Chapter 6

Conservation of ecosystems and water supply

Rachel Bardy Prado
Joyce Maria Monteiro
Luciano Cordoval de Barros
Lucília Maria Parron
Mariana Silveira Guerra Moura e Silva
Paulo Eduardo de Aquino Ribeiro
Ricardo de Oliveira Figueiredo

Introduction

This chapter presents an overview of anthropogenic pressures on water resources and their ecosystems, some strategies for conserving these resources for water production, as well as a picture of Embrapa's actions with the potential to contribute to the achievement of the target 6.6 of the SDG 6: protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes by 2020.

The technological solutions that Embrapa research has generated are related to the reduction of the erosive processes and the sedimentation of the water bodies; planning, monitoring and valuation of ecosystem services, with emphasis on water resources; to conservation practices with consequences for maintaining the quantity and quality of water, among others.

This chapter exposes society the results of research that have greatly contributed to improving the quality of life of men in the field, as well as being a vehicle for attracting new partners that can strengthen these actions.

Water shortage and pressures on hydrological ecosystem services

Although it has large fresh water reserves, including a majority of the world's largest aquifer – Aquifer Guarani (70%) –, Brazil is subject to water distribution in an inhomogeneous way, both in space (North region 68.5%, Midwest region 15.7%, South region 6.5%, Southeast region 6.0% and Northeast region 3.3%) and in time (some regions have their rainfall regime concentrated in a few months, followed by long drought and intermittent rivers). Population concentration and water demand are also differentiated. Income distribution, water management, the amount of investments in infrastructure and human resources and other socioeconomic aspects may also influence the availability of water resources. These natural and social differences are partly responsible for the situation of water scarcity in some regions of the country (Prado et al., 2017).

Hydrological ecosystem services are defined as the benefits offered by freshwater and terrestrial ecosystems, which include fresh water supply, water quality regulation, flood mitigation, erosion control and water-related cultural services (Brauman et al., 2007; Terrado et al., 2009).

The main anthropogenic pressures on ecosystem services are related to the dynamics of land use and cover, changes in biogeochemical cycles, the destruction and fragmentation of environments, the introduction of new species and the interference of human activities in natural resources and climate (Sala et al., 2000). In Brazil, losses of natural environments would be 15% to 18% in the Amazon biome, 50% in the *Cerrado*, *Pampas* and *Caatinga* biomes and 88% in the Atlantic Forest (Relatório..., 2012). It is also worth mentioning the deforestation of Áreas de Preservação Permanente (Permanent Preservation Areas – PPAs), the inadequate construction of roads, the management of lands without the conservationist care that revert to pressures on water resources (Sparovek et al., 2010; Soares-Filho et al., 2014). As a consequence, annual soil losses in Brazil are of the order of 500 million tons by erosion, causing the average loss of storage capacity of the reservoirs very high, in the order of 0.5% per year, which has contributed to many rivers reach the sea with a very low flow due to sedimentation, as is the case of the Paraíba do Sul and São Francisco Rivers, essential for the water supply of a large part of the Brazilian population (Prado et al., 2017).

Sources of pollutants are also a threat to water resources, in the form of domestic and industrial sewage (punctual) and residues from agriculture (nonpuctual). As a result, contamination and diminution of aquatic biodiversity occurs, leading to negative impacts on human health and water supply. Anthropogenic pressures and climatic changes in water resources may be transboundary and there may even be influence of one biome in another, as shown in the recent study by Bergier et al. (2018) regarding the influence of the Amazon in the control of rains in the *Pantanal*.

Strategies for conservation of ecosystems for water production

Tropical forests are in environments rich in natural resources and are influenced by a range of biophysical factors that contribute to the provision of various ecosystem services. It is possible that forests are the environments that most benefit humanity, since these benefits are also systemic, with synergies between them (Locatelli et al., 2014). Protecting forests, the protection of ecosystem services is assured (Arriagada; Perrings, 2009).

Despite the pressures arising from land use and its cover by agriculture and livestock on ecosystem services (Ferreira et al., 2014; Lapola et al., 2014) (Figure 1), Brazil has excelled in measures, policies and legislation related to conservation of ecosystems. As an example of laws and policies, the law of protection of native vegetation (Brasil, 2012), which establishes the preservation of permanent areas such as riparian forests and a legal reserve on rural properties, can be highlighted. In addition, the Sistema Nacional de Unidades de Conservação (National System of Conservation Units – SNUC) (Brasil, 2000) establishes a set of federal, state and municipal conservation units, covering about 20% of the national territory (Hassler, 2005).

The Ecological ICMS is an example of a financial mechanism to encourage conservation at the municipal level. It consists of a tax mechanism that allows municipalities to access parcels – greater than those to which they are already entitled – from the financial resources collected by the states, through the Imposto sobre Circulação de Mercadorias e Serviços (Tax on Circulation of Goods and Services – ICMS), due to the environmental criteria established in state laws (Novion; Vale, 2009; Mattos; Hercowitz, 2011). It is also worth mentioning some methods of logging, fishing, fiber and fruit in a sustainable way in the different Brazilian biomes, with emphasis on the Amazon (Becker, 2006; Gariglio et al., 2010), adding value to the production of small-scale farmers. With regard to water resources, Law 9,433/1997 established the Política Nacional de Recursos Hídricos (National Water Resources Policy – PNRH), providing for various instruments for integrated and participatory management within the framework of river basin committees.

Although soil conservation was not been considered a priority in government agendas in the past (Guerra et al., 2014), many agricultural production systems have been developed by Embrapa, focused on soil conservation, which are

Photo: Rachel Bardy Prado

Figure 1. Land use dynamics on ecosystem services.

currently in use in Brazil, such as the no-till system, integrated crop-livestock system (ILP) and integrated crop-livestock-forest system (ILPF) (Machado; Silva, 2001).

Brazil made a voluntary commitment during the *15th Conference of the Parties* (COP-15) in 2009 to reduce greenhouse gas (GHG) emissions from the agricultural sector by 2020. To do so, it stablished the Política Nacional sobre Mudanças do Clima (National Policy on Climate) (Brasil, 2009), which resulted in the Plano Setorial de Mitigação e de Adaptação às Mudanças Climáticas para Consolidação de uma Economia e Agricultura de Baixa Emissão de Carbono (Sectorial Plan for Mitigation and Adaptation to Climate Change to Consolidate a Low Carbon Economy and Agriculture – Plano ABC). In the Brazilian agricultural sector, new integrated ecologically based systems have been encouraged, such as organic agriculture, agroecology and agroforestry systems (Martinelli et al., 2010; Porro; Miccolis, 2011), which allow greater sustainability of the rural landscape, income support to small-scale farmers, increased food security maintenance of ecosystem service. The adoption of soil and water conservation technologies at the farm level tends to reduce erosive processes and sedimentation of water bodies and contribute to reducing the use of fertilizers and pesticides in agroecosystems.

However, there are many challenges for policies and laws to be effective and for the scale of soil and water conservation programs be expanded in order to cover the great territorial extensions of Brazil (Sparovek et al., 2010; Grisa; Schneider, 2015).

Technological solutions and potential impacts

Embrapa's mission is to contribute, through the results of its research, to the development of agriculture, but also to ensure the sustainability of the environment. Thus, Embrapa technologies and solutions aimed at the conservation of ecosystems and water production are many, being generated, validated, disseminated and adopted by different sectors of society. Some of them are presented in the sequence, but far from exhausting the list of technological solutions focused on the theme of this chapter.

Barraginha

Barraginha (mini-dam) is a technology developed by Embrapa Maize & Sorghum with the objective of capturing rainwater, eliminating floods and providing gradual infiltration of this water throughout the rural property, which contributes to soften the negative effects of drought and enables planting of crops. It is a small basin dug (Figure 2) that fills and empties several times throughout the rainy season. It usually measures 16 m in diameter, and can vary according to the type of soil (Barros; Ribeiro, 2009). Several *barraginhas* must be opened in several places of the property, where significant floods occur, in the pastures and plantations. The set of *barraginhas* provokes the elevation of the groundwater, increasing the availability of water, which can be perceived by the elevation of the water level in cisterns *cacimbão*-type (Figure 3), by the wetting of the lowlands, giving rise to springs and the revitalization of streams and rivers.

Biomonitoring in aquatic systems

In the last 14 years, Embrapa Environment has been working on biomonitoring with benthic macroinvertebrates in natural ecosystems (rivers and lakes) (Silveira et al., 2005) and aquaculture production systems (tanks in reservoirs and excavated fishponds) (Silva et al., 2016). Benthic macroinvertebrates are aquatic organisms that live in the bottom of rivers and lakes, that is, they inhabit the bottom of rivers and lakes attached to stones, gravel and leaves, or buried in mud or sand (Queiroz

Photo: Luciano Cordoval de Barros

Photo: Paulo Eduardo de Aquino Ribeiro

Figure 2. Excavated *barraginhas* (A) and *barraginha* crops (B).

Photo: Luciano Cordoval de Barros

Figure 3. Elevation of water level in *cacimbão*-type cisterns.

et al., 2008). They are organisms that are sensitive to pollution or degradation of aquatic ecosystems (Figure 4), so they are able to reflect in an integrated way the impacts occurring in the water and surrounding environment, for a longer period than the routinely measured physical and chemical variables. Among the compartments of the aquatic ecosystem, pond sediments and fish farms are often the ones that accumulate most organic matter and other pollutants, and

Figure 4. Fresh water ecosystems.

the last (local) repository of anthropogenic contaminants (human action) (Batley; Maher, 2001). It is important that partnerships be established with aquaculture producers to disseminate the method and so that they can – albeit superficially – make a diagnosis of the quality of their water at a lower cost. A tool widely used in natural ecosystems and being tested in the fish culture of excavated fishponds is biomonitoring with samplers with artificial substrate, whose methodology of preparation and application is detailed in Silva et al. (2012). In aquaculture, good quality water means a healthy end product, as well as minimizing impacts on water outside the enterprise. The challenges encountered are mainly to know the colonizing benthic fauna of the water bodies associated to the aquaculture system, and to identify the expected changes in the structure of this aquatic community in case of implantation of the activity.

Monitoring of soil and water in conservationist production systems

Embrapa, in a participatory manner with technicians and farmers, has carried out research on the monitoring of parameters of water quality, climate, soils and the carbon stock in reference areas and in farming systems, with the adoption of soil conservation practices and of water in the state of Rio de Janeiro. These researches are allowing the identification of a set of environmental indicators capable of assessing and monitoring the impacts of these systems on soils and water resources in microcatchments, through the correlation between land use and cover and agricultural production systems. The information generated may support agro-environmental planning and the formulation of public policies, as well as generate information for compensation programs for environmental services (Monteiro et al., 2017).

Tools for evaluation and valuation of water ecosystem services

The identification and measurement of ecosystem services (SEs) and ecosystem disservices (DEs) allow to translate the welfare benefits and losses into monetary metrics (Zhang et al., 2007; Costanza et al., 2014). This is possible because SEs have a positive value for society, and DEs represent a loss (negative cost), and therefore both are valuables. However, it is not always possible to present the result of the valuation in the monetary metric. Therefore, biophysical identification or measurement of SEs and DEs is a step forward in terms of the information available for decision-making. Embrapa Forests and the Federal University of Paraná (UFPR) developed two tools, one to evaluate SEs in productive systems and another to evaluate monetary metrics. The first uses radar-type graphics. For this, it is necessary to previously have a database containing the values of SEs in the same unit of area and/or time. Each system is represented on a graph where the indicators of the SEs are compared to each other. For this to occur, the values for each axis are relative to the maximum values for each service evaluated. A complete axis of the graph represents the maximum provision of services in the system, while a smaller portion represents a reduction in the provision of SEs relative to that provided by another system (Syswerda; Robertson, 2014). The systems in which there is a higher provision of SEs associated to water resources, such as soil water infiltration rate, soil, water and nitrate losses, surface runoff volume, erosion reduction (which directly affect water quality and increase of water flows) are perceived as being more sustainable. The economic valuation tool is a spreadsheet designed to calculate the value of non-measurable goods in the economic market. The value is the product of the quantity of SEs at their respective price. The evaluation of the losses of soil, water and nitrate, volume of surface runoff, as well as erosion reduction is performed based on the replacement cost method (Garcia et al., 2015). The method consists of estimating the economic costs of replenishing soil nutrients in productive areas, and the purpose of valuation is to reverse soil degradation and its effects on water resources. The limitations of the tool can be the low values of the indicators evaluated and the obtaining of the market prices of the inputs.

Manual for payment for water environmental services

The manual is available, in accessible language, aiming at

> [...] deepen knowledge, promote the identification of priority areas for intervention, selection of indicators and guidelines for monitoring, and thus contribute to a more appropriate environment for the application of Payment for Environmental Services (PES), identifying how and when to use it with security and guarantee, the effectiveness of its use. (Santos, 2017 cited by Fidalgo et al., 2017, p. 12, our translation).

Rotational system for family farming in the Amazon

Embrapa's research in the Eastern Amazon confirms the gain in productivity and environmental advantages when the traditional system in family farming with the preparation of planting area by the fallow-and-burning of fallow vegetation (*capoeiras*/secondary vegetation) is replaced by the preparation of area by choping-and-mulching biomass above ground (Davidson et al., 2008; Figueiredo et al., 2013). In this rotational system based on the use of secondary vegetation (*capoeira*), the permanence of the roots in the soil promotes the formation of "protective nets", reducing the leaching of nutrients, avoiding their loss and the contamination of the neighboring water bodies (Sommer et al., 2004).

Watershed assessments indicated that this situation is also detected at the landscape level and potentiated by the presence of riparian vegetation along the streams (Amazonian streams) (Figure 5), avoiding larger transfer of nutrients and sediments to the watercourses. When comparing a catchment area with slash-and-burn with another one with chop-and-mulch, the hydrological evaluations concluded that this last microbasin had a lower variation of the static level between rainy and dry periods, and, consequently, a greater capacity of underground recharge (Wickel, 2004). Consequently, the flows are larger in the *igarapé* (stream) in mulched area compared to the *igarapé* in burned area, since the discharge is are mainly regulated by the underground water stored. In addition, significant

Photo: Ricardo de Oliveira Figueiredo

Figure 5. Riparian vegetation along the Amazonian streams.

changes were observed in the chemical composition of fluvial waters in the watershed with burned areas, with significant calcium and magnesium inputs from the ash into the *igarapé* waters, thus altering the physico-chemical characteristics of this ecosystem and their functions (Comte et al., 2012, 2013). Due to these results, the following are recommended as tools for sustainable agriculture and management of the basins in the region: the conservation of riparian vegetation, nowadays mostly secondary vegetation; the substitution of practices such as the use of fire by sustainable production techniques; and care regarding the use of agrochemicals (Figueiredo, 2009).

Final considerations

Many measures (laws and policies) have been established in recent decades with ecosystem conservation in mind, but the pace of degradation is high and efforts are needed to bring laws and policies into practice. It is important to emphasize that it is important to increase the perception of all sectors of society that the services that ecosystems provide to man are exhaustible.

Embrapa, with its research focused on the sustainability of agriculture, plays an extremely important role in this scenario, and can contribute with its various technological solutions, to reverse the degradation of ecosystem services, especially watershed services, to a more conscious and sustainable agriculture, with gains also environmental and social, as well as economic. To this end, it is necessary to join the different public and private sectors to further advance low cost and easy to apply solutions.

References

ARRIAGADA, R.; PERRINGS, C. **Making payments for ecossystem services work**. Nairobi: Unep, 2009.

BARROS, L. C. de; RIBEIRO, P. E. de A. **Barraginhas**: água de chuva para todos. Brasília, DF: Embrapa Informação Tecnológica, 2009. 49 p. (ABC da agricultura familiar, 21). Available at: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/128246/1/ABC-Barraginhas-agua-de-chuva-para-todos-ed01-2009.pdf>. Accessed on: Jan. 31, 2018.

BATLEY, G.; MAHER, W. A. The development and application of ANZEEC and ARMCANZ Sediment quality Guidelines. **Australasian Journal of Ecotoxicology**, v. 7, p. 81-92, Jan. 2001.

BECKER, B. **Amazônia**: geopolítica na virada do III milênio. Rio de Janeiro: Garamond, 2006.

BERGIER, I.; ASSINE, M. L.; McGLUE, M. M.; ALHO, C. J. R.; SILVA, A.; GUERREIRO, R. L.; CARVALHO, J. C. Amazon rainforest modulation of water security in the Pantanal wetland. **Science of the Total Environment**, v. 619-620, p. 1116-1125, Apr. 2018. DOI: 10.1016/j.scitotenv.2017.11.163.

BRASIL. Lei nº 12.187, de 29 de dezembro de 2009. Institui a Política Nacional sobre Mudança do Clima - PNMC e dá outras providências. **Diário Oficial da União**, 30 dez. 2009. Available at: <http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm>. Accessed on: Mar. 5, 2018.

BRASIL. Lei nº 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nos 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nos 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória no 2.166-67, de 24 de agosto de 2001; e dá outras providências. **Diário Oficial da União**, 28 maio 2012. Available at: <http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm>. Accessed on: Mar. 5, 2018.

BRASIL. Lei nº 9.985, de 18 de julho de 2000. Regulamenta o art. 225, § 1o, incisos I, II, III e VII da Constituição Federal, institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências. **Diário Oficial da União**, 19 jul. 2000. Available at: <http://www.planalto.gov.br/ccivil_03/Leis/L9985.htm>. Accessed on: Mar. 5, 2018.

BRAUMAN, K. A.; DAILY, G. C.; DUARTE, T. K.; MOONEY, H. A. The nature and value of ecosystem services: an overview highlighting hydrologic services. **Annual Review of Environment and Resources**, v. 32, p. 67-98, Nov. 2007. DOI: 10.1146/annurev.energy.32.031306.102758.

COMTE, I.; DAVIDSON, R.; LUCOTTE, M.; CARVALHO, C. J. R. de C.; OLIVEIRA, F. de A.; SILVA, B. P. da; ROUSSEAU, G. X. Physicochemical properties of soils in the Brazilian Amazon following fire-free land preparation and slash-and-burn practices. **Agriculture, Ecosystems and Environment**, v. 156, p. 108-115, Aug. 2012. DOI: 10.1016/j.agee.2012.05.004.

COMTE, I.; LUCOTTE, M.; DAVIDSON, R.; CARVALHO, C. J. R. de; OLIVEIRA, F. de A.; ROUSSEAU, G. X. Impacts of land uses on mercury retention in long-time cultivated soils, Brazilian Amazon. **Water, Air, and Soil Pollution**, v. 224, n. 4, p. 1515-1529, Apr. 2013. DOI: 10.1007/s11270-013-1515-3.

COSTANZA, R.; GROOT, R. de; SUTTON, P.; PLOEG, S. van der; ANDERSON, S.J.; KUBISZEWSKI, I.; FARBER, S.; TURNER, R. K. Changes in the global value of ecosystem services. **Global Environmental Change**, v. 26, n. 1, p. 152-158, May 2014. DOI: 10.1016/j.gloenvcha.2014.04.002.

DAVIDSON, E. A.; SÁ, T. D. A. de; CARVALHO, C. J. R.; FIGUEIREDO, R. de O.; KATO, M. do S. A.; KATO, O. S.; ISHIDA, F. Y. An integrated greenhouse gas assessment of an alternative to slashand-burn agriculture in eastern Amazonia. **Global Change Biology**, v. 14, n. 5, p. 998-1007, May 2008. DOI: 10.1111/j.1365-2486.2008.01542.x.

FERREIRA, L. G.; SOUSA, S. B.; ARANTES, A. E. **Radiografia das pastagens do Brasil**. Goiânia: LAPIG/UFG, 2014.

FIDALGO, E. C. C.; PRADO, R. B.; TURETTA, A. P. D.; SCHULER, A. E. **Manual para pagamento por serviços ambientais hídricos**: seleção de áreas e monitoramento. Brasília, DF: Embrapa, 2017. 80 p. Disponível: <http://ainfo.cnptia.embrapa.br/digital/bitstream/item/160960/1/Manual-PSA-hidricos-2017.pdf>. Accessed on: Jan. 31, 2017.

FIGUEIREDO, R. de O. Processos hidrológicos e biogeoquímicos em bacias hidrográficas sob usos agrícola e agroflorestal na Amazônia Brasileira. In: PORRO, R. (ed.). **Alternativa agroflorestal na Amazônia em transformação**. Brasília, DF: Embrapa Informação Tecnológica; Belém, PA: Embrapa Amazônia Oriental, 2009. p. 477-500.

FIGUEIREDO, R. de O.; BÖRNER, J.; DAVIDSON, E. A. Watershed services payments to smallholders in the Brazilian Amazon: challenges and perspectives. **Revista Ambiente e Água**, v. 8, n. 2, p. 6-17, 2013. DOI: 10.4136/ambi-agua.1056.

GARCIA, J. R.; REIS, J. C. dos; MOREIRA, J. M. M. A. P.; FERRONATO, C. Considerações teórico-metodológicas sobre o processo de valoração dos recursos naturais. In: PARRON, L. M.; GARCIA, J. R.; OLIVEIRA, E. B. de; BROWN, G. G.; PRADO, R. B. (ed.). **Serviços ambientais em sistemas agrícolas e florestais do Bioma Mata Atlântica**. Brasília, DF: Embrapa, 2015. p. 191-198.

GARIGLIO, M. A.; SAMPAIO, E.; CESTARO, KAGEYAMA, L. A. (org.). **Uso sustentável e conservação dos recursos florestais da caatinga**. Brasília, DF: Serviço Florestal Brasileiro, 2010. 368 p.

GRISA, C.; SCHNEIDER, S. **Políticas públicas de desenvolvimento rural no Brasil**. Porto Alegre: Ed. da UFRGS, 2015. 624 p.

GUERRA, A. J. T.; FULLEN, M. A.; JORGE, M. C. O.; ALEXANDRE, S. T. Soil erosion and conservation in Brazil. **Anuário do Instituto de Geociências**, v. 37, p. 81-91, 2014. DOI: 10.11137/2014_1_81_91.

HASSLER, M. L. A importância das Unidades de Conservação no Brasil. **Sociedade e Natureza**, v. 17, n. 33, p. 79-89, 2005.

LAPOLA, D. M.; LAPOLA, D. M.; MARTINELLI, L. A.; PERES, C. A.; OMETTO, J. P. H. B.; FERREIRA, M. E.; NOBRE, C. A.; AGUIAR, A. P. D.; BUSTAMANTE, M. M. C.; CARDOSO, M. F.; COSTA, M. H.; JOLY, C. A.; LEITE, C. C.; MOUTINHO, P.; SAMPAIO, G.; STRASSBURG, B. B. N.; VIEIRA, I. C. G. Pervasive transition of the Brazilian land-use system. **Nature Climate Change**, v. 4, p. 27-35, 2014. DOI: 10.1038/nclimate2056.

LOCATELLI, B.; IMBACH, P. WUNDER, S. Synergies and trade-offs between ecosystem services in Costa Rica. **Environmental Conservation**, v. 41, n. 1, p. 27-36, Mar. 2014. DOI: 10.1017/S0376892913000234.

MACHADO, P. O. L. A.; SILVA, C. A. Soil management under no-tillage systems in the tropics with special reference to Brazil. **Nutrient Cycling in Agroecosystems**, v. 61, n. 1-2, p. 119-130, Sept. 2001. DOI: 10.1023/A:1013331805519.

MARTINELLI, L. A.; NAYLOR, R.; VITOUSEK, P. M.; MOUTINHO, P. Agriculture in Brazil: impacts, costs, and opportunities for a sustainable future. **Current Opinion in Environmental Sustainability**, v. 2, n. 5-6, p. 431-438, 2010. DOI: 10.1016/j.cosust.2010.09.008.

MATTOS, L. M. de; HERCOWITZ, M. (Ed.). **Economia do meio ambiente e serviços ambientais**: estudo aplicado à agricultura familiar, às populações tradicionais e aos povos indígenas. Brasília, DF: Embrapa Informação Tecnológica; Planaltina, DF: Embrapa Cerrados, 2011.

MONTEIRO, J. M. G.; SCHULER, A. E.; PRADO, R. B.; FIDALGO, E. C. C.; TURETTA, A. P. D.; MARTINS, A .L. S.; OLIVEIRA, A. P.; DONAGEMMA, G. K. Soil and water management for ecosystem services provision in agricultural landscapes: the challenge of monitoring. In: NEHREN, U.; SCHLÜTER S.; RAEDIG, C.; SATTLER, D.; HISSA, H. (ed.). **Strategies and tools for a sustainable rural Rio de Janeiro**. [S.l.]: Springer, 2017. In press.

NOVION, H. de; VALLE, R. do. **É pagando que se preserva?**: subsídios para políticas públicas de compensação por serviços ambientais. São Paulo: Instituto Socioambiental, 2009. 343 p.

PORRO, R.; MICCOLIS, A. (org.). **Políticas públicas para o desenvolvimento agroflorestal no Brasil**. Belém, PA: ICRAF, 2011. 80 p.

PRADO, R. B.; FORMIGA-JOHNSSON, R. M.; MARQUES, G. F. Uso e gestão da água: desafios para a sustentabilidade no meio rural. **Boletim Informativo da Sociedade Brasileira de Ciência do Solo**, v. 43, n. 2, p. 43-48, 2017.

QUEIROZ, J. F. de; SILVA, M. S. G. M. e; SILVINHO-STRIXINO, S. **Organismos bentônicos**: biomonitoramento de qualidade de água. Jaguariúna, SP: Embrapa Meio Ambiente, 2008. 91 p. Disponível: <http://www.cnpma.embrapa.br/download/LivroBentonicos.pdf>. Accessed on: Jan. 31, 2018.

RELATÓRIO técnico de monitoramento do desmatamento no bioma Cerrado, 2002 a 2008: dados revisados. Brasília, DF: Ministério do Meio Ambiente, 2009. 71 p. Available at: <https://antigo.mma.gov.br/estruturas/sbf_chm_rbbio/_arquivos/relatorio_tecnico_monitoramento_desmate_bioma_cerrado_csr_rev_72_72.pdf>. Accessed on: Dec. 10, 2017.

SALA, O. E.; CHAPIN, F. S.; ARMESTO, J. J.; BERLOW, E.; BLOOMFIELD, J.; DIRZO, R.; HUBER-SANWALD, E.; HUENNEKE, L. F.; JACKSON, R.; KINZIG, A.; LEEMANS, R.; LODGE, D.; MOONEY, H. A.; OESTERHELD, M.; POFF, L. T.; SYKES, M.; WALKER, B. H.; WALKER, M.; WALL, D. Global biodiversity scenarios for the year 2100. **Science**, v. 287, n. 5459, p. 1770-1774, 2000. DOI: 10.1126/science.287.5459.1770.

SILVA, M. S. G. M. e; GRACIANO, T. S.; LOSEKANN, M. E.; LUIZ, A. J. B. Assessment of benthic macroinvertebrates at Nile tilapia production using artificial substrate samplers. **Brazilian Journal of Biology**, v. 76, n. 3, p. 735-742, July/Sept. 2016. DOI: 10.1590/1519-6984.02815.

SILVA, M. S. G. M. e; QUEIROZ, J. F. de; LOSEKANN, M. E.; MARIGO, A. L. S.; NASCIMENTO, M. **Utilização de coletores com substrato artificial para o biomonitoramento da qualidade da água na aquicultura**. Jaguariúna: Embrapa Meio Ambiente, 2012. 8 p. (Embrapa Meio Ambiente. Circular técnica, 23).

SILVEIRA, M. P.; BAPTISTA, D. F.; BUSS, D. F.; NESSIMIAN, J. L.; EGLER, M. Application of biological measures for stream integrity assessment in South-East Brazil. **Environmental Monitoring and Assessment**, v. 101, n. 1-3, p. 117-128, Feb. 2005.

SOARES-FILHO, B.; RAJÃO, R.; MACEDO, M.; CARNEIRO, A.; COSTA, W.; COE, M.; RODRIGUES, H.; ALENCAR, A. Cracking Brazil's forest code. **Science**, v. 344, n. 6182, p. 363-364, Apr. 2014. DOI: 10.1126/science.1246663.

SOMMER, R.; VLEK P. L. G.; SÁ, T. D. de A.; VIELHAUER, K.; COELHO, R. de F. R.; FÖLSTER, H. Nutrient balance of shifting cultivation by burning or mulching in the Eastern Amazon – evidence for subsoil nutrient accumulation. **Nutrient Cycling in Agroecosystems**, v. 68, p. 257-271, Mar. 2004. DOI: 10.1023/B:FRES.0000019470.93637.54.

SPAROVEK, G.; BERNDES, G.; KLUG, I. L. F.; BARRETTO, A. G. O. P. Brazilian agriculture and environmental legislation: status and future challenges. **Environmental Science and Technology**, v. 44, n. 16, p. 6046-6053, 2010. DOI: 10.1021/es1007824.

SYSWERDA, S. P.; ROBERTSON, G. P. Ecosystem services along a management gradient in Michigan (USA) cropping systems. **Agriculture, Ecosystems and Environment**, v. 189, p. 28-35, May 2014. DOI: 10.1016/j.agee.2014.03.006.

TERRADO, M.; LAVIGNE, M.-P.; TREMBLAY, S.; DUCHESNE, S.; VILLENEUVE, J.-P.; ROUSSEAU, A. N.; BARCELÓ, D.; TAULER, R. Distribution and assessment of surface water contamination by application of chemometric and deterministic models. **Journal of Hydrology**, v. 369, n. 3-4, p. 416-426, May 2009. DOI: 10.1016/j.jhydrol.2009.02.030.

WICKEL, B. **Water and nutrient dynamics of a humid tropical watershed in Eastern Amazonia**. [S.l.]: University of Bonn, 2004. 120 p. (Ecology and development series, 21).

ZHANG, W.; RICKETTS, T. H.; KREMEN, C.; CARNEY, K.; SWINTON, S. M. Ecosystem services and dis-services to agriculture. **Ecological Economics**, v. 4, n. 2, p. 253-260, Dec. 2007. DOI: 10.1016/j.ecolecon.2007.02.024.