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Dynamics of water and nutrients around border of eucalyptus forest and sugar cane field in Rio Claro, São Paulo.

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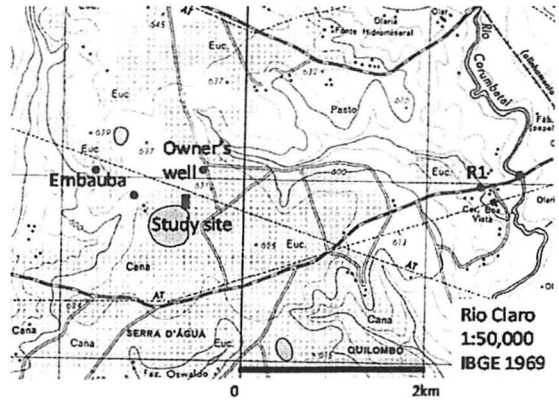
São Paulo is one of the biggest sugarcane production and eucalyptus forestation state in Brazil which is the largest in the world (Nihei et al.,2014). Though there have been several studies by the Embrapa reporting environmental impacts of eucalyptus plantation such as over-uptake of water and nutrients, biodiversity loss, volatilized or emitted harmful substances, salient issues have not reported in Brazil (*ref.*, Lima, 2011). At first, this study investigates dynamics of water and nutrients around border of eucalyptus forest and sugar cane field.

The study site, Rio Claro, is located 35km north of Piracicaba, São Paulo State of Brazil, where sugar cane field and eucalyptus forest are set out sequentially. Piracicaba area is covered by silty sand layers on the undulating peneplain (Fig.1). The annual mean temperature is 21.4°C, and average annual precipitation is 1279mm. The year of 2012 has an average annual rainfall though there was quite little rainfall in July through October. The stands of the eucalyptus are about 5 years old and their heights are around 15m.



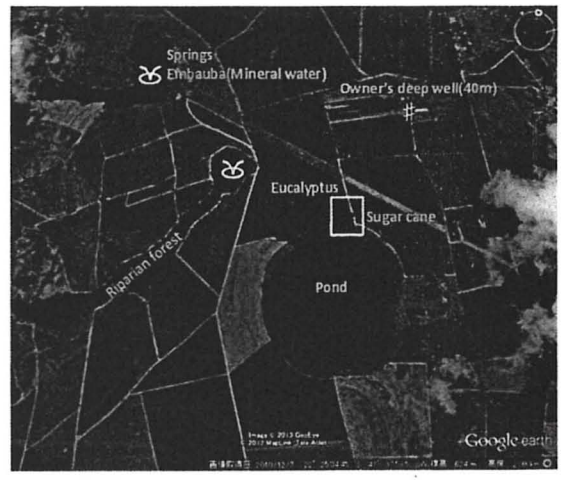


Fig. 1 Study area of Rio Claro
(Photo taken on Dec. 7, 2010)

Forest grazing and manure or excreta on the forest floor were recognized during our survey. The eucalyptus forest was clearly cut on September, 2013.

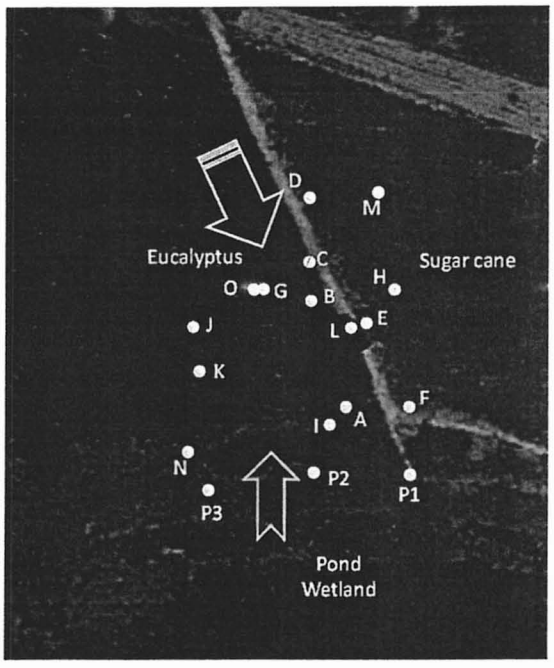


Fig. 2 Distribution of monitoring wells.

Sets of monitoring wells with 3 to 20 m-depth were installed as shown in Fig.2, and groundwater chemistry and stable isotopes of H, O, and N are analyzed and water levels are surveyed regularly.

Results

In order to investigate water dynamics in and around the study area, groundwater levels and isotopes of water were analyzed.

Figure 3 shows our monthly observation of rainfall at ESALQ since November, 2011 and an estimated local meteoric line is D = $8.20^{18}O$ + 14.0, which is almost same as IAEA data. We can use this local meteoric line as the base of our analytical consideration. The values of rainfall during rainy season of October through March are lighter than dry season of April through September.

Values of groundwater and springs in Rio Claro are on an evaporation line and/or a mixing line between pond water and deep groundwater as shown in Fig. 3. As a general trend, isotopic values are moving closer to the pond with time. This fact means that groundwater is recharged from the pond and groundwater flows from the pond to the north, or the eucalyptus forest (see Saraiva, 2014), which indicates eucalyptus forest uptakes soil water and groundwater significantly, maybe after the plantation. Changes of water table and isotope compositions after clear cutting are monitoring now.

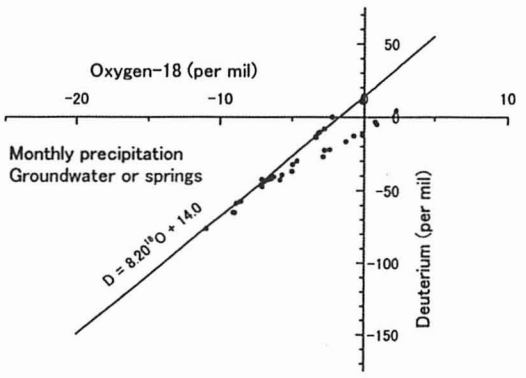


Fig. 3 Delta diagram of rainfall at Piracicaba and groundwater and pond water at the study site.

Water chemistry of groundwater, spring water and river water around the study site have relatively less minerals and nutrients as shown in Fig. 4. Background water chemical composition around the site can be seen at Embauba spring water and 40-m well of the sugar cane owner, whose locations are shown in Fig. 1. They have low EC of 13μS/cm and low nitrate concentrations of less than 2mg/L. While, groundwater in the sugar cane fields (Well E in Fig.4) is affected a little or largely some times by fertilization and has relatively high nitrate concentration. Wells in the eucalyptus forest are generally clear but some wells in the eucalyptus forest have high concentration of nitrate scatteringly, which is due to effects of grazing. Two rivers near the site, one is a small headstream (R1 in Fig.1) and the other is a local main stream of Rio Corumbatai (see in Fig.1), have EC of 102 and 130μS/cm and NO_3^- of 1.95 and 2.17 mg/L, respectively in March, 2013.

These and other observation results indicate that groundwater around the site has basically low mineral content due to eluviation and/or nutrient leaching for a past long time as shown by Takizawa et al. (2014). However, Embauba spring has low mineral contents but the percentage of nitrate is unusually high of 21% in equivalent as shown in Fig.4, which show possible contamination by nitrate, or fertilizers in the future.

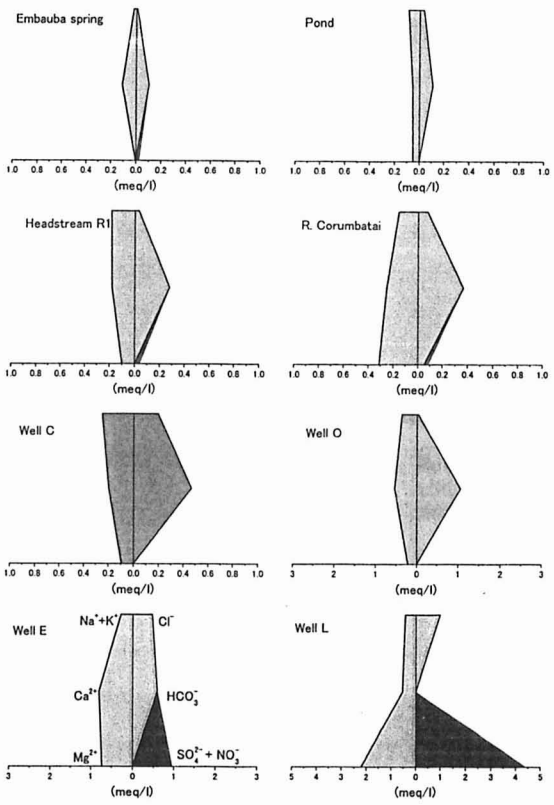


Fig. 4 Groundwater chemistry

Concluding remarks

After the three-year observation, following findings and issues are recognized tentatively:

1. Eucalyptus forest could change hydrological conditions in and around the forest. The groundwater flow direction was opposite against the expected direction.
2. At our study site, the pond could

play significant roles to make hydrochemical conditions.

3. Soil in this region have already leached or eluviation and exchangeable cations and CEC of the soil are very low as shown by Takizawa et al. (2014). Then, groundwater quality around this region has generally low concentration of minerals.
4. Pond water and river water show low water quality in general.
5. Nitrate of groundwater is basically low in eucalyptus forest and even in sugar cane field. However, nitrate leaching can not be denied and contamination with high nitrate concentration can be found in sugar cane field.
6. Intake of fertilizer by sugar cane seems to be high, as well as by eucalyptus forest.
7. Unknown or unrecognized sources of pollution such as working fertilizer and manure yard might exist? Effects of forest grazing might be important.
8. Embauba spring, which are surrounded by sugar cane fields, contains low chemicals, but rate or percentage of nitrate is very high, which may show future risk of spreading nitrate contamination.
9. Landuse sequences can be worked but mal-effects of eucalyptus might be considered. Other possible application of landuse sequence is distribution of eucalyptus forest downstream of cesspits or cesspool areas.
10. There are still many questions such as whether uptakes of water and nutrients by eucalyptus forest induce dilution or concentration of nitrate in groundwater.

Acknowledgments

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