Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v34i3.8703

Evaluating water resource maintenance for lakes of the middle Doce river

Maíra Moreira Morais[1*], Roberta Ferreira Miranda[1], Kariny Barroso-Silva[2] and Anderson Oliveira Latini[3]

*[1]Universidade Federal de Minas Gerais, Minas Gerais, Belo Horizonte, Brazil. [2]Centro Universitário do Leste de Minas Gerais, Rua Bárbara Heliodora, 725, 35160-215, Ipatinga, Minas Gerais, Brazil. [3]Universidade Federal de São João Del Rei, São João Del Rei, Minas Gerais, Brazil. *Author for correspondence. E-mail: mairammorais@yahoo.com.br*

ABSTRACT. The importance of water resources to mankind and the threat level these resources have withstood due to regional and worldwide human intervention are undeniable. In the middle stretch of the Doce river basin, there are close to 170 natural lakes, located between an environmental conservation area and monoculture eucalyptus plantations, with social, economic and biological importance. Our objective was to evaluate whether the water surface area in these lakes has remained constant in the last few decades, and make inferences on the result. To that end, we measured the water surface area of 16 lakes, from satellite images obtained between May and August in the years 1977, 1979, 1981, 2000 and 2005. Total water surface area was compared considering these dates the two different areas. We did not find any changes in water surface area for these lakes in the studied images. Likewise, we did not observe reductions in any single lake for any of the studied areas. These results indicate hydrological constancy of the system, as well as of the services this group of lakes provides to society and biodiversity in its vicinity, regardless of whether the environmental matrix consists of old-growth vegetation or eucalyptus plantations.

Keywords: lakes, water surface area, environmental impacts, remote sensing.

Avaliação da manutenção dos recursos hídricos dos lagos do médio rio Doce

RESUMO. É inegável a importância dos recursos hídricos ao Homem e o grau de ameaça que vêm sofrendo devido a intervenções humanas regionais e globais. No trecho médio da bacia do rio Doce há cerca de 170 lagos naturais, distribuídos entre área de conservação ambiental e área de monocultivo de eucalipto, com importância social, econômica e biológica. O nosso objetivo foi avaliar se a lâmina d'água total destes lagos vem se mantendo nas últimas décadas e inferir sobre esta resposta. Para isto, aferimos a lâmina d'água de 16 lagos a partir de imagens de satélite obtidas entre maio e agosto dos anos de 1977, 1979, 1981, 2000 e 2005. Esta lâmina d'água total foi comparada considerando estas datas e as duas áreas diferentes. Não encontramos alteração na lâmina d'água destes lagos nas imagens estudadas. Do mesmo modo, não observamos redução em lagos de quaisquer das áreas estudadas, isoladamente. Estes resultados apontam para uma constância hidrológica do sistema, bem como dos serviços que este conjunto de lagos presta à sociedade e à biodiversidade de seu entorno, independente da matriz ambiental ser constituída por vegetação conservada ou cultivo de eucalipto.

Palavras-chave: lagos, lâmina d'água, impactos ambientais, sensoriamento remoto.

Introduction

Human activities represent a growing threat to the preservation of natural resources (BIKSEY et al., 2011; VACKAR et al., 2012). It is such an important factor that the main components of ecosystem changes worldwide are habitat fragmentation, climate change and invasion by exotic species (PERRINGS, 2010). These three components have direct effects on the maintenance of diversity and water resources (SÚAREZ; PETRERE JR., 2007; STAKHIV, 2011).

Habitat fragmentation leads to changes in soil surface and reduces its capacity to store water (SCHÄEFFER; PROCHNOW, 2002). The emission of fossil fuel gases alters the concentration of inorganic compounds in the atmosphere (PRATHER; HSU, 2010), affecting light and energy absorption (MEATYARD, 2003). Both factors are related to temporal and spatial rainfall distribution, as well as the availability of water resources (CARTER; PARKER, 2009; FERMÁN-ALMADA et al., 2008; HARRISON et al., 2008).

In the middle stretch of the Doce river basin, about 170 natural lakes were formed between four and ten thousand years ago (TUNDISI; MEIS, 1985). This

lake group is unique in Brazil, and occurs in the Atlantic Forest biome, regarded as one of the world's most important areas for biodiversity conservation (MYERS, 2003). Therefore, these lakes have conservation importance, as already acknowledged in Minas Gerais state and nationwide in Brazil due to the presence of an important conservation unit (Doce river State Park - PERD) and its geological and environmental uniqueness.

The lakes are located over a 100,000 ha area and represent an important resource for the local population and regional businesses; its main uses are amateur fishing and water supply (LIMA et al., 2010). Thus, a reduction in the water surface area of these lakes could represent a serious socioeconomic issue for the region, as well as being yet another environmental problem in addition to the existing difficulties in preserving the fauna and flora present in the lakes (LIMA et al., 2010; GIACOMINI et al., 2011).

The study area of the project "Biological dynamics and conservation of Atlantic Forest biodiversity in the middle Doce river, Minas Gerais State" (PELD/CNPq) includes areas of monoculture eucalyptus plantations, mining and prospecting, and protected areas, such as Private Natural Heritage Reserves. The results of the project suggest there have been abrupt oscillations in regional rainfall in the last 15 years, with effects on the flow of the Doce river. In spite of this, there are no published studies that consider the hydrological balance of these lakes, even if we consider the possible consequences of global climate changes. Thus, our objective was to determine whether the water surface area of lakes in the middle Doce river area has changed in the last few years, which would represent an easily obtainable and highly correlated measurement with water volume in these lakes. We thereby set out to investigate whether: (i) there has been a reduction in water surface area in these lakes; (ii) water surface area reduction was greater in the most dendritic lakes; (iii) the reduction was greater in the lakes whose surroundings consisted of eucalyptus plantations as compared to lakes in areas with natural vegetation; and (iv) water surface area reduction was greater in smaller lakes.

Material and methods

The middle Doce river lake group is located in southeastern Minas Gerais State, in the municipalities of Marliéria, Timóteo and Dionísio. It includes an area between the 42º 38'W and 48º 28'W meridians and 19º 41'S and 19º 30'S parallels, with altitudes varying between 236 and 515 m. The local climate is warm semi-humid tropical, with rainy summers and dry for four to five months, in winter (NIMER, 1989).

In the study area, it is possible to identify two different landscapes adjacent to the lakes: one consisting of a eucalyptus plantation area (approximately 25,000 ha), with economic activity by the Companhia Agrícola e Florestal Santa Bárbara - CAF (Arcelor Mittal Group), and another consisting of about 36,000 ha of Atlantic Forest biome, preserved within Doce river State Park (PERD - IEF/MG). Considering the estimate of 149 lakes in the region obtained from the evaluation of satellite images (Landsat 7 ETM, 1988), we randomly selected 40 lakes in the left margin of the Doce river (20 lakes in the PERD area, and 20 in the CAF area) (Figure 1).

Satellite images from five different years (1977, 1979, 1981, 2000 and 2005) were obtained from the National Institute for Space Research (INPE; www.dgi.inpe.br/CDSR/). Of the 40 lakes selected initially, only 16 could be viewed in all five satellite images and were used in our analyses (7 from the CAF area and 9 from PERD, see Table 1).

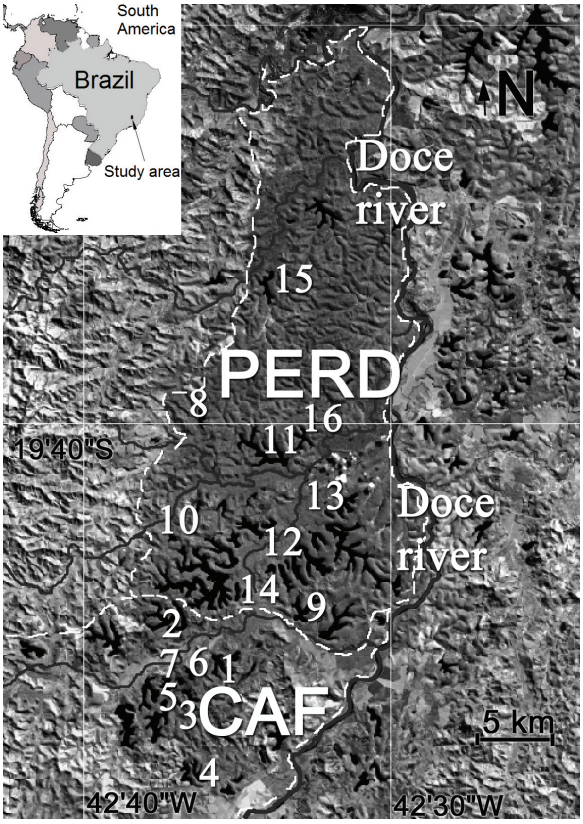

Figure 1. Satellite image (Landsat 7 ETM, 1988) of the middle Doce river. The lakes in the region are highlighted in black, from which the lakes in the study were chosen at random (numbers 1 to 16). The dotted contour represents PERD (north) and CAF (south).

In all PERD and CAF lakes, water surface area (m^2) and perimeter (m) of the lakes were

measured. Using the classification of images from Spring software (htttp://www.dpi.inpe.br/spring), we obtained three classification categories: vegetation (green color), water bodies (black) and others (white), which could be compared quantitatively.

To obtain the contour shape of the lakes, we used the perimeter development index, D_p (HAKANSON, 1981; FANTIN-CRUZ et al., 2008), which produced values closer to 1 when lakes are more circular and lower values when they are more dendritic.

Table 1. Studied lakes and their regions. The numbers in the first column refer to lake positions as shown in Figure 1.

Number	Lake	Region
1	Águas Claras	CAF
2	Barra	CAF
3	Diquada	CAF
4	Palmeiras	CAF
5	Poço Redondo	CAF
6	Romoalda	CAF
7	Timburé	CAF
8	Aceiro	PERD
9	Águas Claras	PERD
10	Carioca	PERD
11	Central	PERD
12	Chatinha	PERD
13	Boné	PERD
14	Gambá	PERD
15	Queiroga	PERD
16	São José	PERD

To test the hypotheses, we used Repeated Measures Analysis of Variance, considering sample dependence among the response variables, obtained at different moments in time (ZAR, 1999). This analysis was used to test the occurrence or not of water surface area reduction in PERD and CAF areas, individually. Whenever necessary, the transformation $v_1 = \sqrt{v} + 0.5$ (KREBS, 1999) was used to obtain homogeneity of variances and enable the use of repeated measures ANOVA parameter statistics. The level of significance used was 5%.

Results

The water surface area of the lakes did not undergo appreciable alteration in the analyzed years (n = 16; F = 1.702; p = 0.162; Figure 2), and there was no difference in water surface area retraction when considering the different areas of PERD and CAF (n = 16; F = 0.512; p = 0.485). Lastly, the interaction between the measurements obtained from the lakes in these two areas over time was not significant, either (n = 16; F = 0.133; p = 0.969).

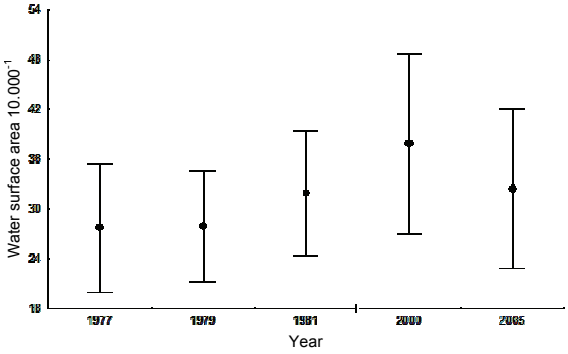

Figure 2. Water surface area (means and standard deviations) of the lakes (given in hectares) in different study years.

Thus, the study revealed an absence of total water surface area reduction in the lakes of the middle Doce river in recent years (hypothesis i) and an influence of shape (hypothesis ii); insertion area (hypothesis iii); and lake size (hypothesis iv) on this reduction, as it does not occur.

Through the visual exploration of total water surface area levels of the lakes in CAF and PERD areas, we can infer a similar pattern of variation for their water surface areas, but with no significant variation effects (Figure 3).

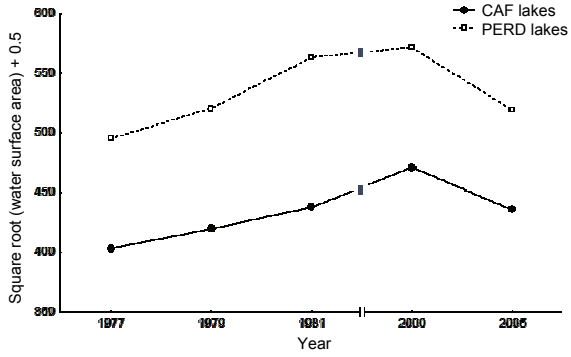

Figure 3. Converted values of total water surface area (in hectares) of CAF and PERD lakes in the different study years.

Discussion

Human actions cause impacts of varying intensity and scope, which currently threaten the maintenance of global biodiversity and natural resources (KASS et al., 2011). Traditionally, it has been reported that water is a renewable, non-finite natural resource. However, water distribution worldwide is inconstant, which frequently occurs due to human action (MACHADO, 2003). Rational maintenance of water resources is essential to guarantee the supply of water for the development of economic or subsistence activities, as well as being necessary to maintain biodiversity (LOPEZ-GUNN; LLAMAS, 2008).

In order to guarantee the preservation of natural resources and aquatic biodiversity - in quantity and quality - it is necessary to control anthropic interference on riparian vegetation (MACHADO, 2003). Riparian vegetation affects the structure of habitats and refuges, and is important in preserving the diversity of aquatic fauna (MCLACHLAN, 1969; GOFORTH; BAIN, 2012) and in reducing silting in water bodies, which affects system biodiversity as well (FELFILI et al., 2000). As such, the composition of the landscape unit (with native vegetation or eucalyptus monoculture) must influence the quality of hydric resources and preservation of the aquatic habitat (GOFORTH; BAIN, 2012). The results found in this study do not indicate a temporal effect of change in total water surface area of the studied lakes, nor did they find any effect among lakes in different areas. Likewise, we did not find relationships to indicate perceptible changes through the analysis of the water surface area of conservation areas (PERD) and eucalyptus plantation areas (CAF). It is possible that the presence of vegetation in the immediate vicinity of the lakes in the region (including eucalyptus) plays an equivalent role in maintain water resources.

Nevertheless, even though it was not the original proposal of this work, after further data exploration we found a reduction in total water surface area between the years 2000 and 2005 ($t = 4.274$; $n = 27$; $p < 0.001$), which indicates that some lakes (Palmeiras, Boné and Chatinha) reduced their water surface area during that period. The causes of this retraction in some lakes may possibly be attributed to local phenomena, as all lakes have a similar geological origin (MEIS; MONTEIRO, 1979; PERÔNICO; CASTRO, 2008). Upon close examination of Figure 3, changes in total water surface area can be seen in individual lakes of the CAF and PERD areas, which may indicate natural changes due to varying yearly rainfall periods. Consequently, the changes found in the water surface area between 2000 and 2005 may be due simply to a return of the lakes to a normal water surface level condition that is above the mean for the study years, as a result of local factors.

Conclusion

Our study indicates that the water surface area of the lakes in the middle Doce river has kept constant in the last three decades, suggesting hydrological stability of these aquatic environments in the studied period, as well as the benefits they represent to society - either economically or in the form of leisure - and to the associated biodiversity.

Acknowledgements

This study was supported by Fundação de Amparo à Pesquisa do Estado de Minas Gerais (Fapemig). The authors thank Dr. Clayton Perônico and an anonymous referee for important contributions. A. O. Latini and colleagues have benefits from FINEP (Financiadora de Estudos e Projetos) through a CT-infra program.

References

BIKSEY, T. M.; SCHULTZ, A. C.; BERNHARDT, A. M.; MARION, B.; PETERSON, C.; SMITH, P. Ecological and Human Health Risk Assessment. **Water Environment Research**, v. 83, n. 10. p. 1876-1905, 2011.

CARTER, R. C.; PARKER, A. Climate change, population trends and groundwater in Africa. **Journal des Sciences Hydrologiques**, v. 54, n. 4, p. 676-689, 2009.

FANTIN-CRUZ, I.; LOVERDE-OLIVEIRA, S.; GIRARD, P. Caracterização morfométrica e suas implicações na limnologia de lagoas do Pantanal Norte. **Acta Scientiarum. Biological Sciences**, v. 30, n. 2, p. 133-140, 2008.

FELFILI, J. M.; RIBEIRO, J. F.; FAGG, C. W.; MACHADO, J. W. B. Recuperação de Matas de Galeria. **Embrapa Cerrados**. Planaltina: Embrapa Cerrados, 2000. v. 21.

FERMÁN-ALMADA, J. L.; SEINGIER, G.; VARGAS, M. L. M.; GASTELUM, A. G.; BECT, L. G.; GARCÍA, C. A. The Colorado river delta (Mexico): ecological importance and management. **Acta Scientiarum. Biological Sciences**, v. 30, n. 4, p. 371-378, 2008.

GIACOMINI, H. C.; LIMA-JÚNIOR, D. P.; LATINI, A. O.; ESPÍRITO-SANTO, H. M. V. Spatio-temporal segregation and size distribution of fish assemblages as related to non-native species occurrence in the middle rio Doce Valley, MG, Brazil. **Neotropical Ichthyology**, v. 9, n. 1, p. 135-146, 2011.

GOFORTH, R. R.; BAIN, M. B. Assessing stream integrity based on interpretations of map-based riparian and subbasin properties. **Landscape and Ecological Engineering**, v.8, n. 1, p. 33-43, 2012.

HAKANSON, L. **A Manual of lake morphometry**. Berlin: Springer Verlag, 1981.

HARRISON, P. A.; BERRY, P. M.; HENRIQUES, C.; HOLMAN, I. P. Impacts of socio-economic and climate change scenarios on wetlands: linking water resource and biodiversity meta-models. **Climatic Change**, v. 90, n. 1/2, p. 113-139, 2008.

KASS, G. S.; SHAW, R. F.; TEW, T.; MACDONALD, D. W. Securing the future of the natural environment: using scenarios to anticipate challenges to biodiversity,

landscapes and public engagement with nature. **Journal of Applied Ecology**, v. 48, n.6, p. 1518-1526, 2011.

KREBS, C. J. **Ecological Methodology**. Menlo Park: Benjamin/Cummings, 1999.

LIMA, F. P.; LATINI, A. O.; DE MARCO, P. How are the lakes? Environmental perception by fishermen and alien fish dispersal in Brazilian tropical lakes. **Interciência**, v. 35, n. 2, p. 84-91, 2010.

LOPEZ-GUNN, E.; LLAMAS, M. R. Re-thinking water scarcity: Can science and technology solve the global water crisis? **Natural Resources Forum**, v. 32, n. 3, p. 228-238, 2008.

MACHADO, A. B. M. Recursos hídricos e cidadania no brasil: limites, alternativas e desafios. **Revista Ambiente e Sociedade**, v. 6, n. 2, p. 121-136, 2003.

MCLACHLAN, A. The effect of aquatic macrophytes on the variety and abundance of benthic fauna in newly created lake in the Tropics (Lake Kariba). **Archiv für Hydrobiologie**, v. 66, n. 1, p. 212-231, 1969.

MEATYARD, B. Global biodiversity in changing world. **Biological Conservation**, v. 109, n. 2, p. 311-312, 2003.

MEIS, M. R. M.; MONTEIRO, A. M. F. Upper Quaternary "rampas": Doce river valley, southeastern Brazilian plateau. **Zeitschrift zur Geomorphologie**, v. 23, n. 2, p.132-151, 1979.

MYERS, N. Biodiversity hotspots for conservation priorities. **Bioscience**, v. 53, n. 10, p. 916-917, 2003.

NIMER, E. **Climatologia do Brasil**. Rio de Janeiro: IBGE, 1989.

PERÔNICO, C.; CASTRO, P. T. A. Análise faciológica e interpretação palinológica de testemunho recuperado de ambiente lacustre assoreado no Parque Estadual do Rio Doce, Minas Gerias. **Revista Brasileira de Geociências**, v. 38, n. 4, p. 654-660, 2008.

PERRINGS, C. The economics of biodiversity: the evolving agenda. **Environment and Development Economics**, v. 15, n. 6, p. 721-746, 2010.

PRATHER, M. J.; HSU, J. Coupling of nitrous oxide and methane by global atmospheric chemistry. **Science**, v. 330, n. 6006, p. 952-954, 2010.

SCHÄEFFER, W. B.; PROCHNOW, M. **A mata Atlântica e você**: Como preservar, recuperar e se beneficiar da mais ameaçada floresta brasileira. Brasília: Apremavi, 2002.

STAKHIV, E. Z. Pragmatic approaches for water management under climate change uncertainty. **Journal of the American Water Resources Association**, v. 47, n. 6, p. 1183-1196, 2011.

SÚAREZ, Y. R.; PETRERE JR., M. Environmental factors predicting fish community structure in two neotropical rivers in Brazil. **Neotropical Ichthyology**, v. 5, n. 1, p. 61-68, 2007.

TUNDISI, J. G.; MEIS, M. R. M. **Limnological studies in rio Doce valley lakes and pantanal wetland, Brazil**. Nagoya: Nagoya University, 1985.

VACKAR, D.; TEN BRINK, B.; LOH, J.; BAILLIE, J. A. M.; REYERS, B. Review of multispecies indices for monitoring human impacts on biodiversity. **Ecological Indicators**, v. 17, p. 58-67, 2012.

ZAR, J. H. **Biostatistical analysis**. New Jersey: Prentice-Hall, Englewood Cliffs, 1999.

Received on November 7, 2009.
Accepted on October 5, 2010.

License information: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.