques), and use them to create and support policies that address sustainable development. During the current state of affairs, in which people are becoming aware of sustainability issues and starting to take immediate and long term actions, we need to monitor if our models, data and policies are correct. One of the solutions points toward the creation of sustainability indices to support our decision making and to measure its effectiveness, as suggested by Kates et al (2001). This is a definite requirement if we intend our models to succeed in situations that are much more complex than the usual geographic application, such as in the broad modeling of the interaction between Society and Nature. Notice that the need to make concrete advancements on these requirements pushes us to improve elements of today's geospatial infrastructures to deal with issues such as the semantic exchange of models and higher-level analysis services.

5 CONCLUSIONS AND FUTURE WORK

Environmental policies should be based in established knowledge and facts, which come mostly from scientific research. Experience shows that engaged and informed citizens can also have a strong presence and can contribute to political decisions. Governmental institutions have, of course, a fundamental role in policy formulation and implementation, and are finally responsible for verifying the effectiveness of such policies in order to reach higher political and environmental goals. The integration and interaction among all these actors is a requirement for any initiative that intends to tackle complex and multifaceted problems such as sustainability. The Web seems to be a natural choice of a foundation for such interaction, and currently available social networking and cooperation tools seem to point a viable course of action. The Amazon works as a prime example on the kinds of interaction and integration resources necessary to push the sustainability agenda forward, but of course the discussions we presented can fit other situations as well. For instance, the same complex setting occurs in the negotiations to reduce global deforestation rates worldwide, as part of the effort to control carbon emissions.

However, much research still needs to be done, if we are to enhance current technology with means to deal with semantics, to share data sets generated by different communities for various purposes, and to achieve the necessary synergy among all actors in complex problems. Special motivation can come from the global importance of sustainability and of the environmental concerns, which attracts strong popular interest, and from the existence of numerous data sets, although most are not readily accessible. We also need more work on scale-related issues, ranging from the need for better modeling to adjustments in the data gathering and dissemination chains, not forgetting the multiplicity of actors and their cultural schemas.

Lessons learned from this kind of research are not restricted to environmental and sustainability issues, but can certainly be used in any other kind of complex interaction between people with different cultural schemas. This is a core problem for the next generation of Web technology, in which semantics and interactivity play a fundamental role.

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