SÉRIE PEIXE VIVO

ECOLOGICAL CONDITIONS

CHAPTER 4
SAMPLING SITE SELECTION, LAND USE AND COVER, FIELD RECONNAISSANCE, AND SAMPLING

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1 – INTRODUCTION

Spatially extensive environmental assessments require samples that facilitate associating physical, chemical, and biological site conditions with watershed conditions. Sites must be selected in a random manner to allow statistical inference to the entire population of sites in the study region. Such studies are severely limited by sampling and processing time and human and financial resources (Hughes & Peck, 2008). Reconnaissance is needed before sending entire field crews to the sites to ensure permission from landowners, efficient and safe access, and appropriate site characteristics. To ensure that sites are sampled under the same hydrologic conditions, multiple crews are needed so that sites can be sampled during a short index period (less than one month during the dry season for streams, at the end of the wet season for reservoirs). Sites sampled once per year maximize the number of sites that can be sampled during an index period. Thus, the objectives of this chapter are to describe how we selected sites, reconnoitered and sampled sites, and determined watershed conditions.

2 – STUDY AREA

The Cerrado, with its different phytophysiognomies, covers nearly 20% of Minas Gerais (Carvalho & Scolforo, 2008), where the São Francisco and the Araguari Rivers headwaters are located. The São Francisco River basin covers an area of 645,000 km2, approximately 7.6% of Brazil (Godinho & Godinho, 2003; Sato & Godinho, 2003). The Araguari River, one of the main tributaries on the left bank of the Paranaiba River, runs over 475 km through a drainage basin covering an area of 21,856 km^2 (Baccaro et al., 2004). The Paranaíba River, in turn, meets the Grande River in the Mineral Triangle region to form the Paraná River.

We considered streams located within the area of influence of four hydropower reservoirs owned by Cemig Geração e Transmissão S.A., namely Nova Ponte, São Simão and Volta Grande HPP in the Upper Paraná River Basin, installed on the Araguari, Paranaíba and Grande Rivers, respectively, and that of Três Marias, located on the São Francisco River.

3 – SURVEY DESIGN

Environmental assessments rely on sample sites that aid associating species distributions with site and watershed physical and chemical conditions. Such sites are identified by their geographical location, as opposed to studies in which the variable space is not accounted for (Stevens & Olsen, 2004; Theobald et al., 2007). Spatially balanced sampling, constructed through probabilities, is able to select a network of points that reflect the spatial conditions of the area studied (Theobald et al., 2007). In the USA, this approach is used nationally and regionally (Olsen & Peck, 2008). In Brazil, however, this was a new approach. Therefore studies featuring this type of sampling design are still rare (Ligeiro et al., 2013; Jimenez-Valencia et al., 2014; Macedo et al., 2014).

In our project, we adopted the GRTS (Generalized Random-Tessellation Stratified) approach, in which the sampling design is hierarchically and spatially balanced and applicable to points, lines, and polygons (Stevens & Olsen, 2004). This approach is based on the conversion of all the objects (for example, stream kilometers or reservoir shorelines) along a unidimensional vector. This vector is like a long avenue, and each site is like a hierarchically distributed address on that avenue (Stevens & Olsen, 2004). We developed a spatially balanced sampling design for the Nova Ponte, Três Marias, Volta Grande and São Simão reservoir margins and their wadeable stream reaches (Kaufmann et al., 1999) located < 35 km upstream from the reservoirs.

To select stream sites we used the IBGE's (Instituto Brasileiro de Geografia e Estatística) and DSG's (Diretoria de Serviço Geográfico do Exército Brasileiro) topographic maps (1:100,000 scale), digitized by the Geominas Project (Vegi et al., 2011). The drainage network was topologically corrected via ArcGis Desktop and Strahler (1953) stream order was determined through use of the Hydroflow software program (Ramos & Silveira, 2008). We defined the potential site spatial distribution using R (R Development Core Team, 2010) based on the Spsurvey library (Kincaid, 2009). We created a stream network master sample and established a random list of potential sampling points with a minimum of 1 km distance between each. Points within the reservoir and rivers greater than third order were eliminated, and the first forty points (first through third order) were selected for reconnaissance. We sampled streams with a Strahler (1953) order lower than four (Figure 1). The sites covered a diverse range of characteristics and we considered both the land use in the riparian zone and its surroundings (pasture, farming, urban) at different disturbance levels. Similarly, within the streams themselves a diversity of meso-habitats were studied in terms of different types of substrate (boulders, gravel, sand, etc), flow (rapids, glides, pools etc), and variations in channel width and depth. Because one purpose of the IBI-Cemig Project was to assess biotic integrity, we needed to guarantee that some sites were minimally altered and others severely altered (Whittier et al., 2007). Therefore, some sites were hand picked in preserved areas (e.g., the Galheiros/Cemig reserve) and in highly altered urban areas (Figure 2). It is important to note that sites considered as reference sites are those minimally disturbed by anthropogenic activities yet representative of the region in which they occur. These served as controls (Hughes et al., 1986).

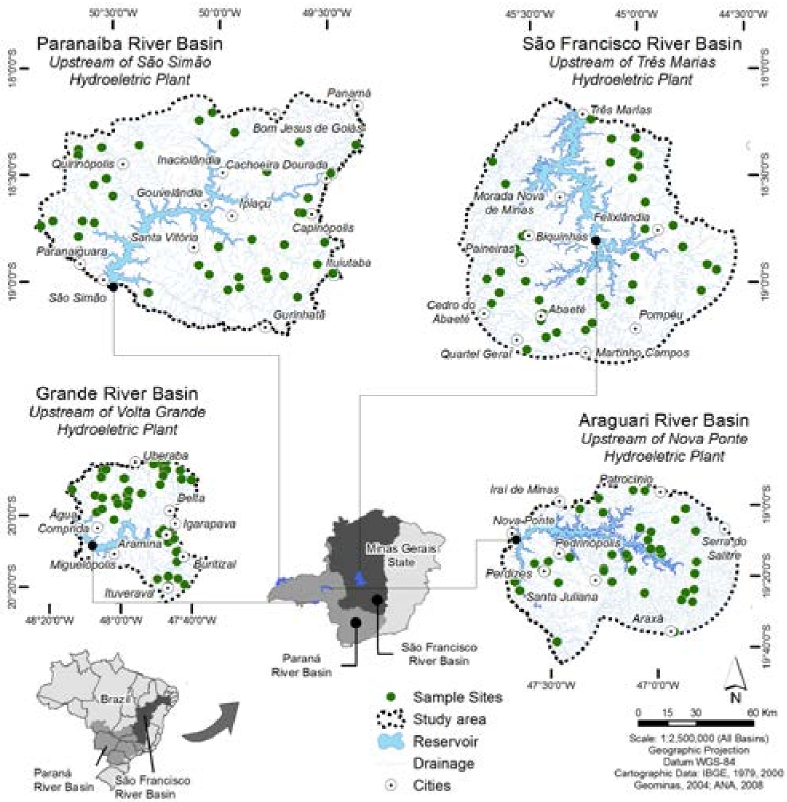

FIGURE 1. Locations of stream sites randomly arranged upstream from São Simão, Três Marias, Volta Grande, and Nova Ponte Reservoirs.

FIGURE 2. Examples of minimally and highly disturbed sites in Nova Ponte, Três Marias, Volta Grande, and São Simão drainages.

We sampled reservoir littoral zones and the reservoir perimeter was established from satellite images. The polygon representative of each reservoir perimeter was extracted from a Landsat image with R7G5B4 composition, eliminating the penetration of light into the water (Jensen, 2006). We used the Maxver classification method to identify the body of water using the Spring/INPE software package (Camara et al., 1996). The randomization process was adapted from Stevens & Olsen (2004) and the routine was implemented using the ArcGis Desktop suite. The perimeter of the reservoir was converted from a line to points; then a point was randomly selected from this group of points and another 39 were positioned equal distances apart along the perimeter (Figure 3).

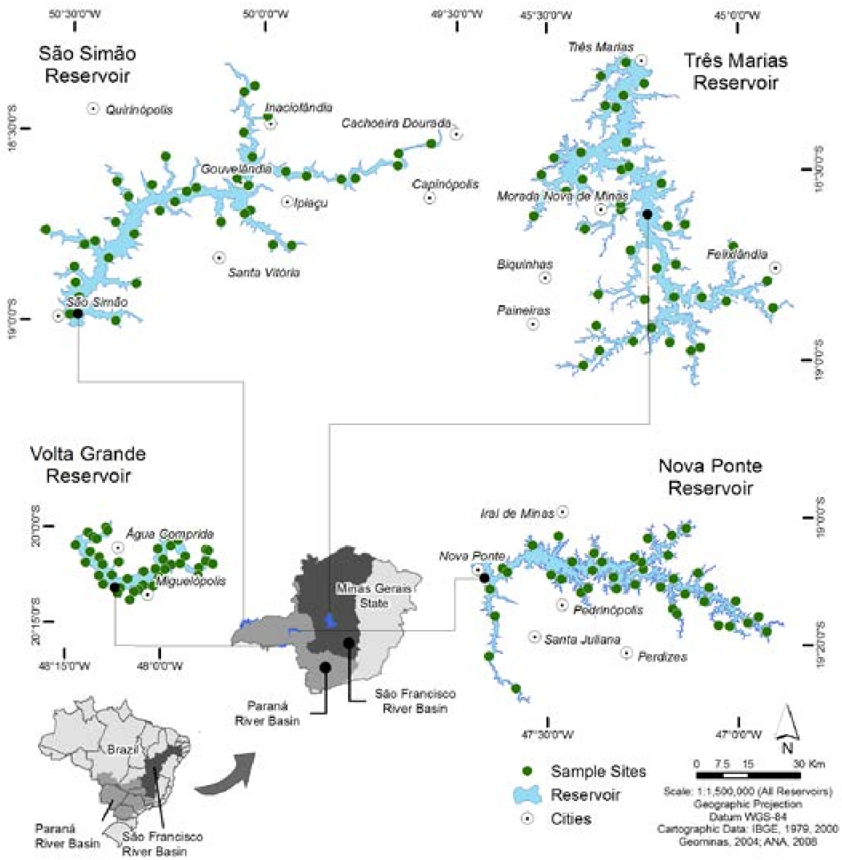

FIGURE 3. Locations of sites in São Simão, Três Marias, Volta Grande, and Nova Ponte Reservoirs.

4 — FIELD RECONNAISSANCE

Once sites had been selected, two-person teams performed field reconnaissance before each sampling campaign. Prior reconnaissance of sampling sites optimized the time required for field sampling, as it ensured that sites were physically and legally accessible and safe to sample. In the case of stream sites, a major purpose was to ensure sites had flowing water and reasonable road access (< 1 km from the site). For reservoirs, the objective was to determine boat access that minimized distances between sites and facilitated sampling multiple sites from a single landing. Following definition of the sampling network, the best access routes were established. We used Google Earth (Google, 2010) software to trace routes (Figure 4) and transferred them to a GPS device connected to a laptop computer (Figure 5) to facilitate navigation and field recognition by the team. At each point, the reconnaissance team recorded useful access information. During field reconnaissance, if site access was excessively difficult or prohibited by land owners, teams were prepared in advance to select new sites, in accordance with the hierarchical rank established using the Master Sample software package. At the end of the field reconnaissance trip, 40 stream sites had been guaranteed for sampling. Reservoir reconnaissance also used Google Earth (Google, 2010) software to locate possible boat access points along the reservoir shore and their respective roads. Distances between points were calculated for sampling points and their respective access points, which aided in planning the sampling sequence (Figure 6).

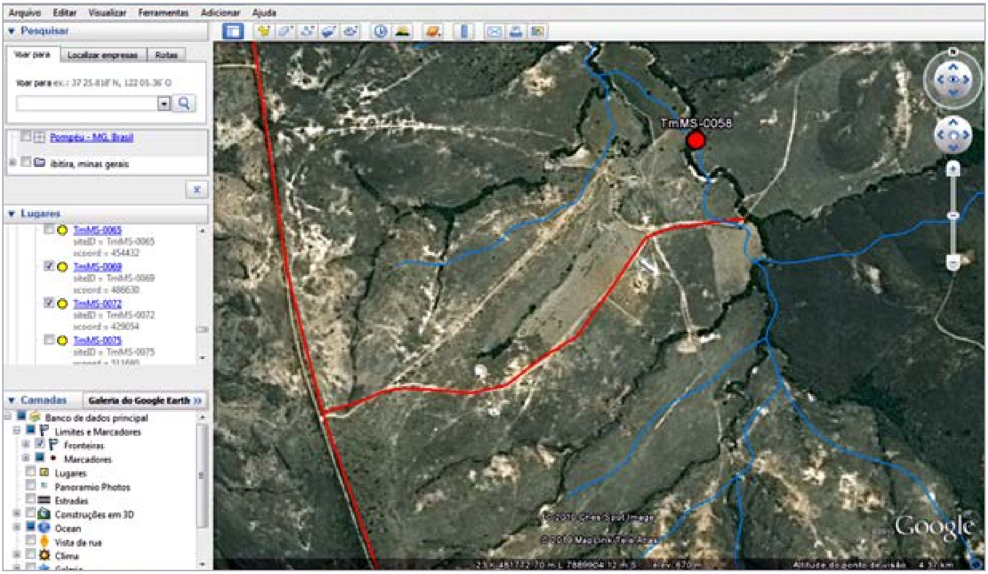

FIGURE 4. Route traced on Google Earth to reach point TMMS-0056, in the Três Marias Reservoir drainage.

FIGURE 5. Field reconnaissance team in the São Simão Reservoir drainage.

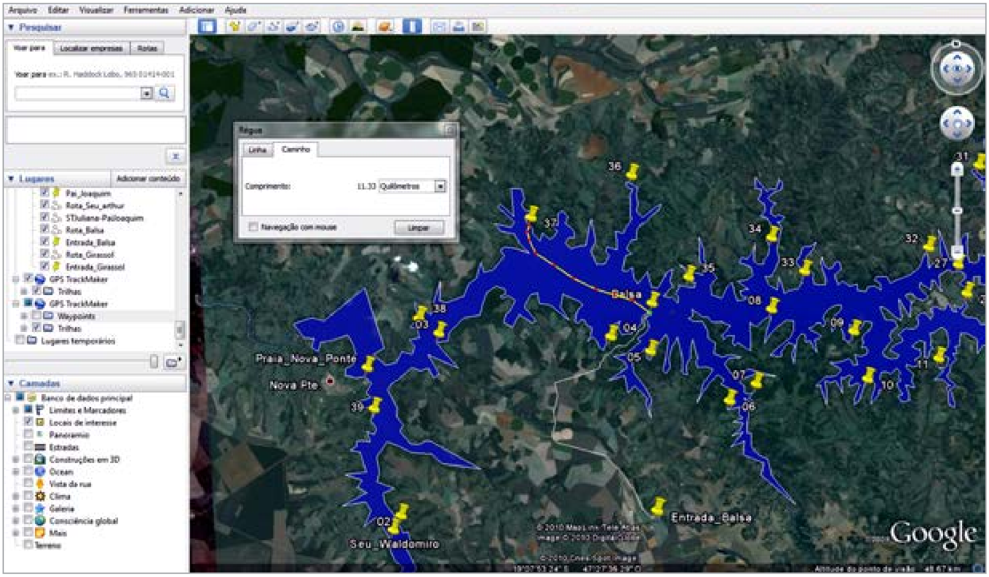

FIGURE 6. Checking distances between sites in Nova Ponte Reservoir through use of Google Earth.

5 – FIELD TEAM GEAR AND EQUIPMENT PREPARATION

The organization of the gear and equipment used by the field teams during the sampling campaigns was undertaken jointly with the partner universities. For stream sampling, when 3 or 4 teams worked simultaneously, all field gear was identified by a different color for each team in advance to avoid confusion. By maintaining several teams in the field at the same time we ensured that sites were sampled under the same hydrologic conditions (within two weeks and one week for streams and reservoirs, respectively), given the fact that each team was able to sample only one stream site per day. Because of differing logistical restrictions for reservoir macroinvertebrate and fish (overnight gill netting) sampling, those two teams worked independently and each specific piece of gear and materials was the responsibility of the UFMG or PUC-MINAS laboratory. Some equipment had to be imported because it could not be found in Brazil. To do so, a market survey was conducted among suppliers and all equipment was acquired according to descriptions made available by the US Environmental Protection Agency (Peck et al., 2006; Callisto et al., THIS VOLUME).

Field teams were established to include representatives of the different skill sets and universities involved. For stream sampling, the labor demand was greater with an average of 12 people required (3 or 4 teams with at least 4 members each). On each crew, there was a person in charge of each function: filling out physical habitat forms, measuring physical and chemical parameters, benthic macroinvertebrate sampling, and fish sampling. Fish sampling in reservoirs required three to four people per team, because they took turns placing gill nets and retrieving them the next morning, seining littoral zones, and sorting and fixing fish. The other reservoir sampling required a three person team with one person in charge of one function: filling out forms, physical and chemical habitat sampling, and benthic macroinvertebrate sampling, with occasional support from another team member. In addition, we hired a licensed boatman familiar with the reservoir for each team. Before any site was sampled, all participants were trained in field safety and to ensure that standard methods and measurements were used in collecting physical, chemical, and biological data.

6 – ENVIRONMENTAL AND BIOLOGICAL CHARACTERIZATION

The length of each stream site was 40 times its wetted width, with a minimum distance of 150 meters (Peck et al., 2006; Hughes & Peck, 2008). The site was divided into 11 cross-sections (A-K) and 10 equidistant measurements were made between each section following the thalweg profile (Figure 7). At the cross-sections, multiple physical habitat characteristics were assessed and macroinvertebrate samples were taken (Ligeiro et al., THIS VOLUME); water samples were collected at the upstream section (K) before all other sampling, (Figure 8). Fish were sampled for proscribed times between each cross section (Leal et al., THIS VOLUME).

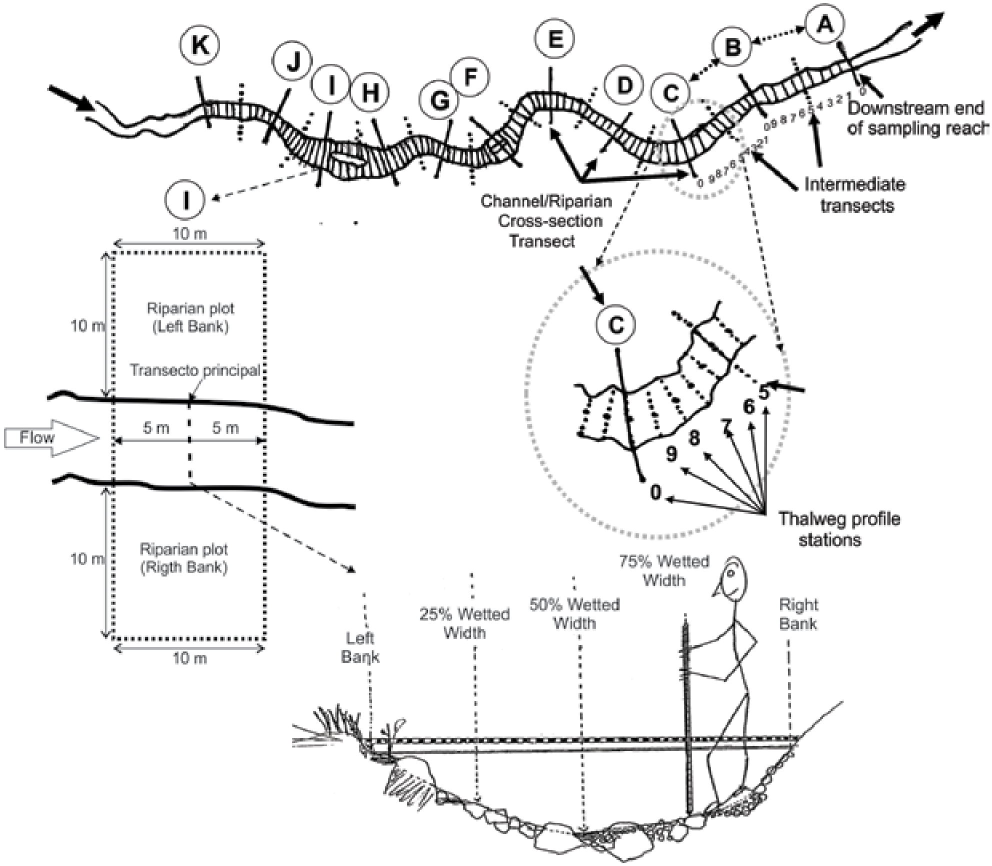

FIGURE 7. Site sampling scheme (from Peck et al., 2006).

FIGURE 8. Photos of field teams sampling streams.

At each of the 40 reservoir sites, we sampled 10 parcels, each 15 meters wide, totaling 150 meters at each sampling site in the littoral region of each reservoir (Figure 9). Each parcel was composed of continuous littoral zones (15 meters wide and 10 meters deep), a riparian zone (15 meters wide and 15 meters deep), and a floodable zone (15 meters wide with a variable depth depending on the degree of reservoir drawdown and the bank slope at the site; USEPA, 2011; Figure 9). Multiple physical habitat characteristics were assessed in each of the three zones; water, sediment texture, macroinvertebrates, and fish were sampled in the littoral zone (Figure 10; Morais et al., THIS VOLUME; Sanches et al., THIS VOLUME).

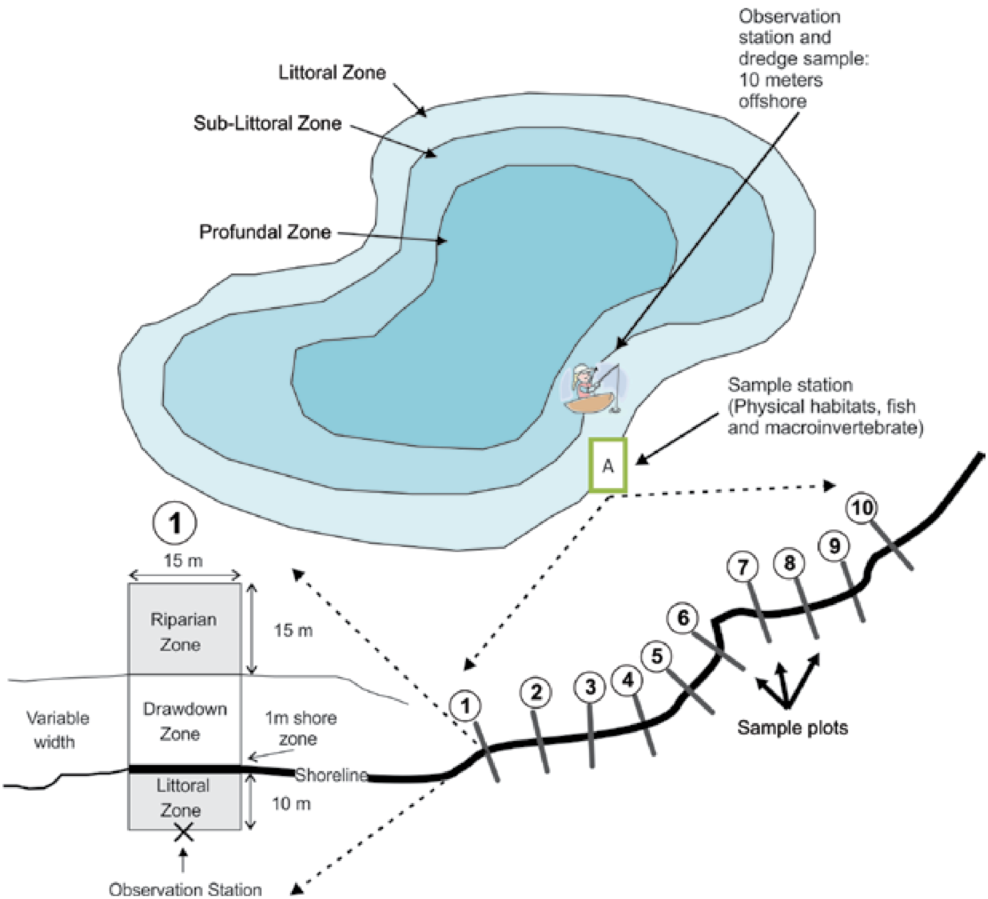

FIGURE 9. Sampling scheme in the reservoir littoral region. Adapted from USEPA (2011).

FIGURE 10. Reservoir sampling. Collecting water samples (A; B; C), applying the physical habitat protocol (D), collecting macroinvertebrates with a kick-net (E), and collecting sediment and macroinvertebrates with an Eckman-Birge dredge (F).

7 – LAND USE AND COVER

Watershed and buffer land use and cover affect the quality of aquatic habitats and, consequently, the aquatic biota. Anthropogenic uses, notably urbanization and agriculture, diminish native vegetation cover, including in the riparian zones, degrading physical habitats, altering hydrology, and increasing sedimentation rates, water temperature, and nutrients (Bryce et al., 2010; Kaufmann et al., 2014). Therefore, it is useful to relate the land use and cover at several different spatial scales with the quality of physical and chemical habitats (Walser & Bart, 1999; Wang et al., 2001).

We determined land use and cover for each stream site catchment and within a 500-meter radius from each reservoir site. To classify land use and cover, we employed manual interpretation of images with fine resolution (0.6 – 5 meters; Google Earth images; Google, 2010) and a set of multispectral images from the TM sensor installed in the Landsat satellite (Figures 11 and 12). Fine resolution images provide the form and texture of elements and the Landsat images produce distinct spectral responses of the targets, facilitating high mapping precision. For example, in the fine spatial resolution featured in Google Earth, vegetation usually appears in the same color (e.g., both forest and sugar cane plantation are green). However, these land uses in a Landsat image look different because foliar structure differences are included (Jensen, 2006). In our study, we mapped four vegetation cover physiognomies (IBGE, 1991): forested savanna, gramineous-woody savanna, park savannah and wet areas. We also mapped four land use types: agriculture, pasture, eucalyptus reforestation, and urban.

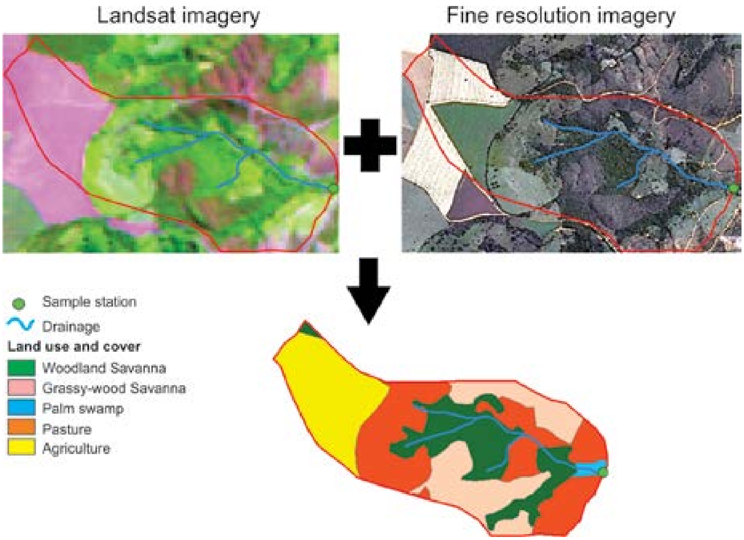

FIGURE 11. Schematic methodology used at site NPMS-00128, Nova Ponte Reservoir drainage.

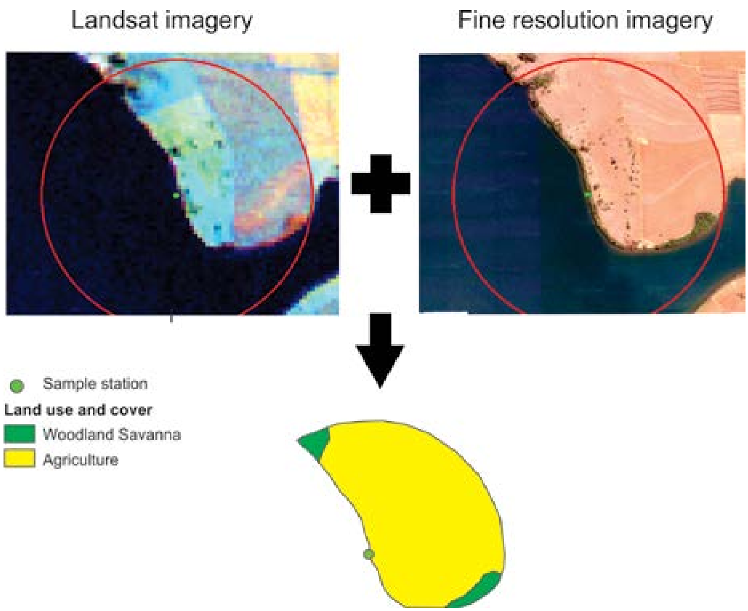

FIGURE 12. Schematic methodology used at site 35, Volta Grande Reservoir.

Agriculture was most predominant in the Volta Grande and São Simão drainages (mean about 70%), followed by Nova Ponte (mean about 50%) and Três Marias, (mean near 0%; Figure 13). Pasture was greatest in the Três Marias drainage (mean near 40%), and the Nova Ponte, Volta Grande, and São Simão drainages were all less than 20%. Regarding natural vegetation cover (forested savanna, gramineous-woody savanna, or park savanna), Nova Ponte and Três Marias were the least altered drainages (natural vegetation means nearly 40%), whereas the other drainages had means of only 10% natural vegetation cover. Mean urban area in all the drainages was lower than 5%, but somewhat higher in Volta Grande and São Simão than the others. These results demonstrate that Nova Ponte and Três Marias watersheds were generally less disturbed than São Simão and Volta Grande watersheds.

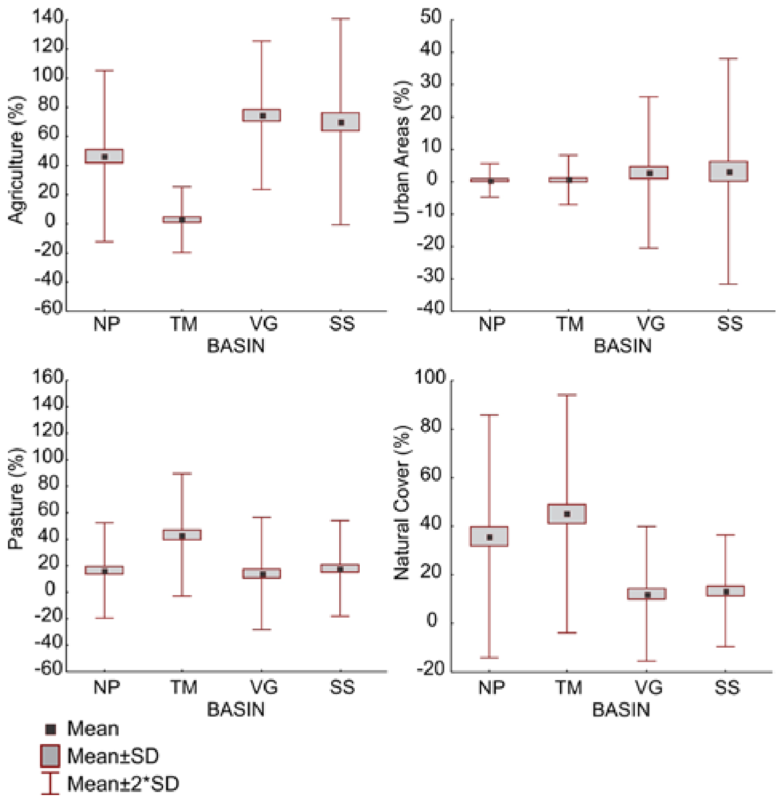

FIGURE 13. Land use in the site watersheds of Nova Ponte (NP), Três Marias (TM), Volta Grande (VG) and São Simão (SS) drainages.

Buffer results for the reservoir sites were similar to those of the drainages' stream sites. The Volta Grande buffers had the highest percentage of agriculture (mean near 85%) compared with São Simão (mean near 20%), and Nova Ponte and Três Marias (means about 10%; Figure 14). Regarding buffer pasture, São Simão had the most (mean near 40%), Nova Ponte and Três Marias pasture means approximated 10%, and the Volta Grande mean was near 0%. Natural vegetation cover was greatest in Nova Ponte and Três Marias buffers (means near 60%); the other reservoirs had means of about 10% of their buffer area in natural vegetation cover. All site buffers had means of less than 5% urban, but Volta Grande and São Simão had slightly more than Três Marias and Nova Ponte. Thus the buffer areas at Nova Ponte and Três Marias were generally less disturbed than those of São Simão and especially Volta Grande.

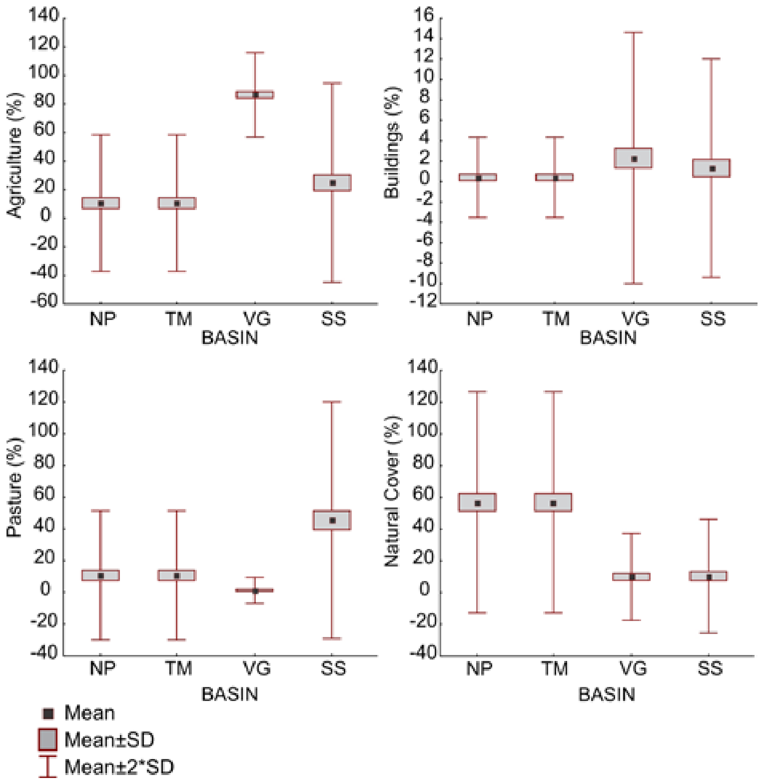

FIGURE 14. Land use in buffers (500 meters) of Nova Ponte (NP), Três Marias (TM), Volta Grande (VG) and São Simão (SS) reservoir sites.

8 – ACKNOWLEDGEMENTS

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