



Workshop on
"Water, Nitrogen, and Agriculture
in the State of São Paulo, Brazil"

Proceedings

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Opening address

—Toward further academic collaboration—

Good afternoon, Ladies and Gentlemen,

Welcome to the University of Tsukuba.

As a vice-president of the university, and on behalf of the University of Tsukuba, I would like to make a brief address on this workshop.

The University of Tsukuba has a long history of research and educational activities on Latin America, especially Brazil.

On February of 2010, I visited São Paulo for signing an academic agreement between Graduate School of Life and Environmental Sciences, the University of Tsukuba and College of Agriculture (ESALQ), University of São Paulo.

Two years later, March 2012, an agreement with Institute of Geosciences (IGc) was also signed.

Last month, January 2014, we could make a new academic agreement between two universities, UT and USP, besides five institutional agreements within both universities.

Therefore, we have developed strong relationships nominally, actual activities between two universities such as cooperative research, researcher and student exchanges etc. are necessary to keep and develop the stronger and closer relationships.

This workshop based on the cooperative research between Japanese universities led by University of Tsukuba, and University of São Paulo, will introduce further steps of academic activities not only between two universities but also between Japan and Brazil.

Key words in this workshop, “water” and “agriculture”, which are most important issues for the future to be solved nationally and globally. Japan and Brazil can have an excellent or maybe ideal combination of countries to challenge these problems.

I hope all attendants on this workshop have productive results through presentation, discussion, and academic and social exchanges and enjoy staying at Tsukuba and Japan.

Thank you.

Teruo HIGASHI
Vice-President,
the University of Tsukuba

Introduction of the Project.

Norio TASE

This project was started when I visited São Paulo in 2008, attending the Symposium Brazil Japan: Contribution to the Agribusiness as the Commemoration of the Centenary of Japanese Immigration to Brazil 1908-2008. Through the financial support by MAFF (Ministry of Agriculture, Forestry, and Fishery project “the Collaborative Research Project on Food and Agriculture by Utilizing University Networks” (2008-2010), we could develop several cooperating relationships between Japan and Brazil, especially the University of Tsukuba and Sao Paulo University.

In 2011, JSPS Grants-in-Aid for Scientific Research Scientific Research (B) “Establishment of sustainable production systems by coupling eucalyptus plantation in land-use sequences” (No.23401003) was started. The research members are from University of Tsukuba, Hiroshima University, Hokkaido University, Ritssho University and Kumamoto University from Japan, and University of São Paulo from Brazil.

Two graduate students, one each

from both countries also join this project.

Brazil is the biggest eucalyptus forestation country in the world, and 0.6% of a country or 3,500,000 ha is eucalypt forest already. Though there have been several studies reporting environmental impacts of eucalyptus plantation on environments such as over-uptake of water and nutrients, biodiversity loss, volatilized or emitted harmful substances, salient issues have not occurred in Brazil. At first, this project reviews and evaluates scientific backgrounds and finds threshold conditions to environmental mal-impacts.

Based on investigating and verifying environmental functions of eucalyptus such as uptake of over-excessed or contaminated nitrate from groundwater and soil erosion control, sustainable crop producing systems with coupling with eucalyptus plantation in *land-use sequences* can be proposed (see Fig. 1). This developed system can help in the development of agriculture and forestry in developing countries.

The purposes of this workshop are several; first, brief presentation of the research results for the last three years, exchanges of knowledge and information on this research and related matters, and concrete discussion on exchanges of researchers and students for future developments of closer academic cooperation between Japan and Brazil.

Acknowledgements

This workshop is partly supported

by Grants-in-Aid for Scientific Research, Scientific Research (B) of JSPS, which is very appreciated.

This research project is based on a long history of Latin American studies first at the Tokyo University of Education and then at the University of Tsukuba, especially Special Research Project on Latin America (1978-1984), and Latin America Study Group. We really appreciate many related researchers supporting the Latin American studies.

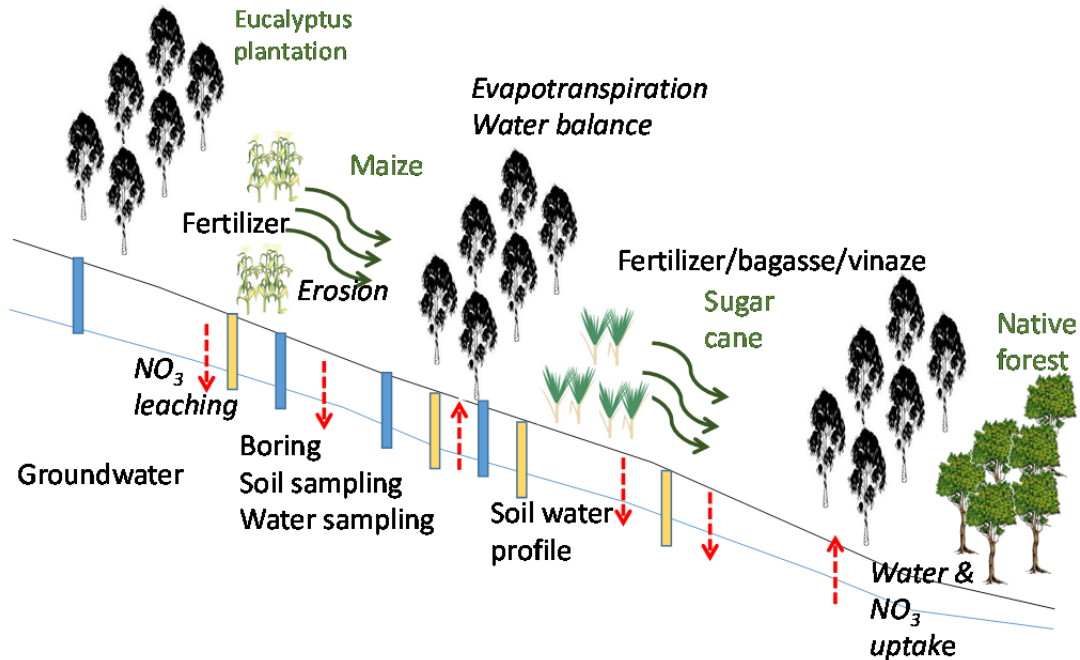


Fig. 1 Conceptual diagram of *landuse sequences* with Eucalyptus plantation.

Agriculture in São Paulo: history, perspectives and challenges.

R. SHIROTA

Modern agriculture in the State of São Paulo can be traced to the early 1500's, right after the discovery of Brazil by Europeans. The King of Portugal granted ownership rights – called Hereditary Captaincies – to selected noblemen that would privately explore their land. Initially, the newly discovered land did not reveal many valuable natural resources and sugar-cane was introduced along the coast, as the first commercial crop. However, out of fifteen Captaincies, only two were successful: Pernambuco (in the northeast) and São Vicente (later called São Paulo). At the time, sugar was a valuable commodity with high demand in Europe. Later, an increased supply from other parts of the world and lagging technology caused a decline of the industry in Brazil. About that time, the settlers in the Captaincy of São Vicente had established a small village away from the coast, called “Vila de São Paulo” (currently city of São Paulo) as an outpost to explore the hinterland in search of slaves and precious metal and stones. From the last part of XVI to XVIII

centuries this village grew slowly and subsistence agriculture developed to supply the local population. For the most part, the region had a sparse population and no significant economic activity, except as a “trading route”.

Commercial agriculture

Introduced in the northern part of the country in 1727, coffee slowly expanded – unsuccessfully – along the coast towards the south, reaching the region of actual state of Rio de Janeiro. By mid XVIII, the demand of coffee had increased in Europe. The US independence war and socio-political problems in coffee producing regions created a unique opportunity to Brazilian producers. Additionally, there was a large supply of labor (slaves) due to the crisis in the sugar-cane industry and ample farmland in the hills of that state where the soils' natural fertility and climate were ideal to the production of coffee. Unfortunately, farmers did not have much knowledge regarding soil conservation and the combined effect of steep topography with

heavy rainfall quickly exhausted the natural fertility after few years, causing the decline of yield.

Coffee production expanded from the exhausted fields of Rio de Janeiro to the unexplored lands in the State of São Paulo through the Ribeira River Valley. From there, it spread to the rest of the State, then an empty land with good soils and climate for coffee. Due to the decline of other activities, coffee turned the most important industry in Brazil, generating most of the income and export. As a result, the economy of São Paulo became the most dynamic in the Country. The political power, which was concentrated in the Northeast Region and Rio de Janeiro during the colonial period and early independence, slowly moved to São Paulo. With the abolition of slavery in 1888 and the high demand for labor in the coffee production, a large number of immigrants were imported from Europe and Japan during the later part of XIX and early XX centuries. These migrant helped the expansion of coffee and, in the long-run, made other important contributions, improving the stock of human capital and the cultural development of Brazil.

The crisis started in 1929 had major impact in the international coffee

market and to the economy of Brazil in general and of the state of São Paulo in particular, which were heavily dependent on this crop.

On the positive side, the decline of coffee stimulated the introduction of other crops as alternative economic activities, diversifying the State's agriculture. Cotton, sugar-cane, livestock, rice, bean and vegetables are few examples of crops that expanded in the first half of XX century in this State.

Modernization

The introduction of modern technology in Brazilian agriculture can be traced to this period. The use of machinery, fertilizer, pesticide and improved seeds started in this period in the State of São Paulo. Initially, most of these technologies were imported, but the State was pioneer to establish academic institutions related to the research and teaching of agriculture sciences. Instituto Agronômico de Campinas (IAC), created by Emperor Pedro II in late XIX century, was the first of such institution in Brazil. Other sister research institutions in different areas of the agricultural sciences were created in São Paulo. A pioneer extension service and several technical and college levels teaching institutions made

significant contributions to turn São Paulo's agriculture into the most diversified and advanced in Brazil. More recently, by mid XX century, many agro-industries were established to process and add value to the State's agricultural production.

Perspective and challenges

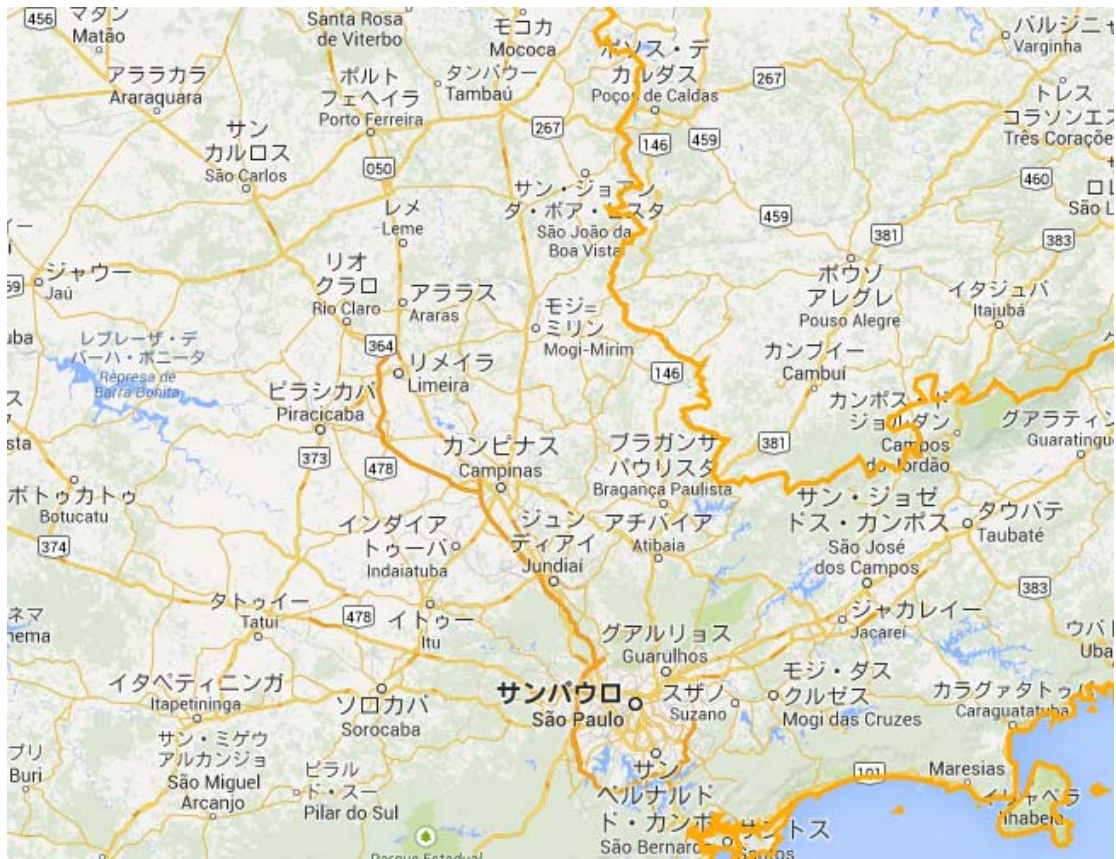
The State of São Paulo is still a major agricultural producer in Brazil, especially in certain crops like sugar-cane, orange, ornamental plants, eucalyptus, coffee, edible bean, vegetables and fruits. Its agriculture is mostly modern, efficient and competitive.

However, in the last 50 years, the rapid expansion of agriculture in

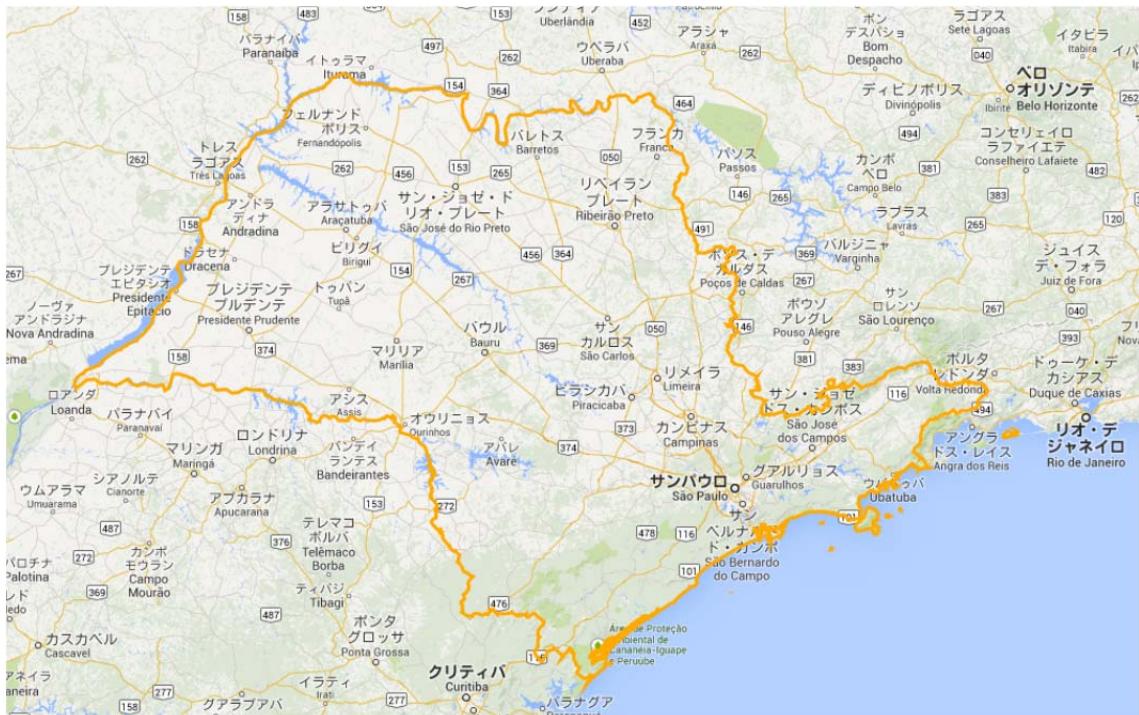
other states decreased the relative importance of São Paulo in terms of area cultivated and production. Exhaustion of new areas for expansion, relatively higher land prices, competition for land from non-farming activities and strict environmental regulations are some of the challenges faced by the farmers in this State.

The author would like to acknowledge the support received from Professor Norio Tase / University of Tsukuba.

This is partly supported by Grants-in-Aid for Scientific Research, Scientific Research(B) of JSPS, which is very appreciated.



São Paulo, Piracicaba, Rio Claro and the vicinity from Google map)



State of São Paulo, Brazil from Google map

Present status of sugar cane production system in the State of São Paulo and its future

Hisayoshi HAYASHI

Sugar cane production in the world and in Brazil

Sugar cane which has been cultivated for more than 200 years in Brazil, is still one of the most important industrial crops in 21st century as it is used not only for making sugar but also ethanol and electricity. It covers 25.4 million ha and produces 1800 million tons in the world. Brazil produced 40.8% of the world sugar cane production and was the biggest producer in the world (Fig. 1). Sugar cane was planted on 9752 thousand ha in Brazil in 2012 and it accounts for 1.1% of the country area and 3.8% of arable land in Brazil. South-Central region planted 87.0% and North-Northeast region planted 13.0% of the country. São Paulo state is the biggest producing state and it planted 5173 thousand ha or 53.0% of planted area in Brazil in 2012 (Fig. 2).

The crop year of sugar cane started in April and ended in March of the next year. Sugar cane production in Brazil was 588.5 million tons in 2012/13 and 90.52% of it was produced in South-Central

region. São Paulo state produced 56.1% followed by Goiás (9.0%), Minas Gerais (8.8%), Paraná (6.8%) and Mato Grosso do Sul (6.3%). Sugar and ethanol produced 38.2 million tons and 23.2 million m³, respectively (Table 1).

Climate condition in Piracicaba

Figure 3 showed temperature and precipitation amount in Piracicaba and cropping season of sugar cane in Brazil. Annual precipitation is ca. 800mm and 80% of rain is distributed in the rainy season from October to March. Average rain fall days in rainy season is around 10 days in each month. The high air temperature, which ranged from 25 to 30°C, is not so different in a year but it decreases in rainy season. The low air temperature fluctuates from 13°C in rainy season to 20°C in dry season.

Cultivation system

Sugar cane fields were plowed by disk plow, chisel plow and/or moldboard plow, then soil pH was adjusted based on the results of soil

analysis. Chemical fertilizer and pesticide for protection against termites and nematode were put in a furrow. Seed stem were put in it and covered with soil. Herbicide was sprayed immediately after planting the sugar cane. Topdressing was made at 10 to 20cm depth and 20 to 30cm apart from the planted position at three month after planting when plant height reaches around one meter. The amount of nitrogen fertilizer is ca. 30kg/ha as basal dressing and ca. 60kg/ha as topdressing. Seed stem was needed from 30 to 35t/ha. There are two planting seasons, namely from August to September and from February to April. Harvesting will be done one year after planting in the former condition or 18 months after planting in the later condition. Average yield is 80-90t/ha in one year cropping and 110-120t/ha in 18 months cropping. Ratooning is a practice of growing sugar cane from the stubbles of previous one. The harvest season is one year after the cutting of the previous crop in ratooning system. How many times can we harvest the sugar cane depends on its yield reduction by cutting times. Growers decide to plant a new sugar cane if the yield reached 75t/ha or below. In rationing system, normally they cut

sugar cane four or five times but up to more than 10 times in some case. Cultivation period was determined by the natural conditions especially for rain. Figure 4 showed the amount of sugar cane crushing by month in São Paulo, South-Central region and the country. The main harvest season is from June to December, and around 95% of sugar cane is crushing in this season.

Cultivar

Sugar cane breeding is conducted mainly at RIDESA (Rede Interuniversitária para o Desenvolvimento do Setor Sucroalcooleiro, Interuniversity Network for the Development of Sugarcane Industry), CTC (Centro de Tecnologia Canavieira, Sugarcane Technology Center), IAC (Instituto Agronômico de Campinas, Agronomic Institute of Campinas) in Brazil. More than 50 varieties are cultivated in Piracicaba, but the top share cultivar was RB857515 (28.5% of planting area in Piracicaba) followed by SP81-3250 (10.3%), RB855156 (7.8%), RB855453 (7.8%) and SP80-3280 (7.1%) in 2012. The variety name RB means the cultivar bread in RIDESA and SP means cultivar bread in CTC (CTC was reorganization in 2004 and after

that time the cultivar bread by CTC was named CTC number).

Hand cutting and burning of sugar cane field

There are two types of harvesting, machine cutting and hand cutting. In most of hand cutting, sugar cane field should be burnt to remove sugar cane straw before harvesting. Pre-harvesting sugar cane field burning is needed to improve the workers' safety and the harvesting yield by removing the straw and dry leaves. It has the following advantages; kill pest for example cuckoo-spit, drive away snakes and other potentially poisonous animals, proper cutting of stems at ground level, not affect soil consolidation and so on. As a result, harvesting system using hand cutting gets more yield and keeps high yield than machine cutting. On the other hand, pre-harvesting sugar cane field burning has the following problems; increase carbon dioxide, dispersing particulate matter and increase the risks associated with the smoke, get dirt to clothes and houses, disturb the transportation systems especially on high-way, increase the risk of air pollution and forest fire. On the other hand, machine harvesting of sugar cane in Brazil actually took

place in the 1980's.

The legal regulations

São Paulo state established the gradual prohibition of sugar cane burning in 1997. Brazilian government and São Paulo state established reduction schedule in Federal Decree 2661 and São Paulo State Law No.11241, respectively (Table 2). Cultivating area was divided into two categories by its tilt, namely area where machine harvesting is possible (tilt is less than 12%) and area where machine harvesting is not possible (more than 12%). Both laws set target year of 20 years after legislation. On the other hand, ORPLANA (Organização de Plantadores de Cana da Região Centro-Sul do Brasil, Sugar Cane Growers Organization of the Central-Southern Brazil) agreed with growers on the prohibition of sugar cane burning by year 2014 where field tilt is less than 12% or field size is greater than 150ha, or by year 2017 where field tilt is greater than 12% or field size is less than 150ha. Although, federal decree and state law on burning sugar cane have been changed several times, but the federal court banned the burning of sugar cane in 19 municipalities in Piracicaba in a

couple of month from July 2012. Federal law No.40 was enacted in May 21, 2013. It states that the period from June 1 to November 30, 2013, is prohibited burning of sugar cane from 6:00 to 20:00, burning of sugar cane is prohibited based on the relative humidity measured from 12:00 to 17:00, and so on. Ten thousand people are still working on the cutting of sugar cane in São Paulo state in 2013. Hand cutting and burning of sugar cane have

some advantages on productivity, land use, insects and disease damages, farm management and so on. I would like to discuss on these points in the view of future sugar cane production in Brazil.

This is partly supported by Grants-in-Aid for Scientific Research, Scientific Research(B) of JSPS, which is highly appreciated.

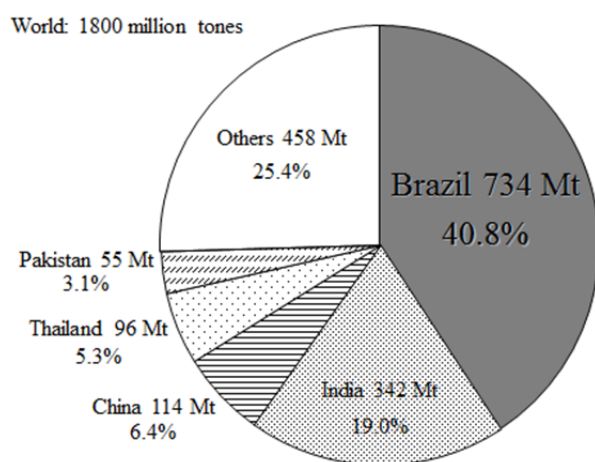


Fig. 1 World production of sugar cane in 2011. (Data source: FAOSTAT 2013)

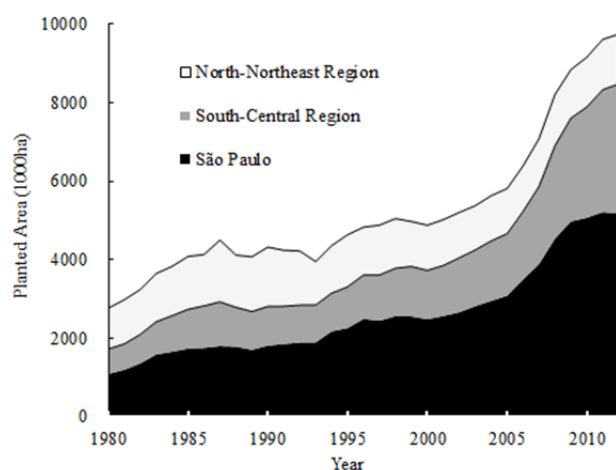


Fig. 2 Planted area of sugar cane in São Paulo and Brazil. (Data source: UNICA)

Table 1 Sugar cane, sugar and ethanol production in Brazil, 2012/2013. (UNICA)

State	SC	NN	Sugar cane		Sugar (million t)	Ethanol (million m ³)		
			(million t)	(%)		Anhydrous	Hydrous	Total
São Paulo	○		329.9	56.1	23.29	5.60	6.23	11.83
Goiás	○		52.7	9.0	1.88	0.81	2.32	3.13
Minas Gerais	○		51.8	8.8	3.42	0.87	1.12	1.99
Paraná	○		39.7	6.8	3.09	0.43	0.87	1.30
Mato Grosso do Sul	○		37.3	6.3	1.74	0.47	1.45	1.92
Alagoas		○	23.5	4.0	2.23	0.34	0.20	0.54
Mato Grosso	○		16.3	2.8	0.49	0.45	0.53	0.97
Pernambuco		○	13.6	2.3	1.22	0.17	0.10	0.27
Paraíba		○	5.3	0.9	0.21	0.15	0.15	0.31
Espírito Santo	○		3.5	0.6	0.10	0.11	0.07	0.18
Bahia		○	3.1	0.5	0.11	0.08	0.08	0.16
Rio Grande do Norte		○	2.2	0.4	0.13	0.04	0.03	0.07
Sergipe		○	2.1	0.4	0.13	0.04	0.08	0.11
Maranhão		○	2.1	0.4	0.01	0.14	0.02	0.16
Tocantins		○	1.8	0.3	0.00	0.11	0.05	0.16
Rio de Janeiro	○		1.4	0.2	0.10	0.00	0.04	0.04
Piauí		○	0.8	0.1	0.05	0.03	0.00	0.03
Pará		○	0.7	0.1	0.04	0.02	0.01	0.03
Amazonas		○	0.3	0.0	0.02	0.00	0.00	0.00
Rondônia		○	0.1	0.0	0.00	0.00	0.01	0.01
Acre		○	0.1	0.0	0.00	0.00	0.00	0.00
Ceará		○	0.1	0.0	0.00	0.00	0.00	0.00
Rio Grande do Sul	○		0.0	0.0	0.00	0.00	0.00	0.00
Santa Catarina	○		0.0	0.0	0.00	0.00	0.00	0.00
Amapá		○	0.0	0.0	0.00	0.00	0.00	0.00
Roraima		○	0.0	0.0	0.00	0.00	0.00	0.00
South-Central Region			532.8	90.5	34.10	8.73	12.63	21.36
North-Northeast Region			55.7	9.5	4.15	1.11	0.75	1.86
Total			588.5	100	38.25	9.84	13.38	23.23

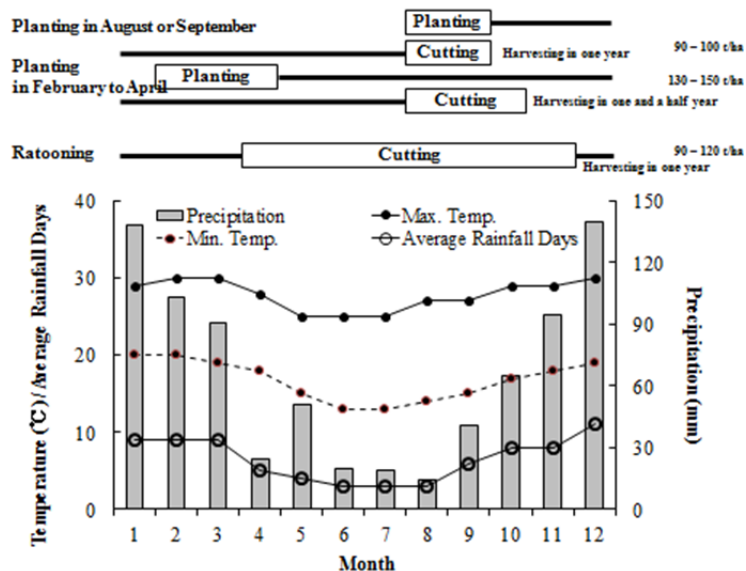


Fig.3 Climatic condition in Piracicaba and cropping season of sugar cane in São Paulo.

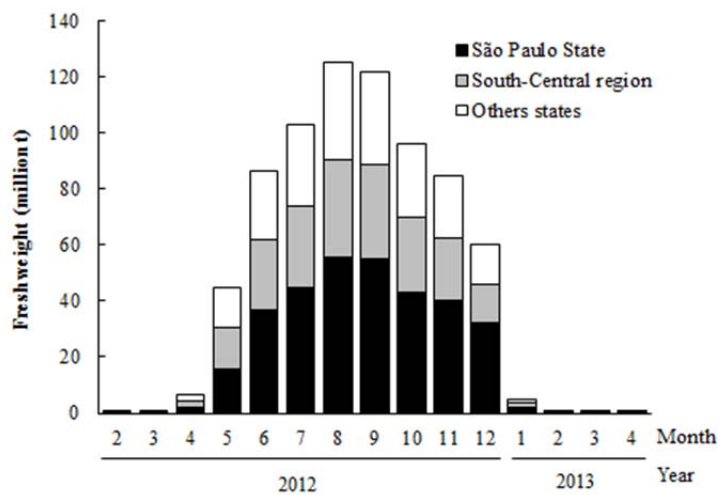


Fig.4 Sugar cane crushing in 2012/2013. (Data source : UNICA)

Table 2. Reduction schedule of sugar cane burning by São Paulo state and the federal government.

Years after legislation	State Law No.11241 (São Paulo)			Federal Decree No. 2,661		
	Year	Tilt < 12%	Tilt > 12%	Year	Tilt < 12%	Tilt > 12%
	2002	20	-			
5	2006	30	-	2003	25	-
10	2011	50	10	2008	50	-
15	2016	80	20	2013	75	-
20	2021	100	30	2018	100	-
25	2026		50			
30	2031		100			

Characteristics of sugar cane and eucalyptus production in the State of São Paulo

T. NIHEI, H. HAYASHI, N. TASE, S. ONODERA, T. YAMANAKA, K. TAMURA,
R. SHIROTA, R. HIRATA & F. SARAIVA

The harvested area of sugar cane has increased significantly in the State of São Paulo recently. The ethanol made from sugarcane is used mainly for fuel, and the usage attracts a great deal of attention because it is considered as carbon-neutral, an environmentally friendly energy. Brazilian government enhanced ethanol production after the oil crisis in the 1970s, and regulated the production of ethanol, sugar and sugar cane. The production was liberalized in the 1990s, and Brazil became the leading country of the world in the production of ethanol and sugar. Especially, the export of sugar accounts for about 50% of the world's trade.

The impact on the environment is worried in the sugar cane production, because a considerable amount of chemical fertilizer is used in the cultivation, and the vinasse (vinhoto or vinhaça in Portuguese) that is a by-product of alcohol refinery also sprayed as fertilizer. The former may contaminate groundwater, and the latter may

cause problems such as soil leaching and hardening. The progress of mechanization operated by heavy agricultural machinery also takes a risk of soil erosion.

The land-use sequences by means of sugar cane and eucalyptus production would present a way to solve the problems. Eucalyptus, growing swiftly, is used as the ideal material for paper pulp, firewood and construction. In particular, the production of paper pulp becomes the export industry of the country, and the plantation of eucalyptus is regarded as the profitable forestry.

The problems of eucalyptus production have also been pointed out. It absorbs a large quantity of water and soil nutrients to degrade the soil condition. However, a good use of the characteristics of eucalyptus may alleviate the environmental problems of sugar cane production. This study examines the possibility of the land-use sequences of sugar cane and eucalyptus by focusing on spatial analysis of maps and the data obtained from field survey.

Results: production structure of sugar cane and eucalyptus

(1) Production centers

The harvested area of sugar cane reaches 5.7 million ha by the Census of Agriculture 2006, and 54% of it is distributed in the State of São Paulo as shown in Fig. 1. The other leading states of sugar cane production are Alagoas (10%), Paraná (5.9) and Pernambuco (5.6). The production area of eucalyptus reaches 3.8 million ha, and the harvested area counts 284,716ha. It is distributed mainly in the Southeast (Sudeste) to the South (Sul) regions, i.e., the States of Minas Gerais (27%), São Paulo (20) and Rio Grande do Sul (15).

Though the State of São Paulo includes a large area of sugar cane and eucalyptus, the distributions differ by regions. In the scale of micro-region (microrregião), the harvest area of sugar cane is distributed largely in the north-central region of the state, i.e., Ribeirão Preto (380 thousand ha), São Joaquim da Barra (254), Jaú (199), Jaboticabal (193), Araraquara (188), Assis (183), and São José do Rio Preto (170). The harvested area of eucalyptus is distributed largely in the south-central region as it surrounds the production centers of sugar cane, i.e., Bauru (7360ha),

Itapeva (4884), Avaré (4631), Piedade (3516), Batatais (3495), and Paraibuna e Paraitinga (3318).

(2) Production calendars

The harvest season of sugar cane continues from early April to late November in the State of São Paulo. The planting season of sugar cane varies from January to March, and June to November. The growing period is 12 months for the former planting and 18 months for the latter one. After the first harvest, sugar cane will be grown and cut four to five more times by ratooning. The period of ratooning varies around 12 months. After sugar cane, other crops such as soybeans, groundnuts, sweet potatoes, kidney beans and green manure are cultivated at once.

Sugar factories cultivate about 60% of the harvested area of sugar cane in Brazil. The factories manage farming divisions and own agricultural equipment, e.g., harvesters, tractors, planting machines. The yield of sugarcane reaches 70-150t/ha (90-110t/ha on average), and producers put considerable volume of chemical fertilizer (200-1500kg/ha). The quantity of fertilizer is no less than the production of maize and soybean. Nitrogen and potassium

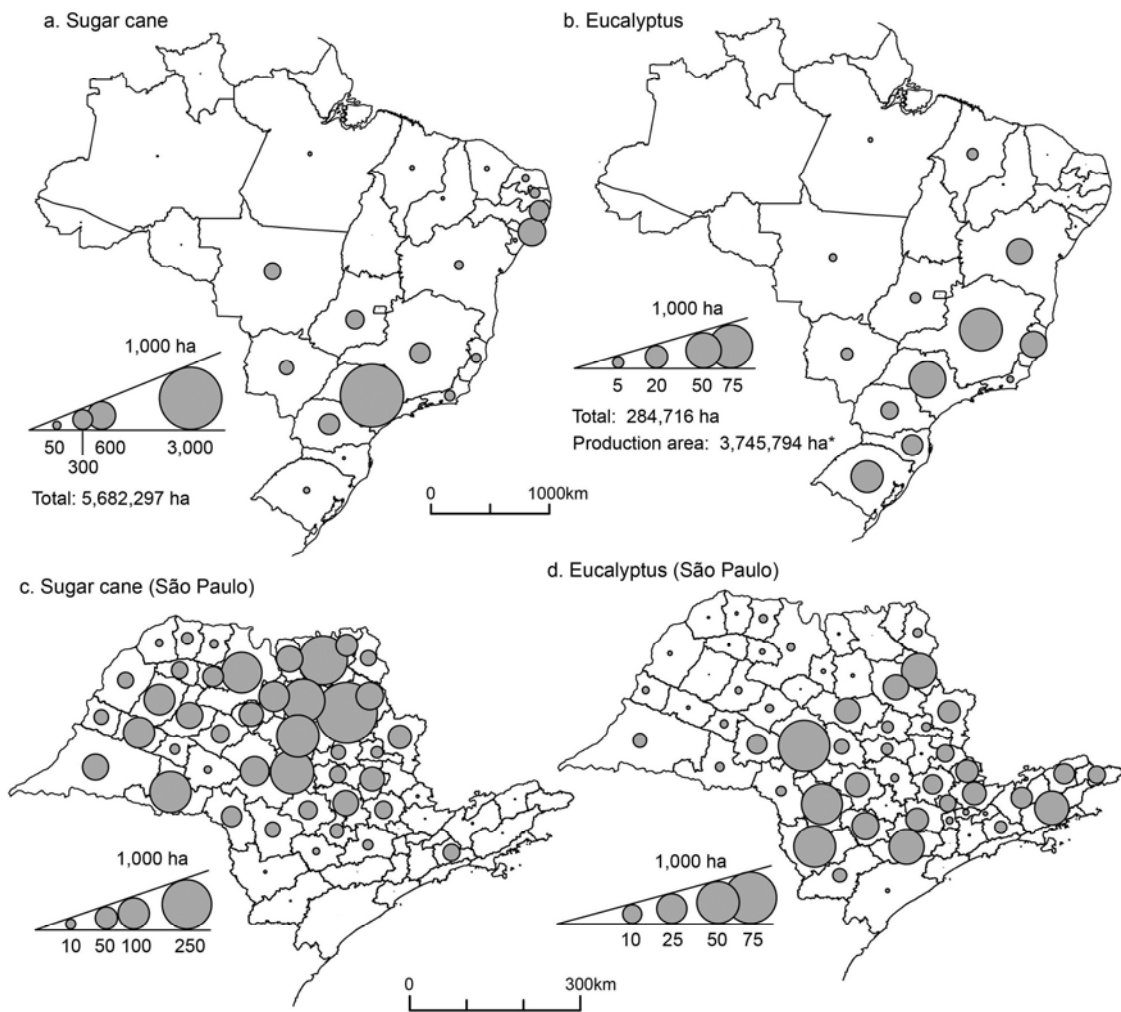


Fig 1. Harvested area of sugar cane and eucalyptus in Brazil, 2006

*Anuário Estatística da ABRAF (Associação Brasileira de Produtores de Florestas Plantadas)
Source: Censo Agropecuário (IBGE: Instituto Brasileiro de Geografia e Estatística).

are the main compositions of the fertilizer. In the past when farms harvested sugar cane by hand cutting, they could cut more 10 times from a stump, though the yield was less than today.

The artificial forest of eucalyptus for pulp is cut in 7 years on average. At the year of cutting, the tree grows to 30-35m of height and 18-20cm of diameter. The young trees grown for 3-5 years, whose diameter

reaches about 10cm, are sometimes cut for firewood and material to make fences. The production of eucalyptus reaches around 40m³/ha/year including thinned wood. After cutting, producers will replant nursery plants after removing stumps. In case they return the forest to the landlords, they remove stumps and convert the land into grassland. The nurseries are planted in the

positions farthest from the old stumps. It is said that about 70% of the forestry (eucalyptus and pine) in Brazil is conducted by firms. By the case of our fieldwork, 75% of eucalyptus is cultivated by paper factory in the State of São Paulo.

(3) Cases of production

a. Sugar factory

The factory belongs to one of the major groups of sugar cane industry in Brazil. It gathers sugar cane from 40,000ha of arable land. Among them, 15,000ha is own land, 15,000ha is leased land, and 10,000ha is the land cultivated by suppliers (fornecedor). Sugar cane is basically cut 5 times from a stem, though the number differs depending on the condition of soil and climate. Among the sugar cane the company cultivates, 90% of is machine harvest, and 10% is manual harvest without burning. The factory possesses 22 combine harvesters, and gathers most of sugar cane within 28km from the processing plant. After the last harvest of sugar cane, the factory leases the land, and tenant producers cultivate soybeans or green manure such as crotalaria. The area of newly planting reaches 5000ha every year, and 60% of them are machine planting. Vinasse is

sprayed in 12,000ha within 20km from the processing plant by the supply system with pipelines, tank lorries, ponds and pump huts. The quantity of the spray leaches 60-80m³/ha for newly planting and ratooning. [Interviewed in September 2013]

b. Small farm of sugar cane

The farm produces sugar cane in 8.5ha of own land, and distills the spirit (cachaça) made from sugar cane. Sugar cane is cut 7-8 times from a stem on average. Depending on soil condition, the number of cut varies from 5 to more than 10 times. The growing period continues 12 months in newly planting, and 12 to 18 months for ratooning. The farm usually takes more than 14 months for ratooning to increase the yield. In the last cultivation of ratooning, the growing period is shortened to 12 months to produce another crop. The farm basically produces maize after sugar cane, however sometimes replants sugar cane. The managers of the farm are two brothers in their forties. Their father started sugar cane production in 1974. Before sugar cane, the farm produced maize, cotton and rice. Among the former crops, the income of maize was stable. [Interviewed in August 2011]

c. Paper factory

The factory runs 24 hours 7 days, and produces 360,000t/year of paper. The collecting area of eucalyptus reaches 100,000ha. It is distributed over 80km from the factory, extending to the State of Minas Gerais. The factory grows 74% of the area including 1500ha of leased land, and contract farms grow the rest. The factory owns 100,000ha of land, and grows 72,500ha of eucalypt, 4,100ha of reservation forest, and holds other land use such as bamboo forests. Eucalyptus is cut in 7 years. The area of felling reaches 11,000ha/year, about 1000ha/month. The factory produces about 1.3 million seedlings per month by tissue culture, and plants 1333 seedlings per hectare. A seedling occupies 8m² in the field. Though many works such as plowing, harvesting and shipping are mechanized, considerable labors are need for planting. [Interviewed in August 2012]

d. Elderly farmer of eucalyptus

The farmer owns 100ha of land. Almost all of the land is artificial forest of eucalyptus for pulp. A paper factory manages the cultivation of eucalyptus. The farmer purchased the land in 1973, moved from Campinas in 1997, and produced oranges, potatoes and tomatoes. The owner started

eucalyptus production in 2004. At the time, he decided to quit farming because he became 75 years' old, and his son managed horticulture in greenhouses adjacent to the main house. Until the year, agents from a paper factory came to negotiate with him for the production of eucalyptus by leased land. Other than the eucalyptus for pulp, the farmer keeps rows of eucalyptus. The trees are settled on the hilltop at the back of a lake. The "garden" eucalyptus were sometimes cut and sold for building material when the farmer needed money. [Interviewed in August 2012]

Discussion

Sugar cane and eucalyptus in Brazil are produced mainly by the factories and entrepreneurial farms that conduct large-scale management. They pursue economical productivity by adopting new technology such as mechanization, new varieties and innovative cultivation methods. As the result, the land use for sugar cane and eucalyptus production became much monotonous ones. The efficacy of leaching (lixiviation) by means of plantation of eucalyptus has been known for about 40 years, however, the land-use sequences including eucalyptus

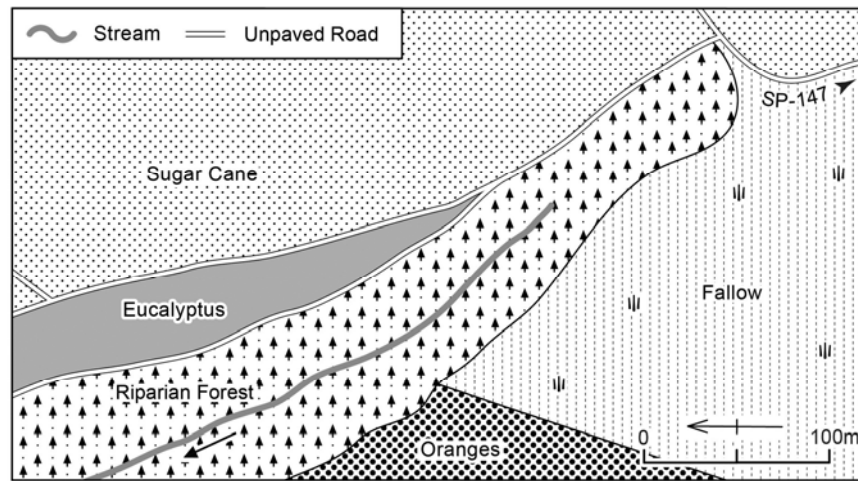


Fig 2. Case of land use in the west of Piracicaba, 2010
Source: Field survey.

have not been realized yet.

To find example of the land-use sequences, we observed a lot of landscape during our field survey, and also surveyed aerial photographs. It was hard to find out but we spotted a small example in the west part of Piracicaba as shown in Fig. 2. In the site, eucalyptus was elongated under the filed of sugar cane, and a valley extended in the lower place. Though detailed examinations in groundwater and geomorphology will be required, such a sequence would lead the environment-friendly land use because the eucalyptus will absorb the excessive fertilizers and flow of topsoil.

Conclusion

The production structure of sugar cane and eucalyptus is carried mainly by the large-scale and entrepreneurial management that follows the economical efficiency. Under the current conditions, it

seems difficult to realize sustainable land-use sequences. In order to accomplish the land use in which eucalyptus is disposed under the field of sugar cane, small-scale management such as elderly farmers and part-time farmers will play an important role. As for political supports, eucalyptus of land-use sequences could be considered as a part of forest reserve by law.

This study is one of the results of JSPS Grant-in-Aids for Scientific Research B (No.23401003)

Groundwater contamination by nitrate in the state of São Paulo (Brazil): research results and implications for management

R. HIRATA, C. VARNIER, S. PROCEL, & F. CAGNON

Introduction

Nitrate is a very insidious and persistent problem that affects almost all urban aquifer in the State of São Paulo. In the last 10 years, CEPAS (Groundwater Research Center, University of São Paulo) has conducted studies that evaluate the problem at different scales, from detailed experiments, in which the nitrogen (water and gases) dynamics were evaluated in both active (São Paulo city) and inactive cesspits (Urânia city), to intermediate scale (neighborhood in Vila Eutália, Parque Ecológico do Tietê and USP campus), and municipal scale studies (Urânia, Presidente Prudente, Marília, Bauru) (Hirata 2012).

This manuscript discusses the main findings of these studies focusing on groundwater management and land urban planning.

Results from detail studies

The evaluation of nitrogen dynamics in abandoned (since 2002) and active cesspits was conducted in two researches. In one of them a

monitoring station was constructed (11.2m excavated well, 1.8m in diameter), in which 12 tensiometers and 12 suction lysimeters were installed to the unsaturated zone (0.5-9.0m) close to an inactive cesspit. It was demonstrated that nitrate remains up to 458mg/L NO_3^- -N (Fig. 1) in the unsaturated zone, even after more than 10 years of abandonment.

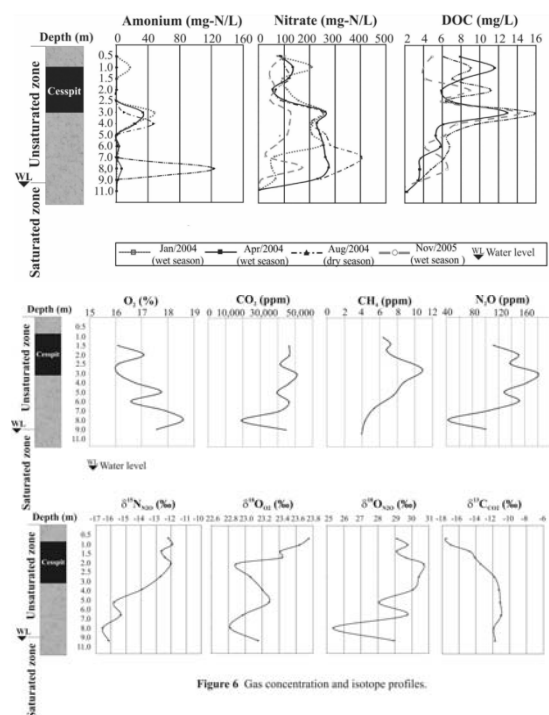


Figure 6 Gas concentration and isotope profiles.

Fig. 1. Geochemical profile in an inactive cesspit in Urânia (Varnier et al 2007)

In the other study, a new cesspit, with pan/single lysimeters, Teflon gas extractors, and tensiometers, was constructed in order to monitor the unsaturated zone. The results of both studies show that denitrification and nitrification coexist on same level due to the presence of microcosms in the pore scale, associated to soil hydraulic conductivity heterogeneity (Fig. 2).

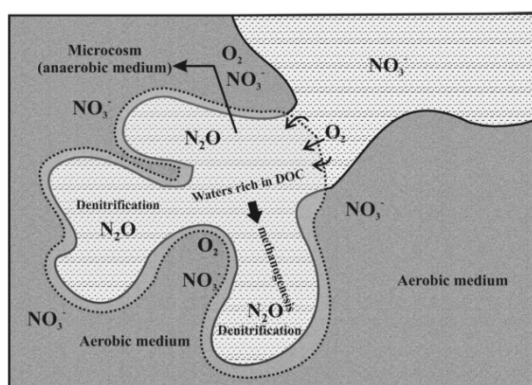


Fig. 2. Anaerobic microcosm generated in an aerobic environment (Varnier et al 2010)

Additionally, the reaction of nitrification and also denitrification is very fast (days-week) in aquifers. The conversion of all organic-N was done in less than 7m distance from the source in a shallow and unconfined aquifer, as observed in the Parque Ecológico do Tietê experiment (São Paulo).

Municipal scale results

In another scale, studies carried

out in several cities have shown that: a) nitrate contamination plumes are found at different depths (>120mbs), showing concentration (>210mg/L- NO_3^-) stratification in unconfined to semiconfined sandy aquifer as in the Bauru Aquifer System (oxidizing and neutral to alkaline pH environment), b) there is a strong correlation between the density of cesspits and nitrate concentrations observed in unconfined aquifers (concentration is directly related to population density and inversely proportional to volume of water use, rainfall infiltration, and capacity of denitrification); c) presence of high nitrate contamination (>100mg/L- NO_3^-), even in areas with sewer system already in place since the 1970s.

The nitrate contamination source in Urânia (9,000 inhabitants) is associated with domestic effluent from residential properties, which previous to mains sewerage construction in the 70s, was injected directly into the soil (Hirata & Cagnon 2004). Today, the mains sewerage covers almost 95% of the urban area, although some cesspits already exist. Basically, all today active cesspits and dug and tube wells were inventoried and an extensive and long sampling for

hydrogeochemistry analysis was performed for many years. Considering the sewage system has been deployed for more than 40 years, the problem still persists, especially in the shallow zone (up to 30mbs) (Fig. 3). The numerical modeling shows that the time required for removing it is longer (more than 10 years) for the shallow and intermediate parts of the aquifer (30-100mbs). For the deeper part (100-160mbs), it will take more than 90 years, but the expected concentration after 10 years, is <11% of the original one.

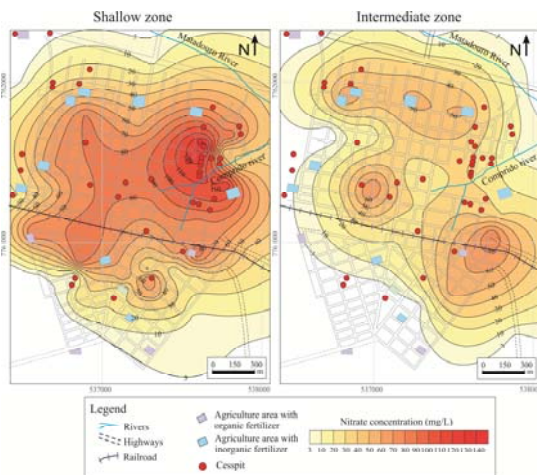


Fig. 3. Nitrate plume at shallow (up to 30mbs) and intermediate (30-100mbs) zones (Hirata & Cagnon 2004)

Presidente Prudente (200,000 inhabitants) has experienced a strong urbanization process in the 70s, initially without mains

sewerage, releasing the domestic effluent into the soil. From the 80s, the septic tanks and cesspits were disabled almost completely and currently the sewer system covers approximately 98% of the city (Varnier et al 2010). For the study, the hydrogeochemical data were obtained from 82 production wells throughout the urban area in different time periods.

The results show a clear direct correlation with density of urban land occupation, and inverse with both the age of occupation (relation to the standard occupancy) and well depth (Fig. 4). It is also clear that in the oldest urban occupation areas is possible to recognize plumes with the highest concentrations of nitrate, probably due to the leakage of old

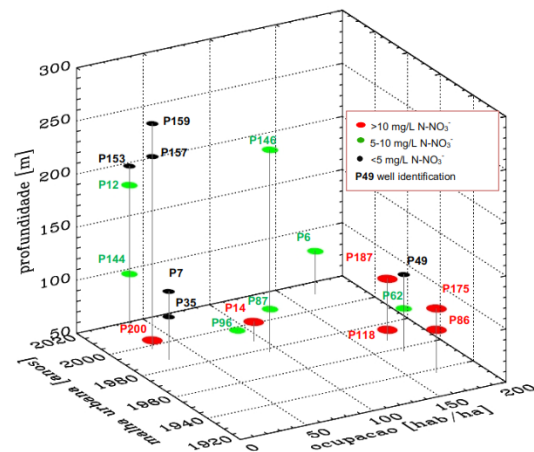


Fig. 4. Nitrate aquifer occurrence with relation to population density in Presidente Prudente (Procel et al 2013)

sewage systems and low maintenances.

Implications to management

The results obtained in studies conducted by CEPAS in the last 10 years have allowed some recommendations for better groundwater management and land use, including mainly: a) new settlements should be constructed only where sewer system (using plastic material) are previously installed and periodical maintenance is provided; b) new public supply wells (organized in wellfields) should be constructed in areas of low residential occupation or in parks/public places or even outside the urban area; c) in contaminated aquifers, groundwater exploitation should be encouraged for uses other than drinking (industrial uses, washing and irrigation) to allow more rapid nitrate plume dilution.

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Geophysical research and present results at Rio Claro study area.

F. A. SARAIVA

Abstract

Environmental impacts related to nitrate in soil and groundwater due to human activity have been studied in many academic surveys. The major problem in nitrate contamination is its extension increasing the cost of remediation. In those studies, researchers have been using various methodologies, especially direct methods of investigation such as wells, water and soil sampling and chemical analysis. Otherwise, indirect methods have the advantage of quickness, relative best prices and quality of results. Electrical geophysical methods has been fairly used in hydrogeological studies. Especially when necessary to investigate depths, temporal and spatial variations of aquifers, preferred underground flow directions and also detection and scaling of plumes of contamination. The increase of moisture and the amount of dissolved salts cause a decrease of soil resistivity values. On the other hand, eucalyptus are known for being an arboreal species that absorbs a significant amount of

water from the unsaturated zone and, in some cases, may even influence the recharge of aquifers. In this context, the application of electric resistivity method, using the technique of handling electric, before and after the cut of a plantation grown eucalyptus, can show if the soil resistivity values change due to the presence of this plantation.

In this project, initially, we believed that after harvesting the resistivity values would decrease, since the roots of eucalyptus would no longer absorb large amounts of water, which would recharge the aquifer. The steady fall of the water level values and the calculation of water balance in the region led to the conclusion that the months during geophysical campaigns were characterized as having water deficit in the region.

Thus, the increase in values of soil resistivity could be linked to water and climatic characteristics of the region, not suffering any influence of eucalyptus. A new survey, after the rainy months (March 2014) may show differences in these results.

The use of the technique of Vertical Electric Sounding and Self Potential indicates, respectively, that the level of water presents average depth around 6.00 meters at the higher portion and the preferred direction of underground flow is to the North of the region, apparently upstream when we consider the present surface topography.

Introduction

In hydro-geological studies, geophysical methods have applicability when it's necessary to evaluate depths, temporal and spatial fluctuations, aquifers, preferential direction of groundwater and also sizing the plumes of contamination..

Among the geophysical methods of exploration, electrical methods are increasingly being used in hydro-geological studies since they have good resolution and relatively cheap cost (Steeple,1991; Telford, 1990) .

According to Gallas (2000), the increase in the moisture content and the amount of dissolved salts cause a decrease of soil resistivity values. This condition allows the immense possibility of application of electric resistivity method in hydrogeological and environmental studies (Saraiva, 2010), where the

presence of water in the saturated zone can be detected by this method, as well as the variation of moisture in unsaturated zone.

The Spontaneous Potential has its main application in the study of flow behavior of subsurface waters. SP anomalies are generated by the fluid flow, heat or underground ions. Has shown satisfactory results when necessary to locate and delineate those streams and their associated sources (Gallas, 2000).

Nowadays, few studies use these methods with the objective of comparing the influence of arborous species in the saturated zone and unsaturated aquifer system. This study main objectivity is to investigate the changes that occur in the soil resistivity values before and after the cut of a eucalyptus plantation.

Therefore, in this study, the use of these two electrical methods is of extreme importance to understand how the aquifer is behaving, compare the indirect research data with the direct research and influence tree species that absorb significant amounts of water, such as eucalyptus, engaged in saturated and unsaturated zone of an aquifer system.

Method

The study area was defined into a few options because in Brazil is not usual cultivating eucalyptus in swallow areas. Most common is to cultivate this species on the top of hills, far from rivers, springs, lakes, etc.

The area, situated near Rio Claro city (Fig. 1) is covered with sand sediments of Rio Claro Formation (Fúlfaro & Suguio, 1968) with a high permeability coefficient, providing a rapid movement in subsurface of the groundwater.

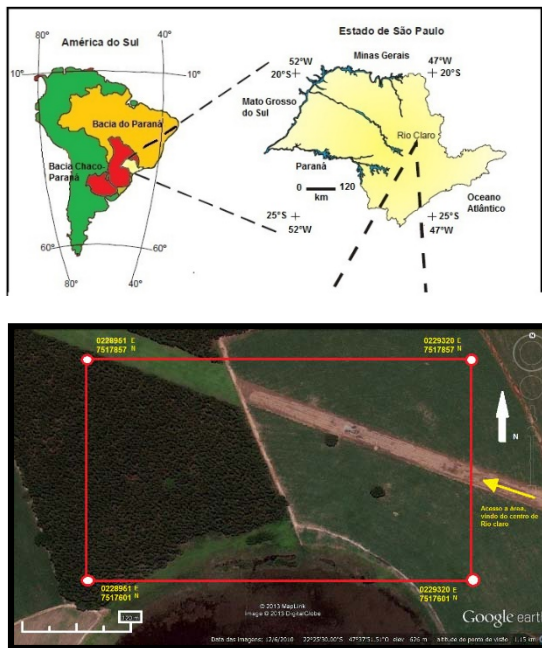


Figure 1 - Location of the area. Adensohn (2013).

The geophysical survey includes six electrical imaging profiles done in July and September of 2013,

respectively before and after the eucalyptus harvesting. The survey included also nine vertical electrical soundings (VES) which indicated the water table depth and helped the results interpretation of the electrical imaging and a self-potential survey (SP) also done. Figure 2 shows the location of the electrical imaging lines and VES.

Electrical imaging were performed using dipole-dipole array and electrode spacing of 5m to profiles 1, 2 and 3 and 2,5m to profiles 4, 5 and 6 due to available space. This arrangement allowed to investigate 10 levels resulting in 915 data for each section.



Figure 2 - Location geophysical survey.

VES survey was performed using $ab/2$ (maximum distance between electrodes) from 50m to 80m investigating more than 20m deep in some cases (Figure 3).

SP was done using a fixed base and taking measures each 10 meters along the same lines 1, 2 and 3 used

to electrical imaging.



Figure 3 – VES-9 survey.

Results

The roots of eucalyptus trees absorb greater quantities of water from the unsaturated zone, since most of its roots can be found in this portion. Thus, when active in this area, may be responsible for preventing the recharge of the aquifer if the quantity of rain is not greater than the demand of the trees.

With the eucalyptus harvesting we expected that the campaign held in September detected smaller resistivity values in surface levels with the increasing of soil moisture and allowing, to some extent, the recharge of the aquifer.

However, what we observed was increased resistivity in all lines, especially in the areas of eucalyptus

planting, which can be attributed to the low rainfall in the period between the campaigns, insufficient to modify substantially the local condition

An example with the results for L2 and L4 are shown on Figure 4 and 5.

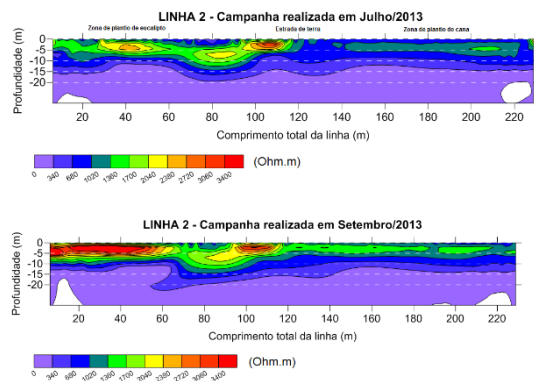


Figure 4 – Electrical Imaging for L2.

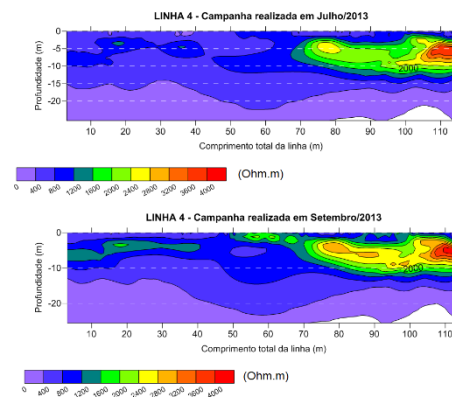


Figure 5 – Electrical Imaging for L4.

VES indicated with good precision the water level and it were made to check these results along the lines for electrical imaging the area. As an example (Figure 6) VES 10 indicates water level at 5,24m and a direct

measurement at monitoring well “O” show water level at 5,5m.

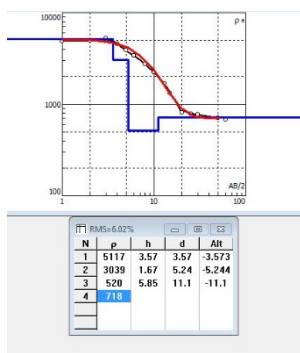


Figure 6 – VES 10 curve, next to monitoring well “O” and table with results.

Finally, SP survey (Figure 7) indicate that, in this aquifer system, the pond is influential in the aquifer recharge and not the opposite as expected, since the local topography decreases towards the lagoon, in this case, South. This result agrees with the measures carried out in monitoring wells in the area over the last two years.

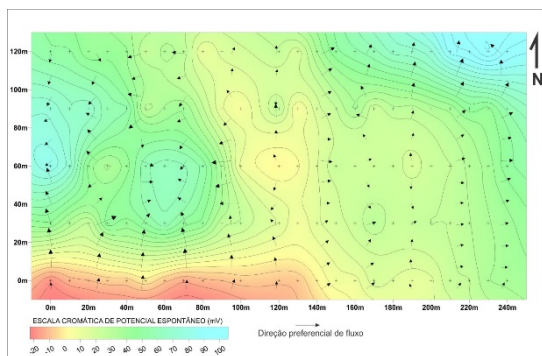


Figure 7 – Result map of SP survey with water flow interpolated directions.

Conclusions

A dry season, longer than expected, could have changed the results. The increase of resistivity instead of its decrease could be referenced to the hydric balance calculated in Adehnson (2013) with few rain after March of 2013 and hydric deficit from June to November of this year. SP survey proves that the water flow is from SW to NE or next to S to N what agrees with the measures carried out in monitoring wells in the area over the last two years.

A new survey that will be done at the end of March/2014 and it may show the increase of conductivity relationship to the expected water level elevation.

Continuing the project, we expect new surveys each three months until the end of 2014 to determinate a possible hydrogeological pattern with eucalyptus presence with the roots grow again.

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Soil properties of *Eucalyptus* forest and Sugarcane field in the State of São Paulo

S. TAKIZAWA, K. TAMURA, & N. TASE

Introduction

In many parts of the world, especially in Brazil, certain *Eucalyptus* species are grown commercially and managed in plantations. However, there have been several studies reporting environmental impacts of *Eucalyptus* plantation such as high rates of water and nutrition use, negative soil biochemical changes. On the other hand, southeast Brazil is also a major producing area of sugarcane along with the problem such as soil erosion and groundwater pollution by nitrate nitrogen from farmland. Based on environmental functions of *Eucalyptus*, sustainable crop production systems with coupling with *Eucalyptus* plantation were proposed. This study aimed to clarify soil physical and chemical properties under *Eucalyptus* plantation and sugarcane field and to evaluate the influence of crop producing

systems with coupling with *Eucalyptus* on soils. The study sites were Rio Claro and Mandacaru, São Paulo, where sugarcane field was located in the upper side and *Eucalyptus* was planted in the lower side.

Materials and Methods

In Rio Claro, soil surveys were conducted in 2 sites in the sugarcane field (RS1 and RS2) and 3 sites in the *Eucalyptus* plantation (RE3, RE4 and RE5), and in Mandacaru, soil surveys were conducted in the sugarcane field (MS) and in the *Eucalyptus* plantation (ME). Table 1 showed the chemical characteristics. Values of $\delta^{15}\text{N}$ were determined using IRMS, and it was carried out micromorphological observation (Bullock method) to evaluate structure of soil surface.

Horizon	Depth cm	pH(H ₂ O)	OC gkg ⁻¹	TN gkg ⁻¹	NO ₃ ⁻ mgN kg ⁻¹	Ex.Ca	Ex.Mg	Ex.K	Ex.Na	CEC
						cmol(+)-kg ⁻¹				
RS2										
Ap1	0-12	6.38	8.17	0.59	13.22	3.14	0.96	0.08	0.09	3.93
Ap2	12-28	6.29	7.88	0.58	7.75	1.64	0.57	0.07	0.08	3.24
AB	28-46	5.04	4.72	0.36	8.65	0.40	0.10	0.03	0.09	2.96
Bw1	46-71	4.84	4.16	0.30	3.63	0.18	0.05	0.02	0.04	2.39
Bw2	71-100+	4.87	4.42	0.37	16.80	0.30	0.08	0.03	0.07	2.15
RE3										
A1	0-13	4.76	11.71	0.85	32.15	0.52	0.20	0.07	0.07	4.04
A2	13-29	4.56	9.91	0.77	15.11	0.17	0.04	0.05	0.07	3.94
A3	29-54	4.72	8.24	0.59	3.67	0.06	0.02	0.05	0.09	4.15
A4	54-72	4.57	6.52	0.39	16.31	0.04	0.02	0.02	0.08	3.25
Bw	72-100+	4.60	4.00	0.28	12.32	0.04	0.02	0.02	0.06	3.10

Table 1 Chemical characteristics of the soils of RS2 and RE3

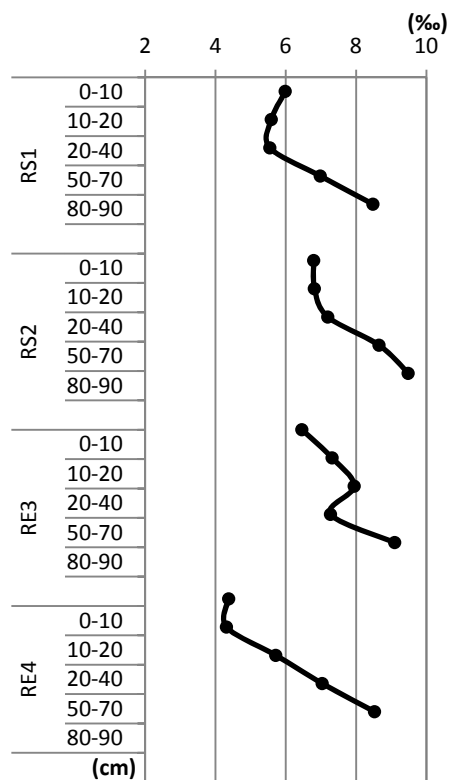


Fig. 1 Distribution of $\delta^{15}\text{N}$

Results and Discussion

Values of $\delta^{15}\text{N}$ ranged from 4.38 to 9.48 ‰, showing low values in surface soils and increases with soil depth (Fig. 1). In Rio Claro, $\delta^{15}\text{N}$ at surface of RE3 located at the end of plantation was close to the value of adjacent sugarcane field. It was suggested that runoff of nitrogen occurred from sugarcane field to *Eucalyptus* plantation with soil erosion.

Figure 2 showed the soil thin-section in Rio Claro. It was confirmed that aggregates consisted of coarse and fine material in the preparation of *Eucalyptus* plantation by direct observation of the preparation. In contrast, coarse material was uniformly distributed in the preparation of sugarcane field. It was

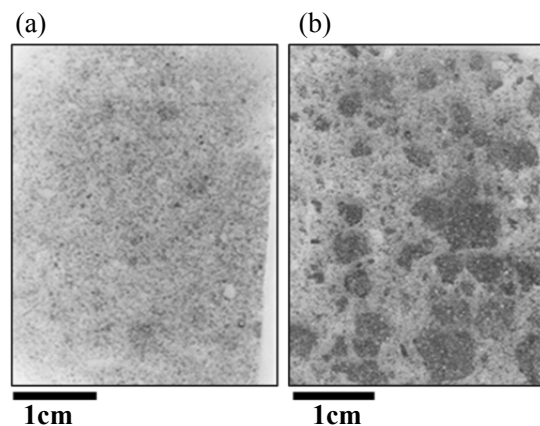


Fig. 2 Soil thin-section in Rio Claro (0-5cm)

(a) in sugarcane field

(b) in *Eucalyptus* plantation

feasible that elongated rootlets enhanced the resistance to water drop impact by binding the soil. Then, it had concluded that the forest aggregates had sufficient internal strength to resist the water drop impacts. Therefore, it was suggested that close-packed aggregates were strongly developed and erodibility was higher in *Eucalyptus* plantation because of elongated plant roots and organic matter.

Conclusion

It was indicated that the soils and nitrogen which ran off from the sugarcane field were trapped at *Eucalyptus* plantation because the soil structure was developed in *Eucalyptus* plantation. In other words, it was suggested that coupling *Eucalyptus* plantation in land-use sequences could be proposed as one of the measures to prevent soil erosion and nitrogen loss in runoff.

Water use by eucalyptus trees: climatic or root-morphological control?

T. YAMANAKA

Introduction

Eucalyptus species, which have naturally occurred in Australia, are now planted in many countries across a wide range of climatic conditions because of its high productivity and adaptability. There is a strong relationship between productivity and water use (Calder, 1992), so that transpiration rates from eucalyptus trees are generally high (Whitehead and Beadle, 2004). Currently, Brazil is the world's biggest country of eucalyptus plantations. Some environmentally-oriented non-governmental organizations have claimed that these plantations may dry out the soil and cause losses of biodiversity (Soares and Almeida, 2001). In reality, eucalyptus plantations in India have caused severe soil-drying because of transpiration losses greater than rainfall inputs (Calder et al., 1997). Therefore, many researches have been carried out for the water use by eucalyptus plantations over the world (Whitehead and Beadle, 2004). However, it is not yet well understood how geographic

difference in eucalyptus transpiration is arisen. One potential cause is climate, such as precipitation, available radiation, air aridity and their seasonality. Another is species-dependent root-morphology (i.e., deep rooting ability) through stomatal closure.

The objective of the present study is to reveal climatic and root-morphological controls of water use by eucalyptus plantations and their effect on soil hydrology.

Materials and methods

A soil-vegetation-atmosphere transfer (SVAT) model was employed for assessing effects of climatic and vegetation conditions on vertical water fluxes (i.e., transpiration, soil evaporation, interception and deep percolation) through eucalyptus plantations. In the model, a two-source (i.e., canopy and ground) energy balance model and a root water uptake model are combined. The model was validated using observation results reported by previous studies in five sites: western Australia, northern Australia, southern India,

northeastern South Africa and southeastern Brazil (Table 1).

Meteorological data (downward short-wave radiation, downward long-wave radiation, specific humidity, wind speed, air pressure,) as input to the model was obtained from NCEP/NCAR Reanalysis, while precipitation and air temperature data were from surface observation station via Global Surface Summary of the Day (GSOD). Standard relationship between stomatal resistance and environmental factors (i.e., photosynthetically active radiation, vapor pressure deficit, and predawn water potential) derived by Mielke et al. (1999) for *Eucalyptus grandis* plantation was used in the model. Root density profile data at each site was not available, so that an exponential function was assumed and its coefficient was determined so as to obtain better agreement between estimated and observed transpiration or evapotranspiration

rates. A constant soil-water potential was assigned as bottom boundary condition at the depth of 10 m. Water flux across the boundary corresponds to net groundwater recharge.

The model used can compute amount of root water uptake in each sub-layer with 0.2 m intervals. Using such data, flux-weighted mean depth of root water uptake was estimated.

Results and discussion

Good agreement between estimated and observed transpiration or evapotranspiration rates was found for all the sites. Annual total transpiration was highest in the northeastern South Africa site (1320 mm/yr) and lowest in the northern Australia site (610 mm/yr). Annual transpiration in each site has no significant correlation with solar radiation (correlation coefficient, $r = 0.09$) and weak negative correlation with

Table 1 Summary of study sites

Site	Latitude	Longitude	Species	Age	Reference
Western Australia	32 °41' S	116 °21' E	<i>E. marginata</i> <i>E. calophylla</i>	N/A	Silberstein et al. (2001)
Northern Australia	12°28' S	131 °05'E	<i>E. miniata</i> <i>E. tetradonta</i>	N/A	Cook et al. (1998)
Southern India	10 °41' N	76 °12' E	<i>E. tereticornis</i>	4	Kallarackal and Somen (1997)
Northeastern South Africa	24 °49' S	30 °43'E	<i>E. grandis</i>	5-6	Dye (1987)
Southeastern Brazil	21 °35' S	47 °36'W	<i>E. grandis</i> × <i>E. urophylla</i>	2-4	Cabral et al. (2010)

precipitation amount ($r = -0.45$), indicating that climate is not a dominant factor controlling transpiration from eucalyptus plantations. On the other hand, leaf area index (LAI) has strong positive correlation with transpiration ($r = 0.92$). This fact suggests that LAI is the dominant factor controlling transpiration rates. At the same time, large LAI may be maintained by high transpiration rates, because plant growth is linked to water use by plants (i.e., transpiration).

Net recharge was positive in western Australia, northern Australia and northeastern Brazil, while it was negative (i.e., water supply from the groundwater body or deep soils) in southern India and northeastern South Africa. Net recharge has strong negative correlation with evapotranspiration ($r = -0.92$) or transpiration ($r = -0.81$) and strong positive correlation with precipitation ($r = 0.82$). This is not surprising, because net recharge equals to precipitation minus evapotranspiration if water storage change is negligible. Net recharge has also negative correlation with mean depth of root water uptake, suggesting that deep rooting ability of some eucalyptus trees increases transpiration and decreases positive recharge.

In cases of northeastern South Africa and southern India sites, deep rooting ability enhances transpiration by consuming more water in deep soils and further strengthen these processes through increasing the growth rate and LAI. In other words, hydrologically active root-morphology, rather than climatic factors, seems to control water use by eucalyptus trees.

It is known that the root system of eucalyptus trees is generally dimorphic, comprising shallow lateral roots and deep sinker roots, and the latter is more developed as trees mature (Knight, 1999). In the present study, the difference in estimated root density profile among sites is not always species dependent, although age of planted trees explains the difference in part. Therefore, to avoid overexploitation of deep soil water or groundwater shortage, age of trees should be properly managed. On the other hand, this ability of water uptake from deep layers may be used for groundwater purification such as nitrate removals.

Conclusions

Dominant factors controlling water use by eucalyptus trees are neither solar radiation nor precipitation amount. Although the

most important, direct factor is LAI, deep rooting ability effectively enhance both transpiration and tree growth or productivity. The use of much water from deep layers has negative impacts on quantity of groundwater on one hand and positive impacts on quality of groundwater on another hand.

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

N. TASE, S. ONODERA, T. YAMANAKA, F. SARAIVA, R. TERADA,
R. HIRATA, R. SHIROTA, T. HOSONO & S.W. LEE

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.

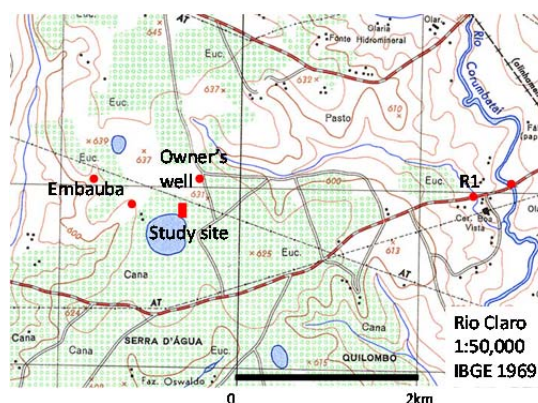


Fig. 1 Study area of Rio Claro
(Photo taken on Dec. 7, 2010)

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

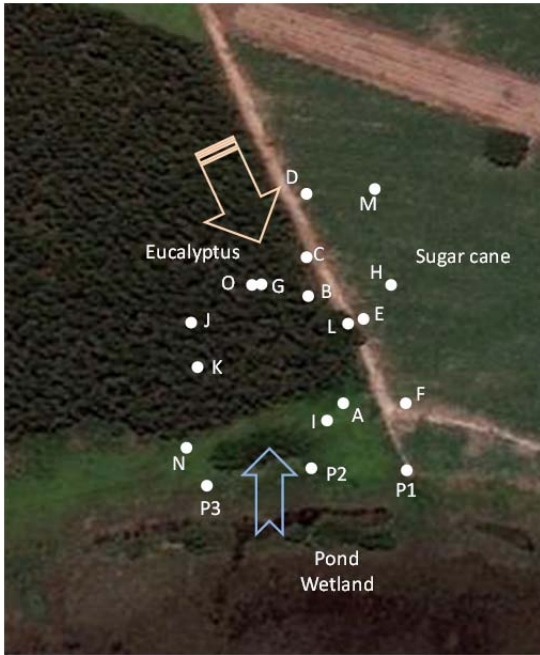


Fig. 2 Distribution of monitoring wells.

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.

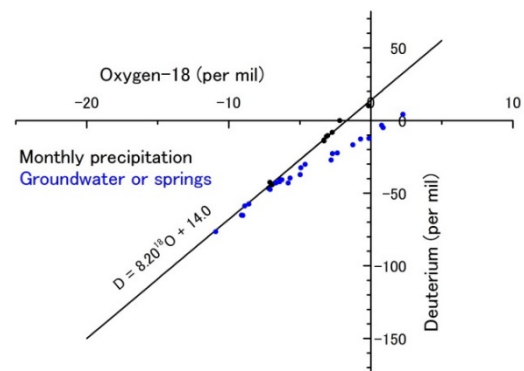


Fig. 3 Delta diagram of rainfall at Piracicaba and groundwater and pond water at the study site.

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 $13\mu\text{S}/\text{cm}$ and low nitrate concentrations of less than $2\text{mg}/\text{L}$. 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 $130\mu\text{S}/\text{cm}$ and NO_3^- of 1.95 and $2.17\text{ mg}/\text{L}$, 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.

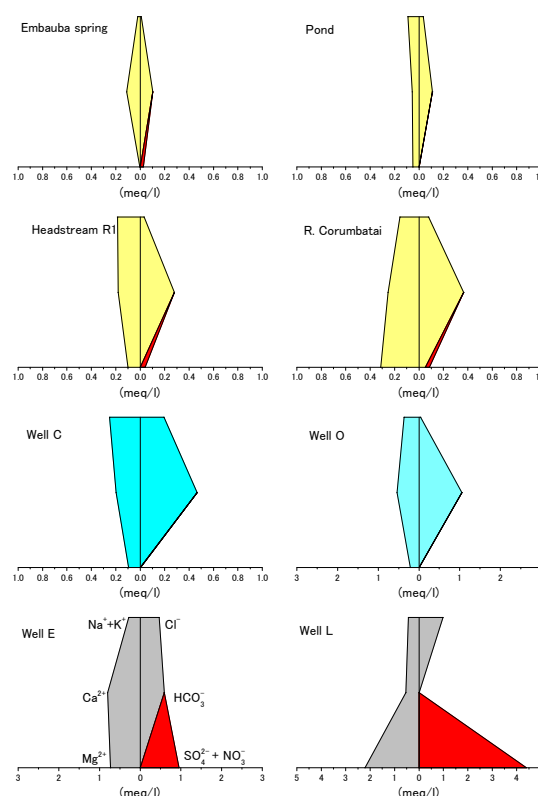


Fig. 4 Groundwater chemistry

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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Nutrient component of groundwater in agricultural land

S. Onodera, N. Tase, R. Terada, F. Saraiva, R. Hirata, M. Saito, Y. Maruyama

Introduction

Agricultural activities with applying much fertilizer have expanded nitrate contamination in the world. To conserve the watersheds environment, it is important to confirm the impacts of nitrate contamination and to manage the risk of its expansion. For example, the rapid increase of nitrate load by human activity causes the imbalanced nutrient components in ecosystems (Umezawa et al., 2009 etc.). Consequently, it would affect negatively the biodiversity, such as the eutrophication in aquatic environment and acidification of soil.

In case of Sao Paulo region in Brazil,

the large-scale agriculture is mainstream as US. Therefore, it is necessary to consider the its impact on nutrient components of groundwater in agricultural lands. We examined the nutrient componet in groundwater in an agricultural land.

Study area and water collection

The study site is located on Rio Claro, 35km north of Piracicaba, Sao Paulo State of Brazil (Fig.1). This area is mainly covered by sugar cane plantation and eucalyptus forest. The shallow groundwater flows in silty sand layers. The annual mean temperature and

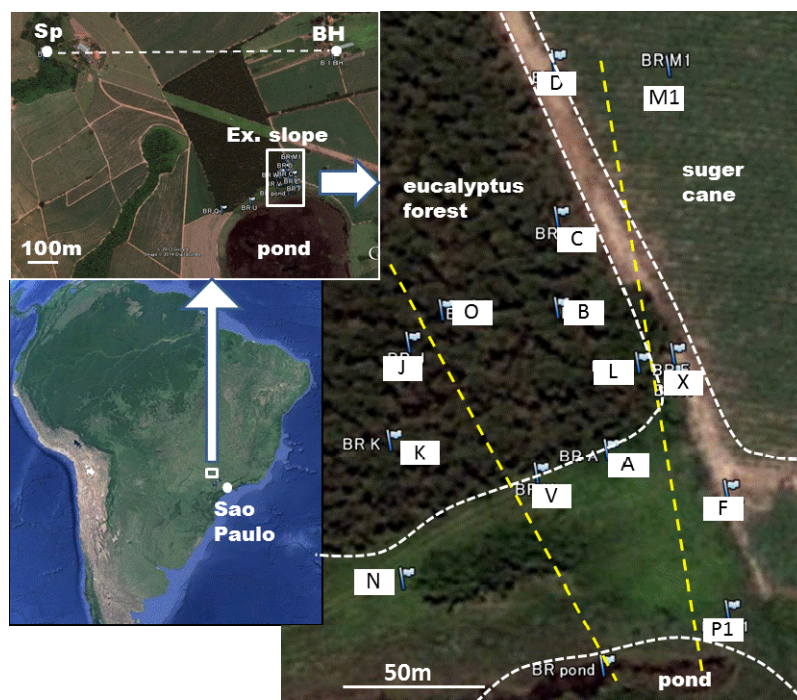


Figure 1 The location of study site

precipitation are 21.4°C and 1,279mm, respectively.

The many piezometers with the depth from 4m to 18m are installed in the experimental slope from the upland to the small pond with the altitude from 633m to 620m. Water samples were collected from some piezometers and one borehole, spring water and pond water in November 2012 and September 2013. Piezometric heads and EC, pH, DO and ORP values were measured in situ at all piezometers with water collections. After bringing back the samples to the laboratory under freezing condition, nutrients, inorganic ions and dissolved organic carbon (DOC) were analyzed by automated analyzer of photo-spectrometer, ion chromatography, ICP-AES analyzer, and TOC analyzer, respectively.

Results and discussion

1. Nutrient components

Figure 2 shows the nutrient components in collected water samples, which is the relationship between the NO_3^- -N and DOC-C and NH_4^+ -N (a), and PO_4^{2-} -P and Si (b), respectively. Nitrate (NO_3^- -N) was totally major form in the dissolved nitrogen, while ammonium (NH_4^+ -N) was higher than NO_3^- -N in a part of collected samples, such as pond water and deep groundwater near the pond. Phosphorus (PO_4^{2-} -P) was minor compared with the other nutrients and

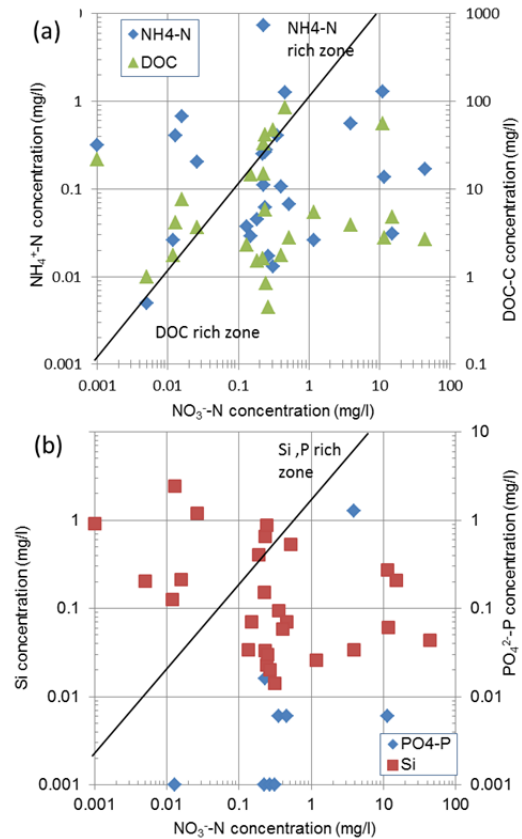


Figure 2 Nutrient components in collected water samples, the relationship between the NO_3^- -N and DOC-C and NH_4^+ -N (a), and PO_4^{2-} -P and Si (b).

was not detected in the most of samples. On the other hand, dissolved organic carbon (DOC) was mainly higher than the NO_3^- -N. Especially, it was hundred times higher in a part of the deep groundwater, spring and pond water. Silica (Si) was also higher than the NO_3^- -N in a part of deep groundwater in the forest. Increase of NO_3^- -N in groundwater around the agricultural land would be due to the fertilizer application. In addition, the high DOC concentration in the pond and groundwater around the pond would be contributed from the deposition of

sediment eroded and transported from the slope.

Table 1 Comparison of average nutrient components in the agricultural land in Brazil and Japan.

($\mu\text{M/l}$)	NH_4^+	NO_3^-	PO_4^{2-}	Si	DOC
Rio Claro, Brazil	37.3	242.2	1.58	11.6	1,175.3
Hiroshima, Japan	14.7	744.0	7.11	331.5	182.9

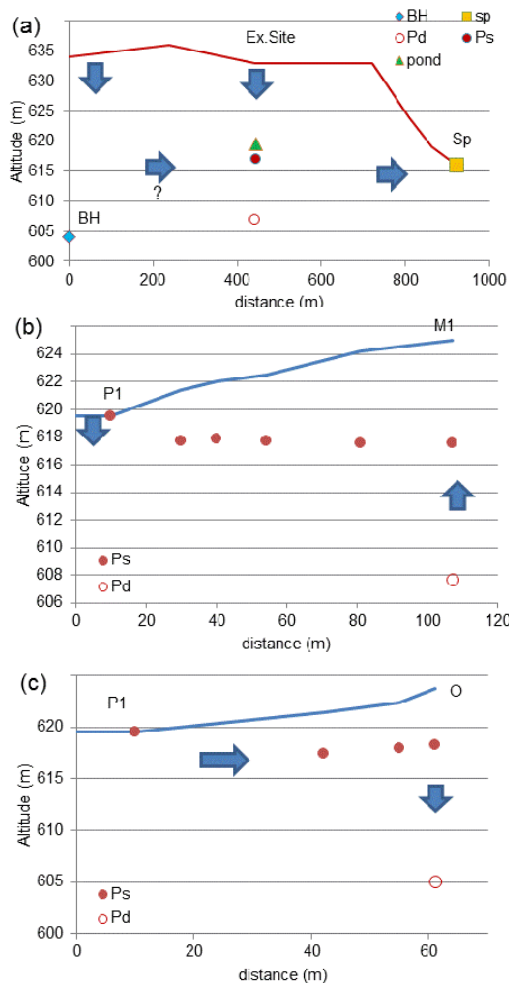


Figure 3 Schematic diagrams of groundwater flow direction in three cross sections on the lines in Fig.1, BH-Sp line (a), M1-P1 line (b), and O-P1 line.

Table 1 shows the comparison of average nutrient components in the

agricultural land in Brazil and Japan. The data in Brazil is based on Fig.2 and the values in Japan were summarized based on Onishi et al. (2014) and Saito and Onodera (2009). NO_3^- -N concentration in Brazil was lower than that in Japan, especially the PO_4^{2-} -P and Si was approximately one tenth lower in Brazil. On the other hand, the ratio of NH_4^+ -N to NO_3^- -N was higher in Brazil, while DOC concentration was tenfold of that in Japan.

2. Solute transport with water flow

Based on the measured water level data, groundwater flow directions were estimated as shown in Fig.3. There were flows from the central part of the upland to the spring at the slope foot in (a), and from the pond to the inside of the slope in (b) and (c) in Fig.3, according to the water level. The water flow with the inverse direction as compared with the slope would be caused by the large evapotranspiration of this vegetation. In the eucalyptus forest, the water head in deep groundwater was lower than that in shallow groundwater, and the flow direction was downward. The evapotranspiration in the forest was estimated to be larger than the other area.

Figure 4 shows relationships between the NO_3^- -N and aluminum (Al) (a) and the pH and NO_3^- -N (b) of groundwater. The values of the deep groundwater in a borehole and the spring water were

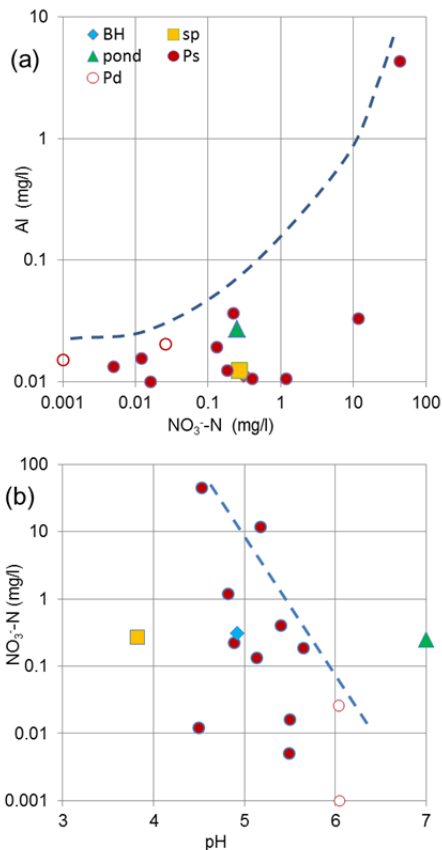


Figure 4 Relationship between the NO_3^- -N and Al (a) and the pH and NO_3^- -N (b) of groundwater.

plotted in this figure. Al concentration increased and the pH decreased with the increase of NO_3^- -N concentration. This means that acidifications occurred with the application of nitrogen fertilizer in an agricultural land. However, the DOC concentration was not related to the pH and Al concentration.

In the Fig. 4, the water of the spring and borehole were plotted on the central part. Though the NO_3^- -N and acid were supplied so much in an agricultural land, they didn't expanded. It is suggested that the denitrification process occurs actively due to the DOC supplied from the forested land and pond. In addition,

calcium (Ca) and magnesium (Mg) concentrations in groundwater were low as well as the high concentrations of acid and Al. Because of the tropical acid soil, the pH of water was also low.

Conclusion

In this study, we examined to confirm the nutrient components of groundwater in an agricultural land in Brazil. NO_3^- -N and DOC concentrations were high, as compared with the PO_4^{2-} -P and Si. It was suggested that the denitrification occurred actively due to the large supply of DOC from the forest and pond. In addition, the acidification of water was confirmed.

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Eucalyptus phytoremediation capacity to attenuate groundwater contamination by nitrate. Preliminary results from Rio Claro and Itatinga (São Paulo state, Brazil) study areas

R. TERADA, R. HIRATA, & F. SARAIVA

Brazil is the largest country forested in eucalyptus in the world. There are several studies reporting negative environmental impacts of eucalyptus plantation such as over-uptake of water and nutrition, biodiversity loss, volatilized or emitted harmful substances. However, few of these studies address the process of aquifer remediation contaminated by nitrate, especially with eucalyptus trees.

According to Cunningham (1996), phytoremediation is a process for cleaning contaminated soil, water and air that takes advantages of absorption properties of the plant. Phytoremediation offers a different way of looking at eucalyptus performance, one that focuses on nutrients and water uptake. Lima et al. (1996) compared the uptake of water between two species of high performances trees that live in Brazil, and found that eucalyptus is able to take up 1.5 times more water than the pines. Indeed the eucalyptus grows very rapidly, and as a consequence, it consumes a

high quantity of nutrients. Its roots are also an important part of this process, because they can reach several meters (>15mbs) searching for water, which is an extremely important characteristic to phytoremediation of aquifers.

Groundwater cleaning is not ordinarily undertaken because it is an expensive process. It usually takes a long time to clean and it is not totally efficient. The ion-nitrate is very mobile and persistent, but the main problem is the contaminant plumes generally are associated to diffuse or multipoint sources (urban areas or agricultural activities) creating large impacts.

In sum, there are several advantages to use phytoremediation to clean up aquifers, including: a) the retention of the contaminant for a long time in the structure of the tree; b) there is no requirement for outside energy, maintenance or structure; c) the ability to cover great areas with a group of plants; and, finally, d) social acceptance. The disadvantages are that it takes long time to remediate depending on

the plant and the process cannot remediate deep plumes due to physiological constraints.

Nitrate is a very common nutrient in groundwater. Many human activities can cause this problem, including leakages from mains sewerage and on site sanitation in cities, and also excess of fertilizers in agricultural activities.

Acute intoxication in humans is manifested primarily by methemoglobin formation. Nitrite ion in contact with RBC oxidizes ferrous iron in hemoglobin to the ferric state, forming stable methemoglobin incapable of oxygen transport, which results in anoxia. Secondary effects due to vasodilatory action of the nitrite ion on vascular smooth muscle may occur. The nitrite ion may also alter metabolic protein enzymes. Ingested nitrates may directly irritate gastrointestinal mucosa and produce abdominal pain and diarrhea (Merck 2014).

The main objective of the *Fitorem* project is to verify the efficiency of using eucalyptus as a remediating agent for groundwater impacted by nitrate. In addition, this project proposes a sustainable crop producing system coupling eucalyptus plantation in land-use

sequences, based on verifying environmental functions of eucalyptus, such as uptake of contaminated nitrate from groundwater.

Method

The first study site, Rio Claro, is located 180km NW of São Paulo city (SP), where sugar cane fields and eucalyptus forests are set out sequentially. The area is covered by silty sand layers on an undulating peneplain (Cenozoic Rio Claro Formation). The annual mean temperature is 21.4°C, and average annual precipitation is 1279mm. The stands of the eucalyptus were about 5 years old and their heights are around 15m until they were cut out in August 2013. Sets of monitoring wells with depths of 3m to 18m were installed, and groundwater chemistry is analyzed and water levels are surveyed regularly.

Itatinga is another study area that was chosen to evaluate the eucalyptus capacity to extract nitrate from a shallow and unconfined aquifer. The city is located approximately 250km west of São Paulo at USP Horto Florestal. This area is covered by Permian sandstone Piramboia Formation. The annual mean temperature is

20°C, and average annual precipitation is 1350 mm (similar to Rio Claro). The stands of the eucalyptus are about 3 years old and their heights are around 15m. Sets of 7 monitoring wells with at depths of 6m to 11m were installed.

In order to avoid the rainfall recharge as much as possible and permit that trees have full access to the groundwater, a plastic liner of approximately 400m² was installed (Fig. 1). A plume of contamination was artificially induced by injecting a solution of 150mg/L KNO₃ and 90mg/L NaCl in Itatinga. Water level and electric conductivity have been monitored since January 20th, 2014. This preliminary injection aims to obtain aquifer hydraulic parameters and help to develop the final experiment, which will occur in the near future. A flow and transport model (Modflow and MT3D) will be used to evaluate the performance of the extraction of nutrients by plants as well as determine the best distribution of trees to a more efficient remediation.

Previous Results

The potentiometric map of Rio Claro area indicates that the water flows to northwest, from the pond to the up topography.



Fig. 1. Picture of the liner covering the Itatinga study area.

Chemicals analysis of all the campaigns have shown average of 5,81mg·NO₃⁻/L. The average value below sugar was 2.29 mg/L and eucalyptus was 4.05 mg/L. The Piper diagram showed a Ca-HCO₃⁻ type of water, and the pHs have ranged between 4.5 and 7.5.

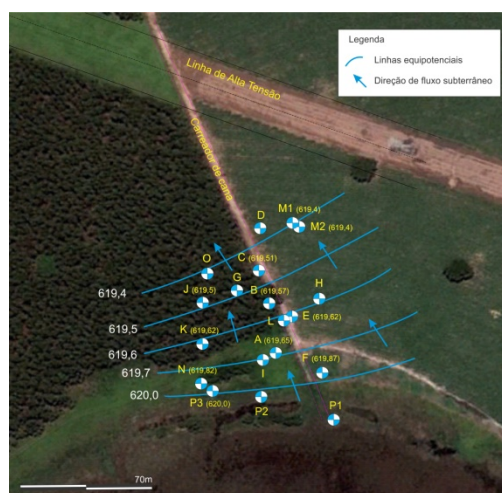


Fig. 2. Hydraulic head distribution in Rio Claro study area

After harvesting, new wells were drilled (Fig. 3) and the water level and electric conductivity have been monitored with a data logger device.

Closing remarks

—Brazil, an attractive country also for researchers—

World Cup in Brazil, and Olympic and Paralympic in Rio Janeiro are coming soon and we will become to know more about Brazil. Of course, fascination of Brazil is more than that. For instance, Brazil has a potential to be one of the richest countries in the near future, especially in the world agricultural sector. It is a pity that such an also academically interesting country is located on the opposite side of the earth. Personally I am interested in land use and agroforestry practices in the Amazon Basin, but the distance creates a disincentive for already aged researcher like me.

In 2008, I accompanied Prof. Tase's trip to São Paulo, where we attended the "Symposium Brazil-Japan: Contribution to the Agribusiness" organized by three State Universities of São Paulo, USP, UNESP, and UniCamp. That was the start of rebuilding academic collaboration between the University of São Paulo and the University of Tsukuba. For last five years, Prof. Tase has played the role of an engine for research activities in geo-science and agricultural science, and this workshop is one of the outcomes.

For this time it was our pleasure to have researchers from USP, and especially I am very glad to see Prof. Shirota and Prof. Hirata again.

In this workshop under collaboration between USP and Japanese universities, environment, water, and agriculture were the common issues, which are the key issues exactly in the global society. Eleven presentations of this workshop did not only provide scientific knowledge and information but also expressed important concerns on sustainable development.

In Brazil there are still many aspects and issues to be studied. Japanese viewpoints and experiences could throw some light on the solutions, and likewise Japanese could be learned from the practices in Brazilian. I think this workshop presents halfway mark to the goal, and the collaborative research will be continuously developed by every participant.

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