

GeoAmazonas—GIS for Water Resources Management

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Abstract

Geographic Information Systems (GIS) are used essentially for spatial analysis. They can lead to the development of methods for analyzing and planning the use of geographical space and, consequently, are helpful to the decision making process, assisting those responsible for planning the use of a certain territory. This article is a result of the “Project for the Integrated and Sustainable Management of Transboundary Hydric Resources of the Amazon Basin considering Variability and Climate Change”, which has the goal of strengthening institutional guidelines in order to plan and execute activities related to the protection of the land, hydric resources and sustainable management of the Amazon Basin, considering the existing impacts of climatic changes. This article aims at analyzing the process of building and implementing the GeoAmazonas GIS as one of the instruments for managing the basin, including its contribution for standardizing different data sources in the entire area of the basin and the identification of conflicts related the use of water resources and vulnerability situations.

Keywords

Geographic Information System, Amazon, Transboundary Basins

1. Introduction

Regional and global changes have altered the climate and the hydrology of the Amazon Region, and this process has intensified due to modifications in land use, which caused the transformation of more than 600,000 km² of tropical forests into pastures and ex-

tensive agriculture areas.

Consequently, the river discharge, which is significantly influenced by anthropic action, is subject to the inter-annual and long term variation of tropical precipitation, causing large variations on the superficial flow and other stages of the hydrologic cycle in the Amazon Basin, such as evaporation and local precipitation, which influence greatly the hydric availability of the region [1] [2].

These processes highlight the need to identify the impacts on the hydrologic cycle and hydric availability of the Amazon Basin, as well as their direct and indirect consequences. The following cases exemplify possible impacts caused by regional changes in hydric resources: Thaw in the Andes; Sea Level Variation; Influence of the Sea Surface Temperature (SST) on the Rainfall Regime in South America and Amazon.

In this context, the “Project for the Integrated and Sustainable Management of Transboundary Hydric Resources of the Amazon Basin considering Variability and Climate Change” (Projeto GEF Amazonas¹) implemented by IVIG (International Virtual Global Change Institute) aims at developing a consensual perspective regarding sustainable development on the region, based on protection and integrated management of transboundary hydric resources and on the adaptation to climate change with the use of GIS².

The goal of this paper is to present the stages of building and implementing a geographic information system which helps the management of Transboundary hydrographic basins, in particular the Amazon Basin. Nowadays, the system is being distributed and updated, and the scale of analysis is becoming more detailed in order to support Project³ AMAZON_COOP_H2O.

Some reasons for elaborating a GIS for managing transboundary hydrographic basins are: the possibility of assessing the entire area of study through the data which are available for the basin; supplying data which allow for an integrated management of hydric resources and providing geographic data and information in a standardized and systemized manner.

Accordingly, the Basic Geographic Information System for the Waters from the Amazon Basin (SIG GeoAmazonas) was organized in the scale of 1:5,000,000, with a content of 1.7 gigabytes of georeferenced information. It provides a better understanding of the land use, the water management of the region and its relation and conse-

¹The project had the support of the Global Environment Fund (GEF), Amazon Cooperation Treaty Organization (ACTO), United Nations Environment Programme (UNEP) and the Organization of American States (OAS-Department of Sustainable Development).

²Geographic Information Systems (GIS) “are an effective tool for storing, managing, and displaying spatial data often encountered in water resources management” (Tsihrintzis *et al.* 1996, p. 251).

³Project proposed by COPPE/UFRJ which is included in PROSUL (South American Program to Support Cooperation Activities in Science and Technology/CNPq/Ministry of Science and Technology). Within the goals of the Project of providing financial support for scientific and technological projects related to international cooperation and integration among Amazon countries, it is possible to include the elaboration of an Information System for the Integrated and Sustainable Management of Transboundary Hydric Resources of the Basins from the MAP region-Madre de Dios in Peru, Acre in Brazil and Pando in Bolivia and the Madeira river (Bolivia and Brazil).

quences on the hydrographic sub-basins of the region.

2. Decision Support Systems for Water Resources Management

2.1. Support Systems for Decision-Making Related to the Planning of Water Resources

Even though the concept was restricted to planning, it is possible to find distinct models of Decision Support Systems (DSS) for hydric resources. Mohaneed *et al.* [3] states that Decision makers usually take their decisions based upon economical and technical analysis, considering the available alternatives. “Traditional understanding of Decision Support Systems (DSS), as tools predominantly developed by water resources experts and for the same experts, is evolving towards viewing DSSs as potential platforms for knowledge exchange among users belonging to a much broader user base, which includes the experts, the involved stakeholders and the decision makers.” Jonoski and Popescu [4].

The mathematical optimization and simulation models have been used in studies focused on the planning of hydric resources since the decade of 1960. They are essential for interpreting and trying to predict the behavior of water bodies. Several researchers have proposed different tools, with different functionalities and capabilities, to assist the decision-making process. These tools can be mathematical models, geomatics systems, performance evaluation systems and others, and they can be used for several challenges related to water planning and management to help the decision-making. For instance:

- Zhang *et al.* [5] proposes a web-based watershed management spatial decision support system based on a Geographic Information System to evaluate different scenarios for watershed planning and management;
- Kronaveter *et al.* [6] proposes a Negotiation Support System applied to the management of conflicts involving the use and management of water resources;
- Pearson *et al.* [7] develops a decision support framework that assists managers in the urban water industry;
- Zhang *et al.* [8] proposes a multi objective decision/bargaining model based on the “satisfaction principle” which is developed for inter-basin water transfer system decision-making;
- Purkey *et al.* [9] presents an overview of decision-making processes ranked based on the application of a 3S: Sensitivity, Significance and Stakeholder support;
- Ana and Bauwens [10] presents a review of selected sewer asset management decision-support tools, which are grouped according to their functionalities and capabilities, and describes the concept behind each one;
- Fanghua and Guanchun [11] discusses how to apply a fuzzy multi-criteria group decision-making (MCDM) model to watershed ecological risk management, presenting a case study of the Three Gorges Reservoir Area in China.

This knowledge may be employed for determining areas in which dams can be constructed and where energy can be captured and generated. In addition, it may help de-

fine the granting of rights to the use of water resources⁴, since the discharge data of the historic series are used by the government agencies which manage hydric resources in order to establish what they call reference discharges, making it possible to determine the limit discharge that can be removed from a water body which can be used in different manners due to a granting of rights.

Nevertheless, there are limitations for including non-quantitative aspects, which reduce the capacity that hydrologic models have in aiding some aspects of the planning, such as: the identification of areas that may potentially affect the resources, the identification of who is involved in each activity and the gaps of space and time coverage when gathering hydrometeorological data, which may lead to inconsistencies in the historical series.

2.2. Support Systems for Decision-Making Related to the Real-Time Management of Water Resources

In this case, mathematical modelling and the Decision Support System (DSS) tools are components of a wider Management System, which must provide information in a dynamic way and integrate technical and administrative routines, allowing for consultations, analyses and the elaboration of reports. In geohydroinformatics, the Management Systems based on DSS tools are Real-Time Control (RTC) systems, for they can manage a wider variety of information in the related database. In this context, the capacity of associating spatial and non-spatial data and the possibility of interacting with a mathematical model and more complex databases and, lastly, the capacity of spatializing the analysis with output graphical interfaces that are becoming increasingly more accessible make the Geographic Information Systems (GIS) an essential tool for the planning and management of hydric resources, as well as for other topics that are directly or indirectly associated with the conflicts and impacts regarding these resources.

Among the several definitions which were presented, the definition proposed by Calkins and Tomlinson, singled out by Christofolletti, emphasizes the potential of integrating technology with its stages and mentions that the GIS is a integrated set of programs (software) elaborated specifically for activities related to data manipulation. These activities include input, storage, recuperation and problems associated with data management, excluding the wide variety of descriptive and analytical processes.

In a more recent work, Burrough and McDonnell [12] state that a GIS is a powerful set of tools to collect, store and recuperate information by transforming and organizing data gathered from the real world into a particular set of goals.

Over the last 20 years, several authors have used GIS technology as a research tool in

⁴The Granting of Rights to the Use of Water Resources one of the instruments of the National Water Resources Policy, which aims to ensure the “qualitative and quantitative control of water use and the effective exercise of rights of access to water resources” (Article 11, Law 9433/1997). There are four categories of granting of rights of water resources: Granting of rights for using hydric resources—for new right requests; Alteration of a Granting of rights for using hydric resources—alters the conditions of a granting of rights which was already given; Renewal of a Granting of rights for using hydric resources—for the cases in which the granting of rights is expiring; Granting of rights for Preventing Use—it aims to separate the discharge which can be used so investors can plan the projects that need these resources.

order to analyze and solve environmental problems. They had different approaches that can be divided into: environmental monitoring and land use: Papastergiadou *et al.* [13]/Bhattarai *et al.* [14]; adaptation studies and modeling of extreme climate events: Amaral *et al.* [15]/Adger [16]/Pahl-Wostl [17]/Sena *et al.* [18] [19]; modeling and monitoring the quality and pollution of water: Tsihrintzis *et al.* [20]/Mantzafleri *et al.* [21]/Singh *et al.* [22]; and specially hydrologic modelling and studies applied to watersheds: Venkata *et al.* [23]/Bhalla *et al.* [24]/Coskun *et al.* [25]/Correia *et al.* [26]/Tsihrintzis *et al.* [27]/Jasrotia *et al.* [28]/Panagopoulos *et al.* [29]/Wiek and Larson [30].

The following organogram demonstrates in a simplified manner how the three operational levels of the SIG are organized as a DSS tool (Figure 1).

In the structure level, the databases are fed and organized, including all information that may be georeferenced. The interface level includes the visual presentation of the information, and several layers of information can be overlaid according to the selected topics and the specific goal of analysis. Lastly, in the user level there are analyses based on the alphanumeric information and other information provided by the layers.

3. Materials and Methods

3.1. The Amazon River Transboundary Basin (Study Area)

The Amazon River Basin is the largest hydrographic basin in the world, with an area of

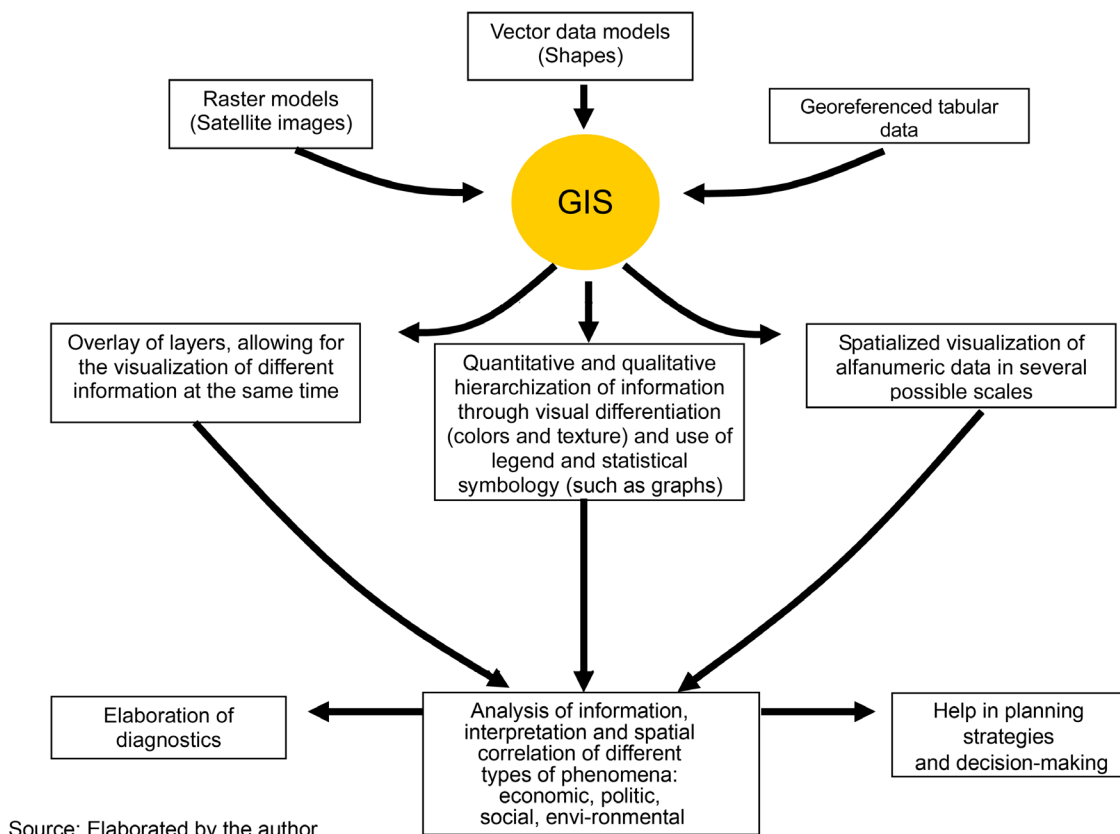


Figure 1. Organogram of the organization levels of the GIS.

6,100,000 km². Its drainage area includes parts of Brazil, Bolivia, Colombia, Ecuador, Guyana, Peru, Venezuela and Suriname (ACTO). The Amazon Basin is extremely important for the climate dynamics and the hydrologic cycle of the planet. It has approximately 16% of the sweet surface water of the planet and, consequently, it plays a significant role on the rainfall regime and evapotranspiration of South America and the world. The basin is also one of the most humid regions on Earth, with average precipitation between 2300 and 2460 mm-year [2] [31].

The rivers that compose the Amazon Basin can be hierarchized and grouped into sub-basins by employing the Otto Pfafstetter methodology—which is adopted officially by Brazil to define the national hydrographic division and also by the United States Geological Survey (USGS) to elaborate the global map of hydrographic basins—to define the main rivers and the influence of the relief in each country of the Amazon Cooperation Treaty Organization (ACTO)⁵.

Figure 2 shows the hydrographic division of the Amazon River Basin and its sub-basins, with levels 1 and 2 respectively according to the criteria established by Otto Pfafstetter. The main sub-basins of the Amazon Basin are the ones from the following rivers: Solimões, Madeira, Negro, Xingu and Tapajós.

Regarding the area called Amazon Region, with South America as a reference, some topics must be discussed. Firstly, it is necessary to point out that, within this context, some concepts and ideas must be debated according to the suggestions of Corrêa [32], for the use of the term region is not done in a standardized way; it is very complex. It is possible to say that there are some difficulties in identifying the limits of the region, especially because there are several criteria that can be considered. These criteria even change from country to country—each country uses different criteria to define their “Amazon” regions (**Figure 3** and **Figure 4**).

In this context, the Amazon and the topics related to it are discussed so widely nowadays that, at least in the common sense, the region is a spatial entity without any geographic delimitations. When the Amazon is mentioned, it is common to overlook the different spatial outlines which can be used to define it. Nevertheless, in theoretical, political and especially quantitative terms, it is important to define the territorial matrix used as reference in order to discuss any theme related to the Amazon.

In this sense, it is possible to define at least four territorial outlines for the Amazon. The first one, determined by the hydrographic basin, includes an area of 7 million·km², 4.8 of which are in Brazilian territory. The second possibility is to consider the vegetation cover, which is estimated to be 40% of the total area of the basin. Another possible outline is to consider the regional division of the country—in this case, the Amazon would include the North Region, which is composed of the states of Acre, Amapá,

⁵The Amazon Cooperation Treaty Organization (ACTO) was created because of the Amazon Cooperation Treaty (TCA) signed in July 3rd 1978. The goals of the treaty are the preservation of the environment and the rational use of the natural resources of the Amazon. In 1995, the eight nations decided to create ACTO to strengthen and implement the goals of the Treaty. The protocol which amended the TCA was signed in Caracas, capital of Venezuela, in December 14th 1998. The main goal of ACTO is to preserve the natural resources of the Amazon with sustainable development principles. Its members are: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela.

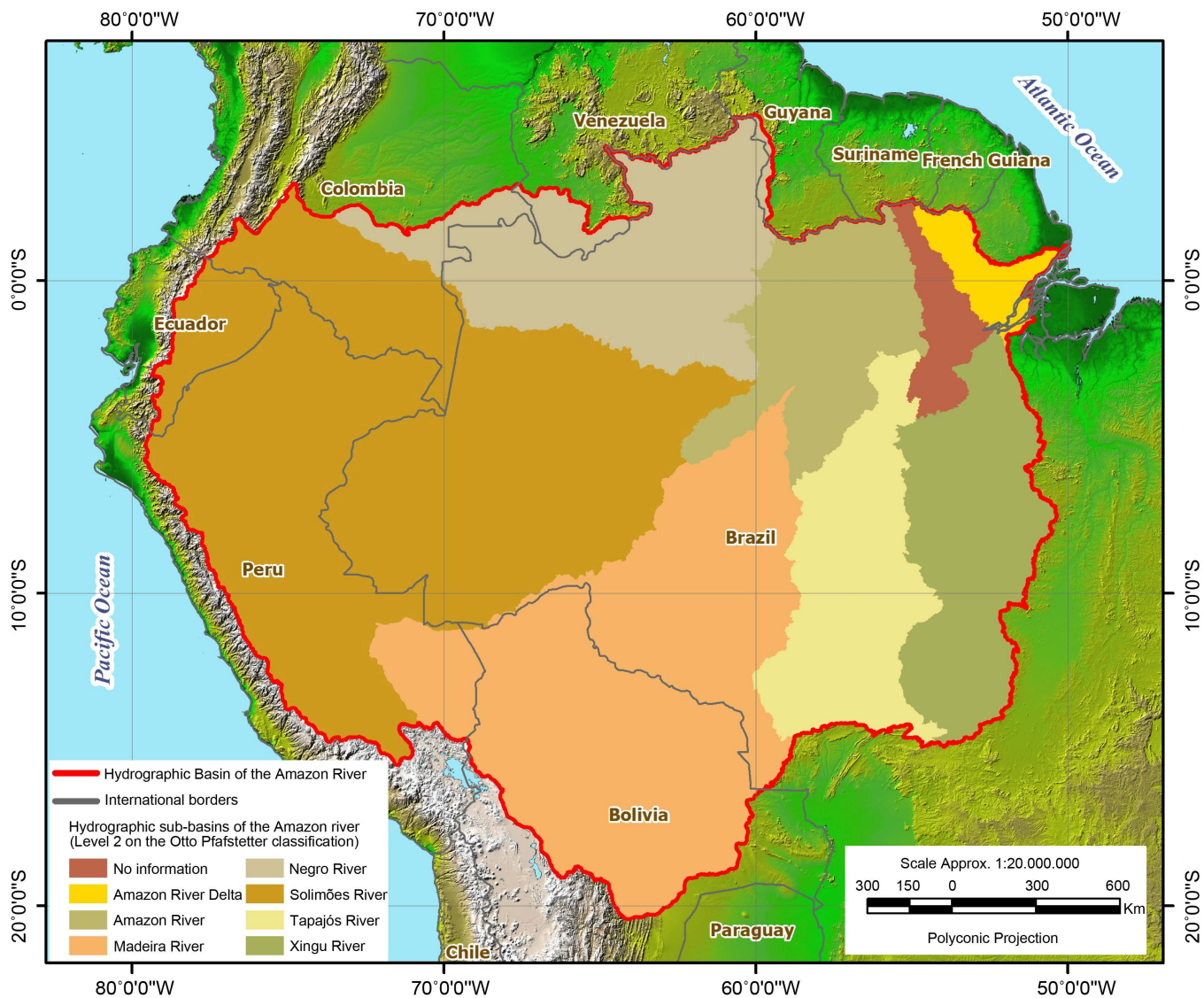


Figure 2. Level 2 hydrographic basins with relief (GeoAmazonas).

Amazonas, Rondônia, Roraima, Pará and Tocantins, and part of the Central-West Region (the state of Mato Grosso). The total area of these states is 4.7 million-km², which indicates that this political-administrative division was based on natural geographical criteria, such as the area of the Amazon Basin which is inside the country. The last alternative is to consider the “Legal Amazon”, which was created in 1955 by a legal provision (Law 1806, 1953) and includes an area of 5,217,423 km². It was created to help the economic and territorial planning defined by the Amazon Valorization Plan approved two years before.

According to Eva and Huber [33], although this situation does not create any problems on a national level, it may create issues for integrating data and statistics (in content or spatial dimension) on a regional level. Therefore, studies about the regionalization of the Amazon must also be done.



Figure 3. The proposed delimitation—Amazon *sensu latissimo* (in red)—includes a sub-region of the Amazon *sensu stricto* (in dotted lines) and four peripheral sub-regions: Andes, Planalto, Guiana and Gurupí [33].



Figure 4. The ACTO region, according to the definition of national entities [33]. It is worth noting that French Guiana is not part of the ACTO.

3.2. Stages for Building the System

The Basic Geographic Information System of the Waters of the Amazon Basin on the scale of 1:5,000,000 was named GeoAmazonas (Geographic Information System of the Amazon River Basin). The initial versions (Beta version in December 2006, with the final version being delivered in February 2007) were built and updated using the software SIG ArcView 3.2a. This version was rebuilt and updated in 2011, using the software SIG ArcGIS 9.3.

The GeoAmazonas GIS was built following these stages:

- 1) Bibliographical and Cartographic Survey;
 - 2) Conceptual Modelling of Data;
 - 3) Data Acquisition and Metadata Creation;
 - 4) Field Research;
 - 5) Building and Spatial Integration of the Data (Implementation):
 - 5.1) Treatment of Graph and Tabular Data;
 - 5.2) Tests and Error Assessment;
 - 6) Interface with the User: Production and Assessment;
 - 7) Storage, Consultations and Analyses.
- Stage 1 (Bibliographical and Cartographic Survey)

The first stage included activities needed for the development of the proposed product. These activities considered a wide survey of data and information sources, including graphic and tabular bases. Some of the institutions consulted and/or visited were: Servicio Nacional de Meteorología e Hidrología (SENAMHI); National Water Agency/Ministry of the Environment (ANA/MMA); Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM); Consejo Nacional de Recursos Hídricos (CNRH); Guyana Water Authority/Hydraulic Research Division (GWA/HRD); Instituto Nacional de Recursos Naturales (INRENA); Ministry of Public Works/Hydraulic Research Division (MPW/HRD); Dirección General de Cuencas Hidrográficas/Ministerio del Ambiente y de los Recursos Naturales (DGCH/MARN); Management of the Ecological-Economical Zoning of the State of Acre; Brazilian Electricity Regulatory Agency (ANEEL); Mineral Technology Center (CETEM); CT-HIDRO—Water Resources Sector Fund; Brazilian Agriculture Research Corporation (EMBRAPA); National Indian Foundation (FUNAI); Global Land Cover 2000 Project (GLC, 2006)—Map of Land Use in South America; Retis Group (Federal University of Rio de Janeiro-UFRJ); Brazilian Institute of Geography and Statistics (IBGE); RADAM Project/IBGE; Amazon Protection System; Amazon Surveillance System; The Smithsonian Atlas of Amazon [34]; Atlas mondial du développement durable [35]; Federal University of Acre (UFAC).

- Stage 2 (Conceptual Modelling of Data)

It was elaborated based on the bibliographical and cartographical survey, considering the topics and spatial outlines delimited on the goals previously determined for the GeoAmazonas Geographic Information System. Subsequently, it was necessary to represent the structure of the information in the system, *i.e.*, the types of data and how they were related to one another, as the following example shows (**Figure 5**).

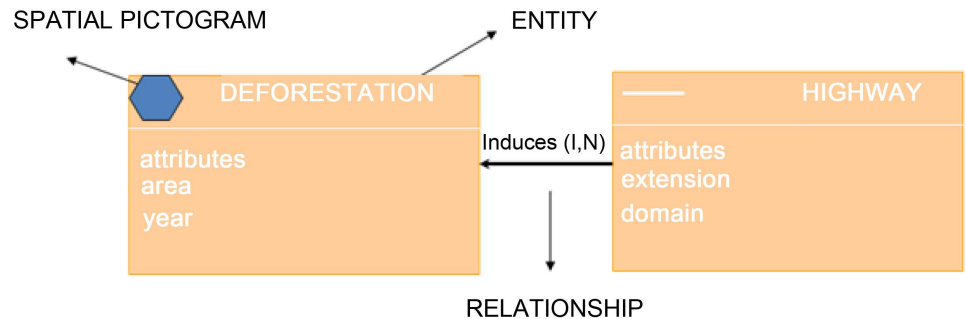


Figure 5. Example of the entity-relationship model.

The building of the GeoAmazonas GIS on this stage had two different approaches which were fundamental: one approach focused on the mapping the anthropic part and the other on the mapping of natural resources. The integration of both approaches using a GIS may lead, for instance, to an analysis of integrated vulnerability, representing the coexistence or spatial overlay of anthropic action and floodable areas or indigenous villages and deforestation. After the subsystems were created, the entities of each group were defined, as well as the main relationships between them.

- Stage 3 (Data Acquisition and Metadata Creation)

After the conceptual model was created, the third stage involved the acquisition of data from the subsystems which are part of the GeoAmazonas GIS. They were related following the proposed conceptual model. Nevertheless, Stage 3 considered several cartographic data (digital cartographic bases, orbital imaging of medium spatial resolution, etc.).

Therefore, the system has information layers on the following themes:

1) Anthropic Action-fundamental modifications in land use in the Amazon Region, highlighting what occurs in the Brazilian part of the Amazon;

2) Floodable Areas;

3) Hydrographic Basins;

4) Main Cities;

5) Boundary Strip;

6) Hydrography;

7) Geographic Boundaries;

8) Ocean;

9) Relief;

10) Indigenous Land;

11) Land Use;

12) Vegetation;

13) Highways/Transportation roads;

14) Energy;

15) Mining;

16) Water: Supply/Sewage.

During Stage 3, the metadata were also produced. They are grouped according to the

subsystems which were created.

- Stage 4 (Field Research)

The field research is done in a area or areas of interest in the Amazon Region, with the goal of collecting and acquiring available data and information, as well as verifying if the database matches local reality. This stage was done when the GIS was being built and also when it was being updated. The following countries were visited: Bolivia, Brazil, Guyana, Peru and Venezuela.

- Stage 5 (System Building and Spatial Integration of the Data Implementation)

Stage 5 was divided into two sub-stages. The first one (Treatment of Graph and Tabular Data) had the goal of gathering the surveyed data/information in order that integrated spatial analyses and thematic maps could be made. The second sub-stage (Tests and Error Assessment) compared the GIS, its bases and the results with the *in loco* reality.

- Stage 6 (Interface with the User: Production and Assessment)

This stage is focused on the interaction the user has with the system. The way to access the system is through the GIS, which allows the user to communicate with the system by requesting consultations and viewing results.

- Stage 7 (Storage, Consultations and Analyses)

Lastly, some files were organized, some consultations were made (for instance, the boundaries and the calculation of the area of the Amazon Basin inside Venezuelan territory were verified due to a request of the Environment Coordination of the ACTO) and analyses were done considering the outlines of the region, country or basin (for instance, spatial analysis regarding occupation and deforestation and spatio-temporal analyses regarding the evolution of the deforestation in the Acre River Basin). With this stage, a series of thematic maps was generated, which will be presented in the results.

4. Results and Discussion

These stages led to the definition of the scope of GeoAmazonas and defined which representation shapes would be more adequate for integrating the surveyed databases (**Figure 6** and **Table 1**).

The following table (**Table 2**) shows data and information of the countries which were analyzed by the GeoAmazonas GIS. The consultations to the GIS can be done by outline of the basin or by country (representations for different themes were created for each country).

As it is possible to see, the GeoAmazonas GIS led to several results, such as the actions for structuring and standardizing the maps of the hydrographic basins of the member countries of the ACTO which are part of Amazon Basin (Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, Venezuela) and the definition of the drainage areas from the Amazon Basin associated with each of them. In addition, it provided more details for the areas of increased interest inside the Amazon (such as main urban centers), the modifications in land use, the confluence of the main rivers of the Amazon, the meanders and islands, etc.

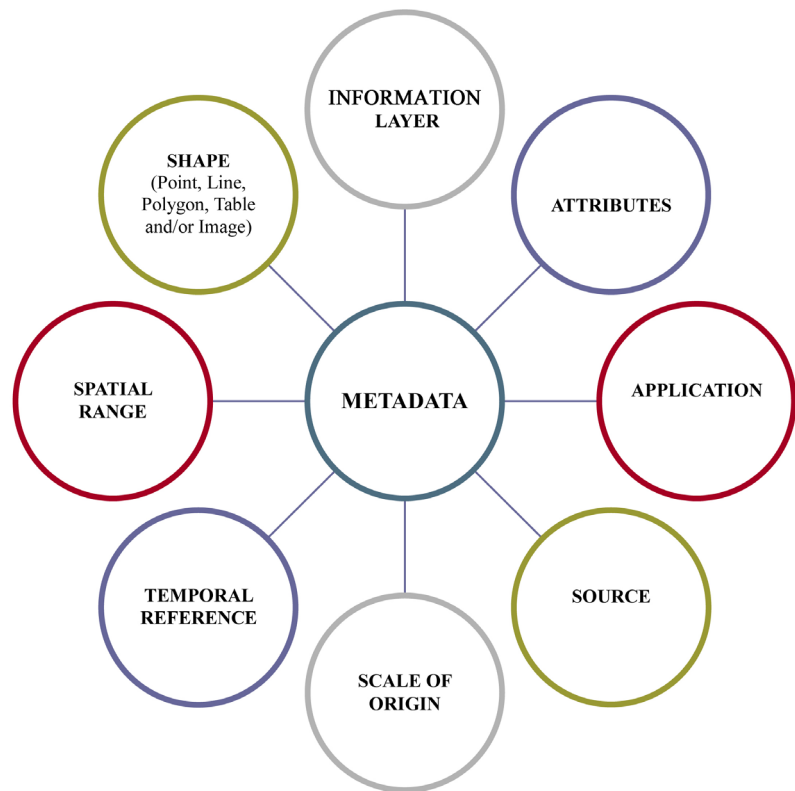


Figure 6. Structure of the metadata from the GeoAmazonas GIS.

The result of this survey is extremely relevant for identifying and understanding the regional water management, types of ecosystems, protection areas and land use, since these data are hard to access and expensive to survey due to the comprehensive area of the basin.

During the process of building GeoAmazonas, there were difficulties and a certain need for some initiatives that would benefit significantly the data production and the research in the region of the Amazon Basin. The initiatives could mean an update for the system or even lead to other studies.

Among the main issues found, it is possible to mention:

- The need to detail the used base for the scales of 1:1,000,000; 1:500,000;
- Stimulating the production of information in a standardized way between the countries that are part of the Amazon Basin, especially when it comes to strategic topics such as water management and climate vulnerability;
- Elaborating a digital Base of Images from SPOT, Landsat and CBERS Satellites for the regions of higher climate vulnerability and with most hydric resources of the Amazon Basin;
- Promote the distribution of the data obtained by making the system available on the internet;
- Develop open user interfaces for the system, allowing the use of free softwares in order that the cartographic base can be more easily exchanged between countries;

Table 1. Metadata from the GeoAmazonas GIS.

Information layer	Attributes	Application	Source	Temporal reference	Spatial range	Scale of origin	Shape
Areas subject to flooding	Location and area	Identification of the lands which may be flooded and which are more vulnerable to modifications in land use and climate change	IBGE/ Embrapa/ Retis-UFRJ	-	South America	-	Line/Polygon
Hydrographic Basins-Otto Pfafstetter	Location, area and name of the basins and sub-basins	Hierarchization and delimitation of the Tocantins-Araguaia basins	ANA	2007	South America	1:1.000.000	Polygon
Deforestation (anthropism)	Location, degraded/ regenerated area, rate of deforestation and period of deforestation (presents the temporal evolution of vegetation loss on the periods mentioned on the temporal reference)	Diagnosis and monitoring of anthropic action on the basins and identification of the areas which are more affected by changes in land use and land cover. It may be integrated with other factors in order to identify different environmental vulnerabilities in the areas of interest.	Prodes-Inpe	2000-2008	Brazil	IBGE: 1:2,500,000/TRF IC-MSU: Spatial resolutions of 28 m and 57 m/ Prodes-Inpe: Spatial Resolution between 20 and 30 m (resampling for 200 m and 400 m)	Polygon/Tabular
Hydrologic Network	Detailed and Generalized (Main Water Bodies)	Diagnosing and mapping hydric resources	IBGE/Retis-UFRJ/ ANA/Aneel	2000-2004	Brazil and South America	1:1,000,000/ 1:5,000,000	Line/Polygon/Tabular (only for the main water bodies)
Indigenous Land	Area and location	Conflicts related to land use	IBGE/Funai/ Retis-UFRJ	-	South America	-	Dots/Polygon/Tabular
Protected Areas (Conservation Units)	Year of creation, decree, category of use	Diagnosing and mapping land use, as well as conflicts related to it	IBGE-MMA -IBAMA/States/ Municipalities	2003	Brazil-States and Municipalities	1:1,000,000	Polygon/Tabular
Water Supply	Water amount per capita	Mapping the water supply conditions	Census 2000	Decennial	Municipalities -Brazil	1:1,000,000	Tabular data

- Integrate GeoAmazonas with hydrological, meteorological and climate databases of the Amazon Basin;
- Include the French Guiana, which was not a member of the ACTO and is not included in GeoAmazonas;
- Creating Georeferenced Scenarios for the Amazon Region.

Table 2. ACTO countries of the Amazon basin: details and maps.

Country	Details	Map* (GeoAmazonas)
Bolivia	<p>Bolivia has a drainage area of the Amazon Basin of 733,000 km², 12% of the total area of the basin, representing 65.5% of the Bolivian territory. The main basins are those of rivers Beni and Mamoré.</p>	
Brazil	<p>Brazil has a drainage area of the Amazon Basin of 3,850,560 km², which is about 63% of the total area of the basin, representing 45% of the Brazilian territory. The main basins are those of rivers Solimões, Madeira, Negro, Xingu and Tapajós.</p>	

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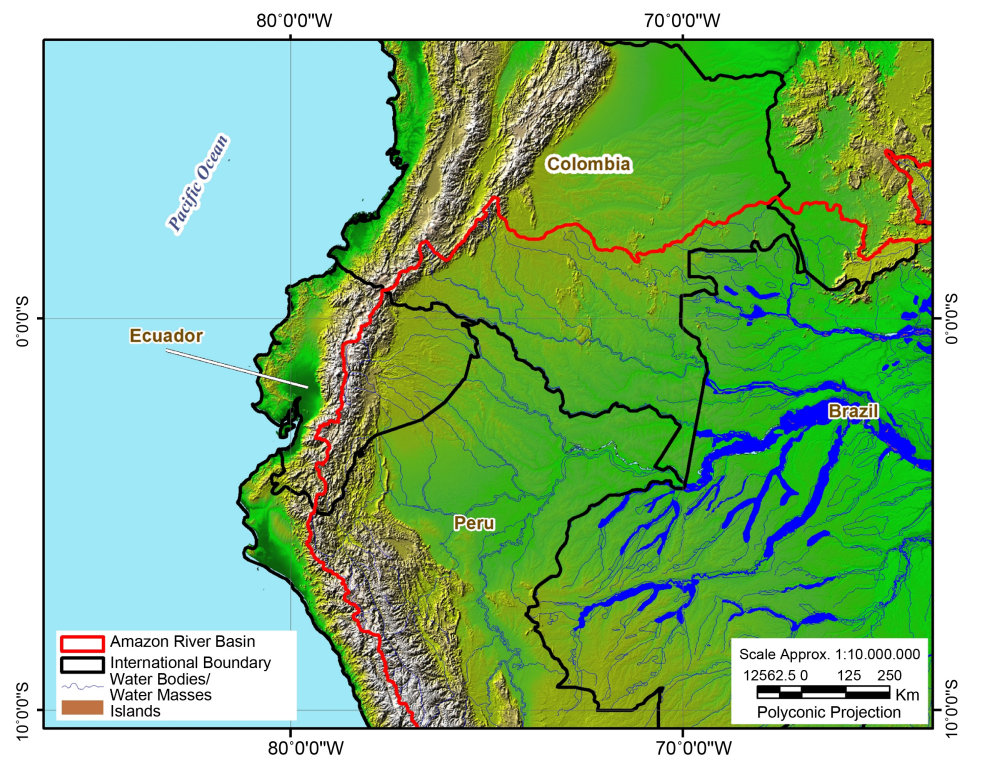
Colombia

Colombia has a drainage area of the Amazon Basin of 348,384 km², which is about 5.6% of the total area of the basin and 30.5% of the Colombian territory. The main basins are those of rivers Putumayo, Apaporis, Caquetá and Negro.



Ecuador

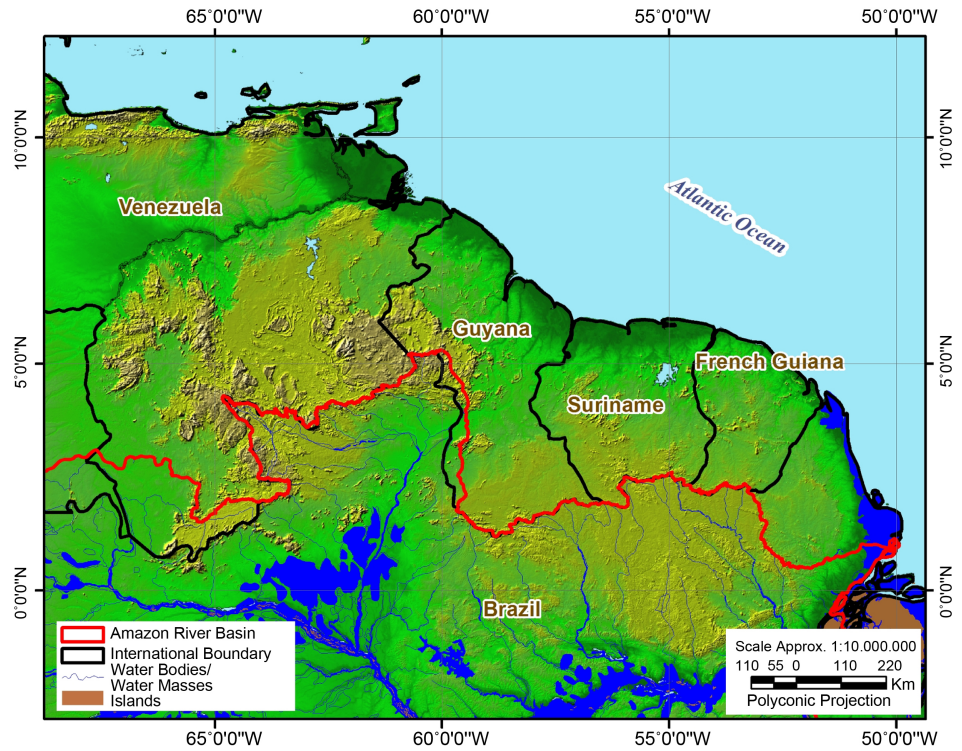
Ecuador has a drainage area of the Amazon Basin of 146,688 km², which represents about 2.43% of the total area of the basin and 54.5% of the Ecuadorian territory. The main basins are those of rivers Napo, Putumayo, Corrientes, Tigre, Pastaza and Morona.



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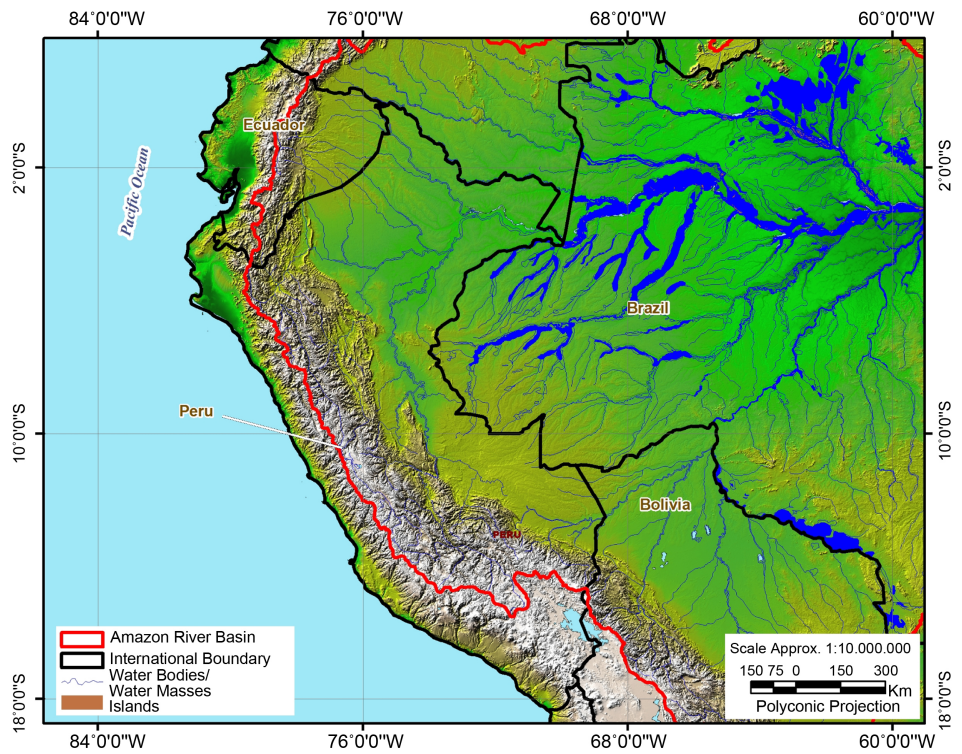
Guyana

Guyana has a drainage area of the Amazon Basin of 12,224 km², which represents about 0.2% of the total area of the basin and 6% of the Guyanese territory. The main basins are those of rivers Mau or Ireng, Tacatu and Sariwaw.



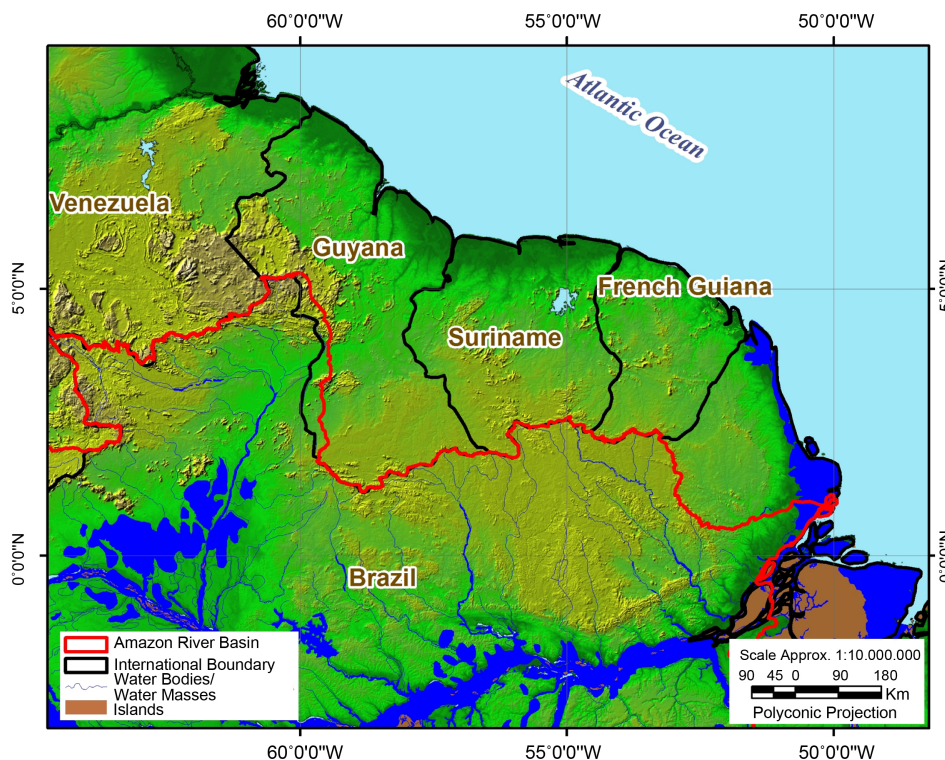
Peru

Peru has a drainage area of the Amazon Basin of 997,920 km², which represents about 16.3% of the total area of the basin and 76.9% of the Peruvian territory. The main basins are those of rivers Marañon and Ucayali.



Continued

Suriname does not have a determined drainage area of the Amazon Basin. One of the goals of the GET Amazonas Project is to define this area, which may represent between 0.05% and 0.1% of the total area of the basin and from 1% to 2% of the territory of the country. The main basins flow into the Atlantic, such as the basins of Rivers Tapanahony and Litani. The rivers that flow into the Amazon still need to be defined.



Venezuela has a drainage surface of the Amazon Basin of 42,784 km², which represents about 0.7% of the total area of the basin and 4.7% of the Venezuelan territory. Its main basin is the Negro river basin.



*It is worth pointing out that some of the enlargements made for the map representations of each country led to enlargements of the graphical error associated with them.

5. Conclusions

The efforts made to create and implement the GeoAmazonas GIS are an evidence of the current valorization and diffusion of the geographic information which has been increasingly stimulated by social and economic demands for a better understanding of the territorial reality, for that is the basis for implementing policies of sustainable management and development.

The challenges in developing a GIS for the region of the Amazon Basin—which is a transboundary area including water bodies under different domains—involve mostly the difficulty in accessing and standardizing the data of several sources. Therefore, it is extremely important to create agreements for sharing geospatial databases in order to integrate and share the most commonly used sources.

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