DOI: 10.5935/1809-2667.20140016 **Artigo Original**

Geoprocessing applied to spatial and temporal analyses of aquatic ecosystems as a tool in Science Education

Geoprocessamento aplicado à análise espacial e temporal de ecossistemas aquáticos como uma ferramenta para o ensino de Ciências

Lucíola S. Lannes*
Beatriz Quintal**

As novas tecnologias fazem parte da vida moderna, e sua aplicação no processo educacional básico constitui uma demanda importante dos programas de educação vigentes. No campo das ciências, essa estratégia é fundamental para a construção de um estudante inquisitivo, o que forma a base para o desenvolvimento de um processo efetivo de aprendizagem. Este trabalho apresenta uma técnica de geoprocessamento que visa auxiliar professores e estudantes de escolas básicas e secundárias nos campos de ciências, biologia e geografia a desenvolverem habilidades para análise ambiental objetivando um aprendizado participativo.

Palavras-chave: Análise ambiental. Aprendizagem participativa. Ensino de Ciências. Geoprocessamento. Tecnologia.

New technologies are inserted in all aspects of modern human life, and their application in the educational process is a main demand from official educational programs. In the field of Sciences, such strategy is fundamental for a construction on an inquisitive student, which is the basis for the development of an effective learning process. This work develops a geoprocessing technique consisting on the use of satellite images. This will aid K-12 teachers and students in subjects such as Sciences, Biology and Geography to develop skills for environmental analysis aiming at a participatory learning.

Key words: Environmental analyses. Geoprocessing. Participatory learning. Sciences learning. Technology.

Introduction

Over the last years, several authors have stated that both teachers and students can benefit from learning Science by working the way scientists do (DUCKWORTH, 1978; HAWKINS, 1974; SHAPIRO, 1991; TYLER, 1992); such as posing their own problem questions and proposing a development of means to answer them, and share the results with others (SHAPIRO, 1996). This would also help to change the view that Science is an impersonal, obscure and inaccessible subject. The law that regulates educational directives and bases in Brazil (Lei de Diretrizes e Bases da Educação Nacional - LDB) (BRASIL, 2000) follows this view, proposing that lectures

* Doutora em Ciências (Ciências Ambientais) pelo Instituto Federal Suíço de Tecnologia (ETH Zurich). Docente da UNESP - Universidade Estadual Paulista, Departamento de Biologia e Zootecnia – Ilha Solteira/SP – Brasil. E-mail: luciola.lannes@bio.feis.unesp.br
** Doutora em Geociências (Geofísica) pelo Instituto Federal Suíço de Tecnologia (ETH Zurich). Docente da UNIL - Universidade de Lausanne, Grupo de Geofísica Aplicada e Ambiental – Lausanne – Suíça. E-mail: beatriz.quintal@unil.ch

on natural sciences should focus on the comprehension of the meaning of science and on the learning of the principles that conduct to the scientific progress. Additionally, the official documents that specifically guide the directives related to the teaching "Sciences" in Brazilian schools, the National Curricular Parameters (PCNs) (BRASIL, 1998), require that the organization of topics be approached in classes is bound to the reality of the student. In this realm, it is important that teachers and students interact in the same language, that is, the topic being studied in the classroom should resemble aspects of the student's daily life as well as instigate this student to create methods to solve real problems.

Lakes and lagoons are an integrative part of the life of every citizen living in the State of Rio de Janeiro because it constitutes a fundamental component of the landscape. In ecological terms, the formation of low-income urban communities in developing countries is followed by failures in the removal of domestic residues and their deposition in the closest water body (BRADLEY; BARTRAM, 2013; VIANNA, 1991). This promotes an increase of nutrients in the system, being the main cause of overproliferation of aquatic macrophytes in natural water bodies placed in urban areas, leading to a process of precocious aging of the aquatic system. This is characterized by the rapid reduction of depth and surface area, turning it into an early terrestrial system (MITSCH; GOSSELINK, 2000). Such dynamics is commonly accelerated by margin invasions, such as cattle grazing and civil constructions. Low-cost surveys through satellite images processing and interpretation can be useful for monitoring the proliferation of such plants, as they yield valuable spatial and temporal information. The use of remote sensing techniques is recommended for the monitoring and inventory of freshwater ecosystems (GOUDIE, 2013), especially in developing countries, where economic resources for research are normally scarce, as well as lack of information about those areas and their changing over time.

Gomes (2004) studied how continental aquatic environments were approached in Geography and Biology books for public K-9th grade schools in Brazil, and found several conceptual mistakes that have been propagated over the years. The author argued that school coordinators strongly encourage the fulfillment of the pre-determined curriculum of the textbook, not considering whether the contents are fit to the students' socio-environmental reality. Therefore, in most cases, teachers don't emphasize important subjects nor use cross-curricular themes, a fact that decreases the optimization of learning and the student's interest for Sciences (BARNES, 2011).

Teachers are substantially limited by social and administrative pressures to teach and guide students in a particular way (KERR, 1989; WELCH et al., 1981), since the way the subject "Sciences" is worked in the classroom is largely dependent on features of the school learning environment, such as textbook resources, examinations, and administrative duties (SHAPIRO, 1996). Nevertheless, the use of new technologies in the learning process is nowadays an important demand of the world official programs of Education. For example, it is pointed out in the PCNs that one of the most important tasks of the school is to provide students with different information sources and technological resources to make them get and build knowledge (BRASIL, 2002). According to Bybee (2000), it is important that students not only learn about Science, but also develop skills associated to investigative processes.

Recent studies have shown, indeed, that it is possible and recommendable to work with an investigative focus with students of different ages (GOUW; FRANZOLIN; FEJES, 2013), which will allow them to construct knowledge instead of just accepting the information given, which is the basis for a formation of an inquisitive citizen and perhaps a scientist (BYBEE, 2000; KRASILCHIK, 2000).

Students are likely to learn and retain more from their experience if they are involved in a participatory rather than a submissive role (JERKINS; PEPPER, 1988; SHARP, 1989; MOSSA, 1995). The PCNs and the Brazilian law no. 9.795/99, which regulates the Environmental Education and institutes the National Policy of Environmental Education, encourage an articulated approach of local, regional, national and global environmental issues, and also the local experiences from the students in the formal and non formal learning environments. Such activities foster the regionalization of knowledge aiming at a participatory learning.

It is also pointed out in the PCNs that technology must be used to enrich the learning environment, allowing knowledge building through the teacher's active, creative and critical performance (BRASIL, 2002). Furthermore, Tedesco (2004) states that the use of new technologies in Education should be considered as part of a global learning strategy. Macagnan (2001) points out that children learn more easily than adults how to deal with computers, and that the use of geoprocessing in schools helps students to develop quick thinking, to match single phenomena to wider contexts, to work well in groups, to improve aesthetics, to find solutions, and to propose alternatives to different problems. With the use of remote sensing, the student is able to observe and study places in a new temporal, spatial and visual perspective, creating new learning opportunities (SANTOS; LAHM; BORGES, 2008).

The use of Geographic Information Systems (GIS) offer many advantages to the learning process, such as: (1) it allows students to make analysis, correlations and synthesis due to the practicality and fastness on handling large amounts of information; (2) it allows teachers and students to interact with files, databases, multimedia and other kinds of technologies, such as remote sensing; (3) it contributes to the development of analytical thinking, since the user seeks new possibilities of answers, analyzing the information in face of the challenges. According to Dwyer (1999), today's students need not only to know how to learn, but how to analyze and summarize data, make decisions, work in teams, plan solutions to complex problems, as well as be capable to adapt to the unexpected. For instance, students understand graphing better if they have the opportunity to graph their own data point-by-point than taking secondary data generated by others (LINN; HSI, 2009).

The objective of this paper is to propose an exploratory practical activity to be developed throughout the basic years of Geography, Biology or Science learning. We implemented a simple instrumental methodology encouraging the use of geoprocessing techniques for environmental analyses. Such methodology aims at positioning the student as an active builder of his/her environmental knowledge in a way to turn learning into an even more attractive task. The methodology is described in a way that can be used in classrooms equipped with computers and current GIS software for an effective monitoring of diverse kinds of dynamic landscapes, such as lakes, forests, wetlands, urban areas and water dams.

Material and Methods

The variation of the water surface area in lakes of the State of Rio de Janeiro was measured by using a simple set of geoprocessing techniques. For six urban and non-urban lakes, Landsat images were spatially and temporally analyzed in order to better access the dynamics of such environments. Three different Landsat scenes were compared to evaluate the dynamics of the lakes' cover by changes in aquatic plant cover and urbanization, for example. The images were dated from 1986, 1994 and 1999, and all of them were taken in the dry period in the region. These satellite images were freely obtained via the Brazilian Space Research Institute homepage (INPE, 2013).

Three of the studied lakes are located in urban areas: Vigário Lake, Taquaruçu Lake, and Imboassica Lagoon. The other three are not essentially urban systems: Campelo Lake, Cima Lake and Feia Lake (Figures 1 and 2). The Vigario-Taquaruçu System is located in Campos dos Goytacazes, a region of peripheral development status in relation to the Brazilian economy, and is known as one of the poorest areas in the country (VIANNA, 1991). The Vigario-Taquaruçu system is formed by the Vigario Lake, which is connected to the Taquaruçu Lake through a wetland. The areas surrounding the Vigario Lake are under the pressure of intensive urban occupation (GATTS et al., 2003). The Imboassica Lagoon is also located in urban area, and a sand bar separates it from the sea – eventually opened by local residents for water renewal. The Campelo, Cima, and Feia Lakes are located in non-urban areas, surrounded by a cattle grazing area and fragments of native forests.

Spatial and temporal information of satellite images were assessed after the simple geoprocessing steps below-described:

i) An R7G4B1 color composition was done using the software Envi 3.2. This step aimed at outlining the different compartments of the landscape: vegetation, water bodies and urban area. This first step of the process can be bypassed, once color-composed images can be easily gotten through spatial agencies websites, for example at the Brazilian National Institute for Space Research (INPE, 2013);

ii) Twelve control ground points (CGPs) were accessed with a GPS receptor around the area of the image for further georeferencing. This is also an optional step in the work, since most images are already georeferenced by the image provider;

iii) We pointed out the 12 CGPs in the images in order to geo-reference them. With image georeferencing, two important topics are achieved: i) the geographic coordinates are real in the images, and ii) the spatial resolution of the raster image is guaranteed (a pixel of 30 meters in the case of such Landsat images). This step can be done if the image obtained is not georeferenced, as mentioned in the previous item;

iv) Using the software ArcView 3.2, we created three vector files which contained the three images (1986, 1994 and 1999). Each vector file contained the internal contour of the six lakes for each year (areas with water surface, not covered by aquatic plants). This is the most important step of the work, and the one that teachers will practice with students. Therefore, details on how to do it are described as follows.

1) Start the software ArcView 3.2;

2) The software must be configured with the *View* mode;

3) In the menu bar, click on *View* and select *Add Theme*. Then, the file with the satellite image must be selected (it is usually a .TIF image). The file name will appear on the left side of the screen, and the image will appear in the middle;

4) With the zoom tool, one of the components of the landscape can be selected (a lake, in our case), which will be zoomed in and located in the middle of the screen, in order to facilitate the visualization and the work;

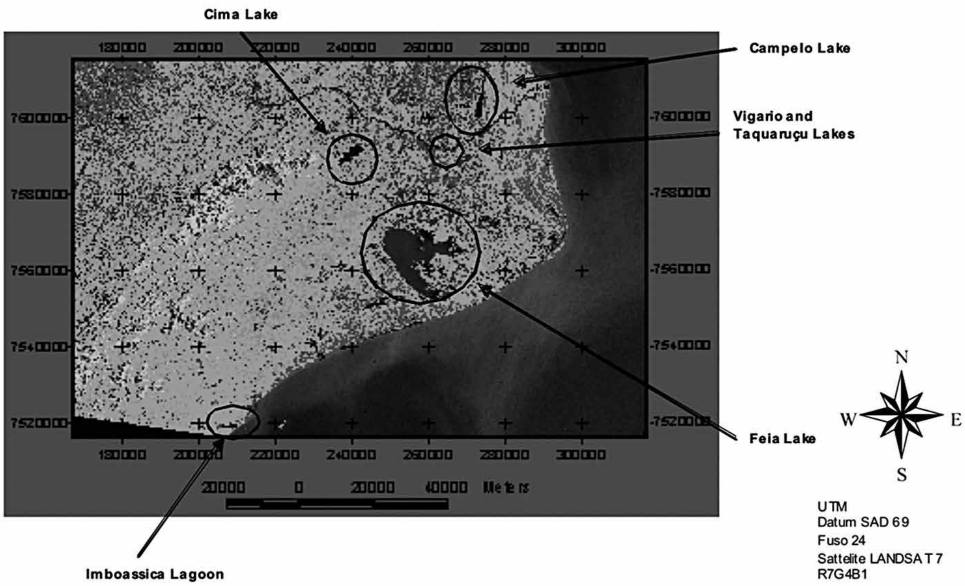
5) With the tool *Draw polygon*, the contours of the internal area of the lake can be drawn, until ending. Each contour is marked point-to-point, according to the desired scale and accuracy, to create a geometric figure that is approximate to the real contour of the lake. The software shows, in real time, the areas and the perimeters of the polygons. The same procedure was done for each of the six studied lakes, of the three images (years of 1986, 1994 e 1999).

It is also possible to print out the produced maps. For that, a *layout* mode can be created and the images with the respective internal contours and scales may be inserted.

Finally, some *layout* adjustments are made in order to give a better presentation to the printed maps, such as the insertion a north arrow, of a grid and the description of the used type of the projection. As an example of what we have done for each of the six lakes, Figure 3 shows the Vigário Lake in the years of 1986, 1994 and 1999. The inner areas of the polygons were calculated using ArcView 3.2, and then compared to the official areas found in the literature for each of the six lakes.

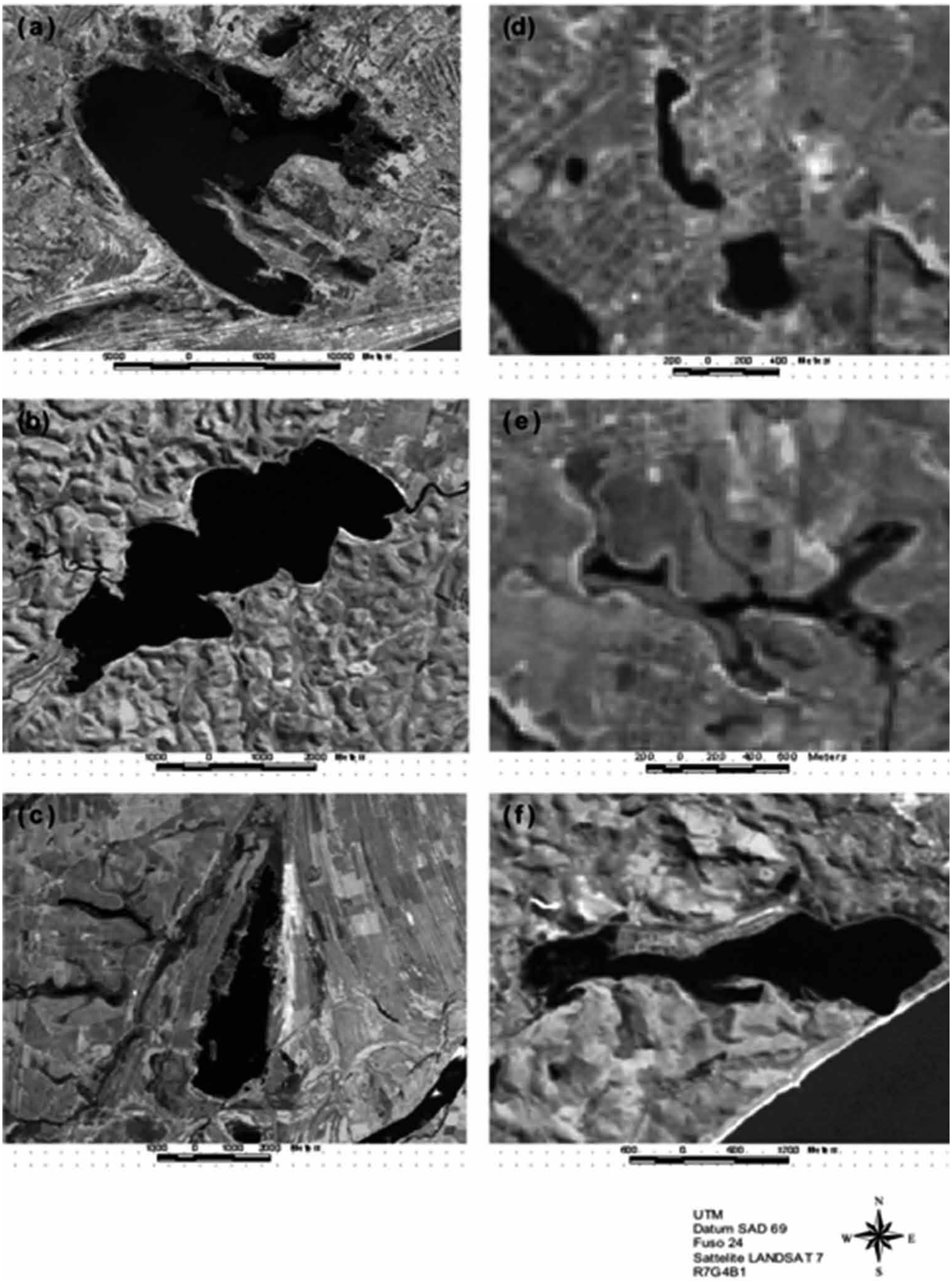
At this point, it is relevant to mention that there are some other software that could be used instead of ArcView GIS. A few open source GIS software are available for free download, for example the Grass GIS (http://grass.osgeo.org), offered by the Open Source Geospatial Foundation. Another software possibility for performing the same procedure is by means of the widely known Google Earth Pro (http://www.google.com/earth/), which has lately been used in several scientific works on environmental analysis (YU; GONG, 2012; GOUDIE, 2013) due to its practicality. Both software can be used by following the same principles as described above for the ArcView GIS (step iv).

Figure 1 – Landsat image (1999) representing the spatial distribution of the 6 studied water bodies: Cima Lake, Campelo Lake, Vigário Lake, Taquaruçu Lake, Feia Lake and Imboassica Lagoon



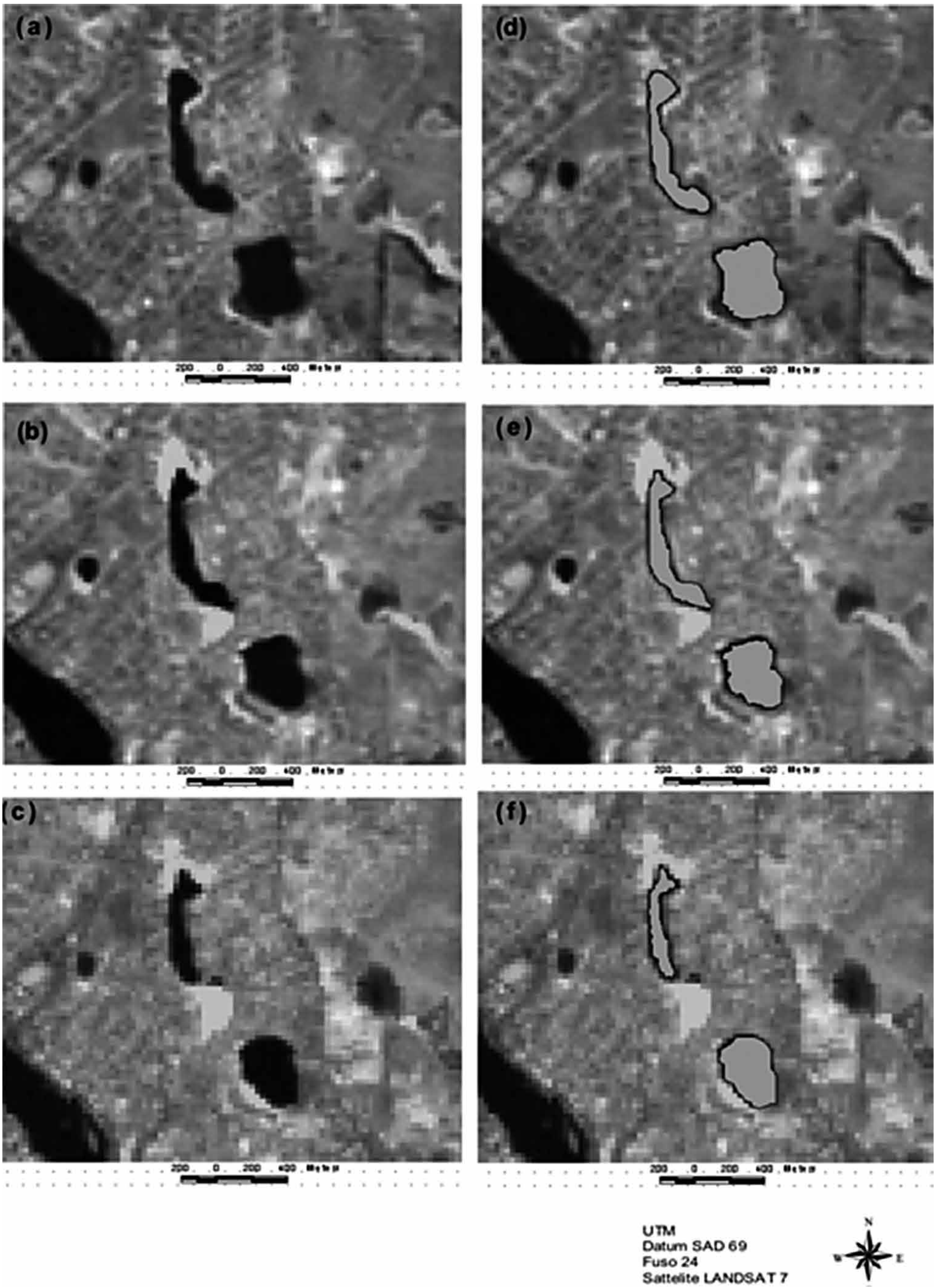
Fonte: INSTITUTO... (2013)

Figure 2 – Landsat images (1999) detailing the studied areas: Feia Lake (a), Cima Lake (b), Campelo Lake (c), Vigario Lake (d), Taquaruçu Lake (e) and Imboassica Lagoon (f). Note in the scale under each figure that the different lakes have areas diverse from each other



Fonte: INSTITUTO... (2013)

Figure 3 – Images of the Vigario Lake in 1986 (a and d), 1994 (b and e) and 1999 (c and f) with their respective inner polygons in order to exemplify part of the methodology proposed by this study



Fonte: INSTITUTO... (2013)

Results and Discussion

Bizerril (2004) and Gomes (2004) show in various studies in different regions that the Brazilian ecosystems are not treated adequately in Biology, Geography and Science textbooks. In general, Brazilian students have more affectivity for exotic ecosystems than for native ones. This happens because they know the former better, due to advertisements and to the teacher's approach in the classroom. In addition, some teachers are not familiar with some Brazilian ecosystems, such as lakes, wetlands, restingas and even the macro region of the Brazilian Cerrado (BIZERRIL, 2004). Therefore, there is an urgent need for the involvement of teachers and students in more regional and local environmental contexts, improving their ability to adapt the curriculum to their reality, promoting a process of "customization" of teaching methods according to local circumstances (GOUW; FRANZOLIN; FEJES, 2013).

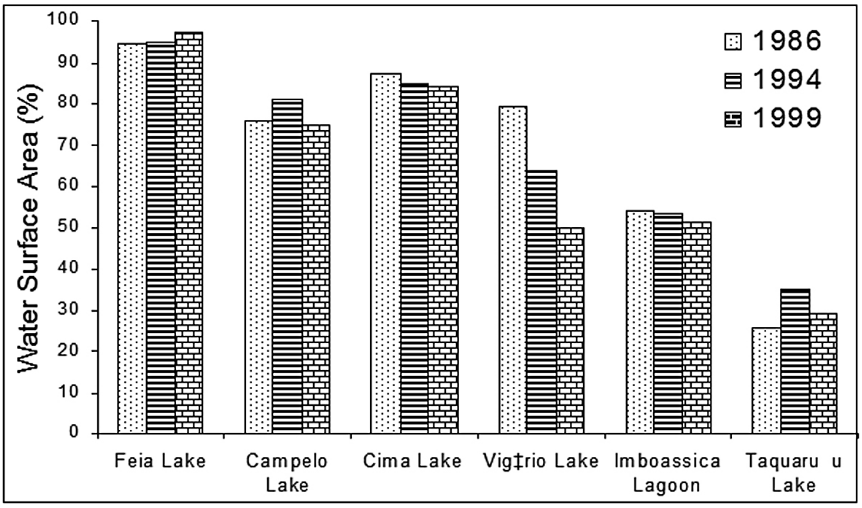
The versatility of application of the method proposed in this article is relevant for countries with large areas and a large array of cultures and ecosystems, such as Brazil. In these countries, the complementation of the traditional educational material used in schools is extremely important, since they consist of books with general contents, distant from the socio-cultural and environmental reality of the students and, furthermore, they have many flaws, due to mistakes and absence of relevant subjects (CARO; PELKEY; GRIGIONE, 1994; GOMES, 2004). The use of the cross-curricular themes of education for sustainable development and environmental education need to be emphasized on learning experiences relating to some of the subjects (PALMER; BIRCH, 2004), such as Geography and Biology.

After performing the proposed steps for the analyses of the surface of the lakes, we detected that comparing data obtained in this study to paper maps from 50 years ago, the surface area of the Feia Lake had been reduced in about 40%, mainly due to invasion of its margins by cropping activities over the last 50-60 years. Recently, 5% of the remaining area of this lake were covered by aquatic plants (Figure 4). The original area of the Campelo Lake was reduced mainly due to proliferation of aquatic plant species such as *Typha domingensis* and *Eicchornia crassipes*, which led to depth reduction and, consequently, to the reduction of the lake area to 9.5 km^2. According to this research, in the recent years, the water surface area is approximately 7.3 km^2 (and not 9.5 km^2), considering the area covered by the aquatic macrophytes. Differently from the last two lakes described above, which are placed in a plain and coastal region, the Cima Lake is situated in a region of hilly geomorphology. The images show a small reduction of the water surface area in the last years. The Vigario, Imboassica and Taquaruçu Lakes are placed in urban areas; the first and the second ones receive a large amount of domestic sewage all around their margins, while the third receives a small quantity of sewage in its southern portion. We observe an intense colonization by aquatic plants in these lakes, which is responsible for the variation of the water lake surface area in the past years, as well as some margin invasion activities.

This research suggests that several lakes can be evaluated in a simple and accurate way through this methodology, which can be useful for decision making related to these environments and for environmental monitoring and management. It can also be emphasized that the simplicity of the proposed methodology enables the analysis of many water bodies with reduced human and financial resources, which facilitates its use in schools. Besides, this methodology can be useful for the evaluation of other environments, considering, in special cases, the spectral range of the different components of the landscape. It is important to remark that the color composition used here (R7G4B1) is generally well applicable for most of the natural environments.

Considering such results, teachers could approach diverse topics involving, at the same time, many areas of knowledge. Students would want to know, for example, why some lakes had their water surface area more affected than others over the years. The discussion following this question would lead to themes such as (i) the different types of land use in the diverse drainage basins, (ii) the stability of the ecosystem depending on its size, and (iii) the fluctuation on the amount of aquatic plants depending on the quantity of domestic sewage disposed in the lakes. Another issue for discussion would be related to fluctuations over water surface area in some lakes (such as the Campelo and Taquarucu lakes), promoting a discussion on the dynamicity of such water systems according, for example, to the mobility of the plants present.

Figure 4 – Remaining water surfaces in relation to the total official area of each studied water body. (Feia Lake, 172 km2 (BIDEGAIN; BIZERRIL; SOFIATTI, 2002); Campelo Lake, 9.8 km2 (GOMES; SUZUKI, 2008); Cima Lake, 15 km2 (BIDEGAIN; BIZERRIL; SOFIATTI, 2002); Vigário Lake 0.3 km2 (LANNES, 2002); Imboassica Lagoon, 3.3 km2 (ALBERTONI; PALMA-SILVA; ESTEVES, 2001); Taquaruçu Lake, 0.4 km2 (LANNES, 2002)



Fonte: Dos autores

Results also suggest that the official data related to the area of the studied lakes should be revised, since they do not correspond to the current water surface area of those environments, due to the margin invasions and to marginal colonization by aquatic plants. To know the real area of the ecosystems is relevant for making important decisions, concerning their management and conservation. When this inconsistence between official data and data measured by students is detected, they question whether or not they should blindly believe on the information given in the books or other documents, which will contribute to de development of a more critical, inquisitive citizen.

The Brazilian National Policy for Environmental Education encourages the use of new technologies in the teaching/learning process, to attract the attention of the student towards environmental problems. This approach is also encouraged by the Brazilian National Curricular Parameters (PCNs), which affirm that a more efficient and effective learning comes from the immersion of the student in the process through its identification with the tool and the object of learning. According to the American National Education Standards, which is the equivalent to the Brazilian PCNs, students shall participate in activities that help them understand how knowledge is built, which will allow them to further develop the ability to conduct a complete investigative process (NATIONAL RESEARCH COUNCIL, 2000). The proposed methodology can be used as a complementary technique in the teaching of subjects related to Science, Geography and Biology in K-12 teaching, with different levels of difficulty according to the performance of the group.

Educational technology has been found to have positive effects on student attitudes toward learning and on the student's self-concept. Students feel more successful in school, are more motivated to learn, and increase their self-confidence and self-esteem when using computer-based instruction (INSTITUTE FOR THE TRANSFER OF TECHNOLOGY TO EDUCATION, 2008). This is particularly true when technology allows learners to control their own-learning. Furthermore, teachers who use technology in their classrooms seem to change their instructional methods and attitudes (JORDAN; FOLLMAN, 1993).

Besides creating educational, scientific and cultural challenges, new technologies are promoting the development of a different kind of student, with new habits, perceptions, attitudes, wishes and mental processes, that is, a new culture, based on the audiovisual resources. This new culture in Education presuppose some shifts in behavior, conceptions and methods for teaching, integrating the global education of the student and giving him/her the possibility of participating actively as a citizen aware of the issues concerning his/her time and space.

Final remarks

The proliferation of certain plants in aquatic ecosystems due to domestic sewage disposal, connected to the idea of diminishing the area of such environments is an example of ecosystem's behavior that can be better understood by the students with the application of the proposed technique. In addition, this is an example of environmental dynamics, which is not intuitive for the population. The use of technologies that promote the interaction of the student with environmental information is important to change this situation. The geoprocessing technique described by this article is adequate for students in elementary and high schools, for space and time evaluation of different ecosystems. It constitutes a tool for Environmental Education which can be applied in the formal and in the non-formal teaching environments.

Finally, the learning environments proposed by the method presented in this paper could support a change in the way students learn in the classroom. Instead of memorizing facts out of their context, they learn new concepts by using an example of the environment they are immersed in, helping to shape an authentic, active, and effective learning process.

References

ALBERTONI, E. F.; PALMA-SILVA, C.; ESTEVES, F. A. Macroinvertebrates associated with Chara in a tropical coastal lagoon (Imboassica lagoon, Rio de Janeiro, Brazil). *Hydrobiologia*, v. 457, p. 215-224, 2001.

BARNES, J. *Cross-curricular learning*. London: SAGE, 2011.

BIDEGAIN, P.; BIZERRIL, C.; SOFFIATI, A. *Lagoas do Norte Fluminense*: perfil ambiental. Rio de Janeiro: SERLA, 2002.

BIZERRIL, M. X. A. Children's perceptions of Brazilian Cerrado landscape and biodiversity. *The Journal of Environmental Education*, v. 35, n. 4, p. 47-58, 2004.

BRADLEY, D. J.; BARTRAM, J. K. Domestic water and sanitation as water security: monitoring, concepts and strategy. *Philosophical transactions of the royal society A*, v. 371, 10120420, 2013.

BRASIL. *Lei de diretrizes e bases da educação: lei n. 9.394/96.* Brasília: DP&A, 2000.

BRASIL. *Parâmetros Curriculares Nacionais: Ciências Naturais*. Brasília: MEC, Secretaria do Ensino Médio, 1998.

BYBEE, R. W. Teaching science as inquiry. In: MINSTRELL, J.; VAN ZEE, E. *Inquiring into inquiry learning and teaching in science*. Washington: American Association for the Advancement of Science, p. 21-46, 2000.

CARO, T. M.; PELKEY, N.; GRIGIONE, N. Effects of conservation biology education on attitudes toward nature. *Conservation Biology*, v. 8, n. 3, p. 846-852, 1994.

DUCKWORTH, E. *"The having of wonderful ideas" and other essays on teaching and learning*. New York: Teachers College Press, 1978.

DWYER, C. A. Using emerging technologies to construct effective learning environments. *Educational Media International*, v. 36, n. 4, p. 300-309, 1999.

GATTS, C. E. et al. On the use of photothermal techniques for monitoring constructed wetlands. *Review of Scientific Instruments,* v. 74, p. 510-512, 2003.

GOMES, S. A. *A importância das áreas alagáveis para a região Norte Fluminense e a abordagem desse tema nos livros didáticos do Ensino Médio*. Undergraduation Thesis (Licenciatura em Ciências Biológicas) – Universidade Estadual do Norte Fluminense, Campos dos Goytacazes, 2004.

GOMES, M. A. C.; SUZUKI, M. S. Aspectos ambientais e históricos da Lagoa do Campelo. *Perspectivas online*, v. 2, n. 7, p. 140-151, 2008.

GOUDIE, A. Characterising the distribution and morphology of creeks and pans on salt marshes in England and Wales using Google Earth. *Estuarine, Coastal and Shelf Science*, v. 129, p. 112-123, 2013.

GOUW, A. M. S., FRANZOLIN, F.; FEJES, M. E. Desafios enfrentados por professores na implementação de atividades investigativas nas aulas de ciências. *Ciência & Educação*, v. 19, n. 2, p. 439-454, 2013.

HAWKINS, D. *The informed vision: Essays on learning and human nature*. New York: Agathon Press, 1974.

INSTITUTE FOR THE TRANSFER OF TECHNOLOGY TO EDUCATION, NATIONAL SCHOOL BOARDS ASSOCIATION. *Education leadership toolkit: Change and technology in America's schools*. Available at: <http://www.nsba.org/sbot/toolkit/tiol.html>. Access in: 26 mar. 2008.

INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS (Brasil). *[Imagens].* [S. l.: S. n.: 2013]. Available at: <http://satelite.cptec.inpe.br/home/novoSite/index.jsp?i=br>. Access in: 26 nov. 2013.

JERKINS, A.; PEPPER, D. Enhancing students' employability and self-expression: how to teach oral and groupwork skills in geography. *Journal of Geography in Higher Education*, v. 12, n. 1, p. 67-83, 1988.

JORDAN, W. R.; FOLLMAN, J. M. *Using technology to improve teaching and learning*: Hot topics: Usable research. (ERIC Document Reproduction Service No. ED355930). [S. l.: S. n.]: 1993.

KERR, S. P. Technology, teachers, and the search for school reform. *Educational Technology, Research and Development,* v. 37, n. 4, p. 5-17, 1989.

KRASILCHIK, M. Reformas e realidade: o caso do ensino de ciências. *São Paulo em Perspectiva*, São Paulo, v. 14, n. 1, p. 85-93, 2000.

LANNES, L. S. *Hidroquímica do sistema alagado urbano Vigário-Taquaruçu, Campos dos Goytacazes, RJ.* Undergraduation Thesis (Bacharelado em Ciências Biológicas) – Universidade Estadual do Norte Fluminense, Campos dos Goytacazes, 2002.

LINN, M. C.; HSI, S. *Computers, teachers, peers: Science learning partners.* New Jersey: Lawrence Erlbaum Associates, 2009.

MACAGNAN, I. R. Utilizando Sistemas de Informação Geográfica na Escola. In: COLOQUIO DE CARTOGRAFIA PARA ESCOLARES, 4, 2001, Maringá. *Anais...* Maringá: [S. n.: 2001?].

MITSCH, W. J.; GOSSELINK, J. G. *Wetlands*. New York: John Wiley & Sons, 2000.

MOSSA, J. Participatory student field guides and excursions. *Journal of Geography in Higher Education,* v. 19, n. 1, p. 83-90, 1995.

NATIONAL RESEARCH COUNCIL. *National science education standards*. Washington: National Academy Press, 2000.

PALMER, J. A.; BIRCH, J. C. *Geography in the Early Years*. New York: Routledge Falmer, 2004.

SANTOS, J. M.; LAHM, R. A; BORGES, R. M. R. O Sensoriamento Remoto como recurso para a educação científica e tecnológica. In: Borges, R. M. R; Basso, N. R.; Rocha Filho, J. B. *Propostas Interativas na Educação Científica e Tecnológica*. Porto Alegre: EDIPUCRS, 2008.

SHAPIRO, B. A collaborative approach to help novice science teachers reflect on changes in their construction of the role of science teacher. *Alberta Journal of Educational Research,* v. 7, p. 119-132, 1991.

SHAPIRO, B. A case study of change in elementary student teacher thinking during an independent investigation in science: learning about the "face of science that does not yet know". *Science Education*, v. 80, n. 5, p. 535-560, 1996.

SHARP, N. How to teach oral and groupwork skills in geography. *Journal of Geography in Higher Education*, v. 13, n. 2, p. 207-209, 1989.

TEDESCO, J. C. (Org.). *Educação e novas tecnologias: esperança ou incerteza?* São Paulo: Cortez, 2004.

TYLER, R. Independent research projects in school science: Case studies of autonomous behavior. *International Journal of Science Education*, v. 14, p. 393-411, 1992.

VIANNA, M. S. R. *Salubridade domiciliar: uma discussão sobre o saneamento básico nas favelas do município do Rio de Janeiro.* Master's thesis (Escola Nacional de Saúde Pública) – Fiocruz, Rio de Janeiro, 1991.

WELCH, W. W. et al. The role of inquiry in science education: analysis and recommendations. *Science Education*, v. 65, n. 1, p. 33-50, 1981.

YU, L; GONG, P. Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives. *International Journal of Remote Sensing*, v. 33, n. 12, p. 3966-3986, 2012.

Artigo recebido em: 06 dez. 2013
Aceito para publicação em: 21 ago. 2014