3.07.01 – Engenharia Sanitária / Recursos Hídricos.

IMPACT OF LAND USE CHANGE ON GROUNDWATER RECHARGE

Tiago S. Mattos[1]*, Murilo C. Lucas[2], Edson C. Wendland[3] Paulo Tarso S. Oliveira[4]

1. PhD student in Water Resources at University of Mato Grosso do sul
2. Professor of Federal University of Technology – Paraná, Department of Civil Engineering
3. Professor of University of São Paulo, Department of Hydraulics and Sanitary Engineering
4. Professor of Federal University of Mato Grosso do Sul / Advisor

Resumo

Historically, forest plantations are intensely debated on their impact on groundwater. However, the decrease or increase recharge amounts due Eucalyptus afforestation need of more attention for raising water. In this study, recharge estimates were assessed before and after converting grassland to eucalyptus (*Eucalyptus grandis* x *Eucalyptus urophylla*). Average annual recharge estimates decrease of 470 mm.y-1 to 170 mm.y-1, under similar rainfall, after land use change. Recharge reduced almost 44% in 2012 and more than 60% in 2013, under similar rainfall comparing to 2005 year. Our study suggests that the high evapotranspiration by eucalyptus forest tend to provide a decrease in groundwater levels and, thus in recharge.

Palavras-chave: Water Table Fluctuation method; Urograndis; Forest plantation.

Apoio financeiro: CNPq, CAPES and FAPESP.

Introdução

The impact of land use and land cover (LULC) changes on groundwater levels has been a hot topic over the past decade (Kim; Jackson, 2012; Salemi et al., 2013; Scanlon, Bridget R. et al., 2006; Scanlon, Bridget R. et al., 2005) due to the increasing use of groundwater as a primary human water source (Famiglietti, 2014). LULC changes lead to a variation in the hydrological processes, mainly on the groundwater recharge (Juang et al., 2007; Stonestrom; Scanlon; Zhang, 2009). The increase in recharge has led to rise of groundwater levels due to lower evapotranspiration of crop plantations after native forest clearing in African Sahel (Leblanc et al., 2008). Kim; Jackson (2012) noted that vegetation type and potential evapotranspiration together explained about 28% of the statistical variation in recharge across the global recharge data set, while water inputs (precipitation + irrigation) explained about 29% of recharge variation.

The increase of planted tree forest areas has been one of the most significant LULC global changes. The global area of forest plantations increased from 167.5 to 277.9 million hectares (mha) from 1990 to 2015 (Payn et al., 2015). Brazil, Argentina and Chile have the largest forest plantations in South America (Onyekwelu; Stimm; Evans, 2011). Currently, Brazil has about 7.8 million hectares of planted forests, mainly genera Eucalyptus (5.7 mha) and Pinus (1.6 mha) (IBA, 2017). Planted tree forests in agricultural areas have significantly decreased recharge and thus, groundwater levels (Adelana et al., 2015) and water yield (Bosch; Hewlett, 1982; Stednick, 1996; Webb; Kathuria, 2012). Thus, the objective of this study was to assess the effect on groundwater recharge due to the LULC change from pasture to eucalyptus.

Metodologia

The Onça Creek Basin (OCB) is located in the municipality of Brotas, São Paulo State, between the meridians 47º55' e 48º00' west longitude and the parallels 22º10 'and 22º15' south latitude. The OCB has an approximate area of 6500 ha (65 km²) and is located in the Cerrado Biome. The site under investigation has been monitored since 2004. Until 2011, the predominant land use in the study area was pasture. From 2012, the coverage changed to planting clones of hybrid eucalyptus (Eucalyptus grandis x Eucalyptus urophylla), also known as "Urograndis". To evaluate the impact of land use change on the phreatic aquifer was used the Water Table Fluctuaction (WTF) Method. The WTF method is based on the hypothesis that rises in groundwater levels in unconfined aquifers are entirely attributed to recharge water arriving at the water table (Healy; Cook, 2002). Thus, considering a small enough time interval (hours or few days) for this premise to be valid, the recharge is expressed as (Delin et al., 2007):

$$R(t_j) = S_y \Delta H(t_j) \quad (1)$$

where $R(t_j)$ is the recharge that occurs between times t_0 and t_j, S_y is the specific yield of the aquifer, and $\Delta H(t_j)$ is the difference between the peak of the rising curve and the lowest point of the previous recession curve, extrapolated to the moment of the peak. To apply the method, the following steps were applied (Lucas, M. C.;

Wendland, 2015):

a) The hydrograph recess periods of each monitoring well is identified according to the precipitation events observed and the changes in the slope of the recession curve;

b) To reduce the subjectivity of freehand tracing, after an identification of the curves, an adjustment was made for the recession period using a power law function (Eq. 2);

$$N_{aq} = a \cdot (X)^b \quad (2)$$

where, N_{aq} is the observed groundwater level, a and b are adjustment parameters and X is the number of days corresponding to the recession curve of the well.

c) From the adjustment of equation (2) for each recession curve, the curves were extrapolated to the point at which a new recessive period begins, in order to determine ΔH;

The difficulty of applying the WTF method is the determination of a representative value for S_y and the assurance that the water levels fluctuation depends only on the recharge instead of changes in the atmospheric pressure, presence of imprisoned air, or even water withdrawal by pumping (Scanlon, B. R.; Healy; Cook, 2002). In this study, the values monitored were corrected by the atmospheric pressure variation and there are not pumping wells in the area. We used S_y values, which were determined in laboratory using undisturbed soil samples collected at different depths, corresponding to the water table fluctuation range (Wendland; Gomes; Troeger, 2015).

Resultados e Discussão

All results were analyzed considering hydrological years (September to August). In addition, the hydrological years are simply named using the year it ends, for example, 2004-2005 is mentioned as 2005. The Figure 1 shows the annual groundwater recharge estimated by WTF method. The mean of groundwater recharge was close at 318 ($\pm$77mm) over the 12-year study period. The uncertainty corresponds to a value of 24% of the annual mean recharge, which is consistent with others results (Lucas, M. et al., 2015; Maréchal et al., 2006). Before the land use change, the highest recharge value (667 mm) was estimated for the 2011 hydrological year, corresponding to about 36% of the annual precipitation (1862 mm). On the other hand, the lowest recharge value (155 mm), equivalent to almost 13% of the annual precipitation (1209 mm), was observed in 2006 when the lowest rainfall during the pasture period was recorded.

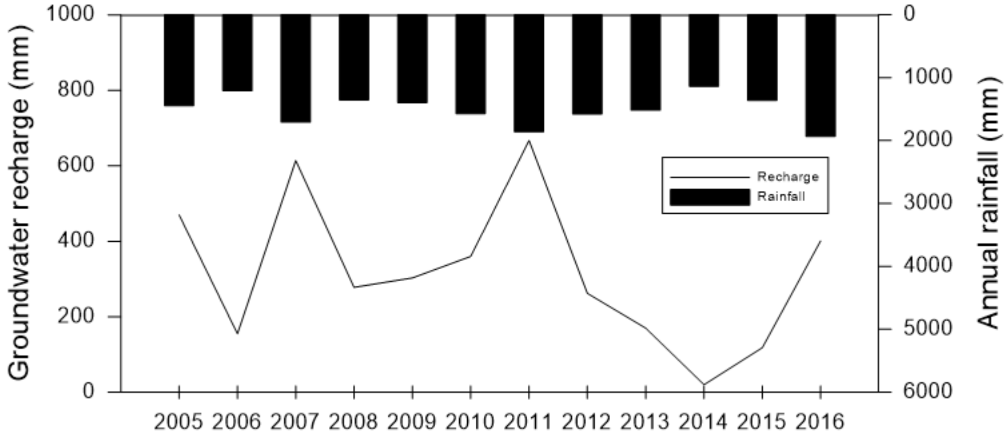

Figure 1 - Groundwater recharge estimated by WTF method.

After the land use change, groundwater recharge was significantly reduced. In the first year with eucalyptus (2012) the recharge was estimated as 262 mm, about 17% of the annual rainfall (1578 mm). During the eucalyptus development, the recharge decreased to approximately 170 mm in 2013, corresponding to about 11% of the annual precipitation (1517 mm). For the year 2014, the average recharge was estimated to be only 20 mm. The recharge was almost zero in 2014, due to a high evapotranspiration associated with low precipitation (1137 mm). Remarkably, two years later (2016), the highest precipitation (1991 mm) was recorded resulting in an increase in recharge to about 400 mm (20% of annual precipitation). Using the annual groundwater recharge data normalized by the respective rainfall, we noticed a significant difference ($p < 0.05$) between the pasture and eucalyptus periods.

Conclusões

This study assessed the impact of land use change from pasture to eucalyptus on groundwater recharge in a Guarani Aquifer System (GAS) outcrop area, during september of 2004 to august of 2016. Comparing the years 2005 and 2012 or 2013, which are hydrological years with annual rainfall similar to the long term mean, the recharge reduced almost 44% in 2012 and more than 60% in 2013, leading to water table decrease of approximately 2.0 m and 3.0 m, respectively. Our study suggests that the high evapotranspiration by eucalyptus forest tend to provide a decrease in groundwater recharge and water table depth, even in sandy soils with high infiltration rate such as in the Guarani Aquifer System (GAS) outcrop zone.

Referências bibliográficas

ADELANA, S. M. et al. A comparison of streamflow, salt and water balances in adjacent farmland and forest catchments in south-western Victoria, Australia. **Hydrological Processes,** v. 29, n. 6, p. 1630-1643, 2015.

BOSCH, J. M.; HEWLETT, J. D. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. **Journal of Hydrology,** v. 55, n. 1-4, p. 3-23, 1982.

DELIN, G. N. et al. Comparison of local- to regional-scale estimates of ground-water recharge in Minnesota, USA. **Journal of Hydrology,** v. 334, n. 1-2, p. 231-249, Feb 2007.

FAMIGLIETTI, J. S. The global groundwater crisis. **Nature Climate Change,** v. 4, p. 945, 10/29/online 2014.

HEALY, R. W.; COOK, P. G. Using groundwater levels to estimate recharge. **Hydrogeology Journal,** v. 10, n. 1, p. 91-109, Feb 2002.

IBA. **Report Ibá** Brazilian Tree Industry. São Paulo. 2017

JUANG, J.-Y. et al. Hydrologic and atmospheric controls on initiation of convective precipitation events. **Water Resources Research,** v. 43, n. 3, p. n/a-n/a, 2007.

KIM, J. H.; JACKSON, R. B. A Global Analysis of Groundwater Recharge for Vegetation, Climate, and Soils. **Vadose Zone Journal,** v. 11, n. 1, 2012.

LEBLANC, M. J. et al. Land clearance and hydrological change in the Sahel: SW Niger. **Global and Planetary Change,** v. 61, n. 3, p. 135-150, 2008/04/01/ 2008.

LUCAS, M. et al. Evaluation of remotely sensed data for estimating recharge to an outcrop zone of the Guarani Aquifer System (South America). **Hydrogeology Journal,** v. 23, n. 5, p. 961-969, August 01 2015.

LUCAS, M. C.; WENDLAND, E. Recharge estimates for various land uses in the guarani aquifer system outcrop area. **Hydrological Sciences Journal**, 2015.

MARÉCHAL, J. C. et al. Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture. **Journal of Hydrology,** v. 329, n. 1, p. 281-293, 2006/09/30/ 2006.

ONYEKWELU, J. C.; STIMM, B.; EVANS, J. Review Plantation Forestry. In: GUNTER, S.;WEBER, M., *et al* (Ed.). **Silviculture in the Tropics**, 2011. p.399-454. (Tropical Forestry). ISBN 1614-9785
978-3-642-19985-1.

PAYN, T. et al. Changes in planted forests and future global implications. **Forest Ecology and Management,** v. 352, p. 57-67, Sep 2015.

SALEMI, L. F. et al. Land-use change in the Atlantic rainforest region: Consequences for the hydrology of small catchments. **Journal of Hydrology,** v. 499, p. 100-109, Aug 2013.

SCANLON, B. R.; HEALY, R. W.; COOK, P. G. Choosing appropriate techniques for quantifying groundwater recharge. **Hydrogeology Journal,** v. 10, n. 1, p. 18-39, Feb 2002.

SCANLON, B. R. et al. Global synthesis of groundwater recharge in semiarid and arid regions. **Hydrological Processes,** v. 20, n. 15, p. 3335-3370, 2006.

SCANLON, B. R. et al. Impact of land use and land cover change on groundwater recharge and quality in the southwestern US. **Global Change Biology,** v. 11, n. 10, p. 1577-1593, 2005.

STEDNICK, J. D. Monitoring the effects of timber harvest on annual water yield. **Journal of Hydrology,** v. 176, n. 1-4, p. 79-95, 1996.

STONESTROM, D. A.; SCANLON, B. R.; ZHANG, L. Introduction to special section on Impacts of Land Use Change on Water Resources. **Water Resources Research,** v. 45, n. 7, 2009.

WEBB, A. A.; KATHURIA, A. Response of streamflow to afforestation and thinning at Red Hill, Murray Darling Basin, Australia.

Journal of Hydrology, v. 412-413, p. 133-140, 2012/01/04/ 2012.

WENDLAND, E.; GOMES, L. H.; TROEGER, U. Recharge contribution to the Guarani Aquifer System estimated from the water balance method in a representative watershed. **Anais da Academia Brasileira de Ciências,** v. 87, p. 595-609, 2015.