

# Nutrient transport from various agricultural sources in the Pagsanjan-Lumban watershed in Laguna de Bay, Philippines

Pearl Sanchez<sup>A</sup>, Hernan Castillo<sup>A</sup>, Rex Victor Cruz<sup>B</sup>, Rai Kookana<sup>C</sup> and Danni Oliver<sup>C</sup>

<sup>A</sup>Agricultural Systems Cluster, College of Agriculture, University of the Philippines Los Baños

<sup>B</sup>College of Forestry and Natural Resources, University of the Philippines Los Baños

<sup>C</sup>Centre for Environmental Contaminants Research, CSIRO Land and Water Urrbrae South Australia

## Abstract

The off-site transport of nutrients can have detrimental effects on waterways hence this study was conducted to monitor the sources and quantify the amount and form of transported nutrients in order to identify strategies that can minimise their impact. Four sites representing various land uses were selected and installed with automated water samplers and Odyssey water level loggers to measure water flow. Total suspended solids (TSS), total Kjeldahl nitrogen (TKN) and total phosphorus (TP) were determined in both unfiltered and filtered (<1.2 µm) samples. Agriculture is the major source of nitrogen (N) and phosphorus (P) transported in the Pagsanjan-Lumban watershed and the dominant land use upstream of the sampling sites greatly influenced the parameters measured. The effluent from the piggery farm had the highest TSS, TKN and TP concentrations. Among the cropped lands, higher concentrations of suspended sediments and nutrients were found in Pagsanjan (rice site). A positive linear relationship between TSS and TKN was noted in Pagsanjan and Lumban (vegetable site). The colloidal fraction dominated the transport process of N and P in the same sites. Nitrogen transport in Cavinti was mostly colloidal (>1.2 µm)-bound, although in some instances the soluble (<1.2 µm) fraction dominated. In Majayjay (piggery site), the soluble fraction dominated P transport.

## Key Words

Diffuse sources, dissolved N, dissolved P, sediment-bound N, sediment-bound P.

## Introduction

Laguna de Bay is one of the five largest lakes in Southeast Asia and is considered a very important natural resource in the Philippines. It occupies a total surface area of 900 km<sup>2</sup> with an average depth of 2.5 m and a maximum water holding capacity of about 2.9 billion m<sup>3</sup>. The catchments in the eastern bay of the lake are mainly agricultural and the water quality is relatively less polluted than the west and central bays. Water will be extracted from the eastern bay as a potable water supply for part of metro Manila so it is important to monitor the impact of agricultural activities on water quality in this part of the lake. Nitrogen (N) and phosphorus (P) are essential nutrients for plant growth and healthy waters. However enrichment of surface waters (e.g. rivers, lakes) with these nutrients can result in excessive algal growth and other potential problems. This study was conducted to monitor the off-site transport of nutrients and sediments in the Pagsanjan-Lumban watershed which is located in the southeastern part of Laguna de Bay and to identify management strategies that will minimise off-site contamination.

## Methods

### *The study area*

The Pagsanjan-Lumban watershed is one of the 22 major watersheds that drain to into Laguna de Bay. Four sites representing the major agricultural activities were selected and installed with automated water samplers (Figure 1). Cavinti is mostly grown to coconut and the autosampler was in Cavinti River which drains into Bonbongan River. Lucban is predominantly grown to vegetable with some rice and the autosampler was installed in Lucban River. Pagsanjan is a rice production area and the autosampler was in Salasad River. Majayjay is a piggery site and represents a point source of contamination. At Majayjay the effluent drains into the Initian creek which eventually drains to Balanac River. Autosamplers were also installed in two rivers (Balanac and Bonbongan) located at the northern end of the watershed and which drain into Laguna de Bay, to monitor nutrient and sediment levels transported into it from the Pagsanjan-Lumban watershed.

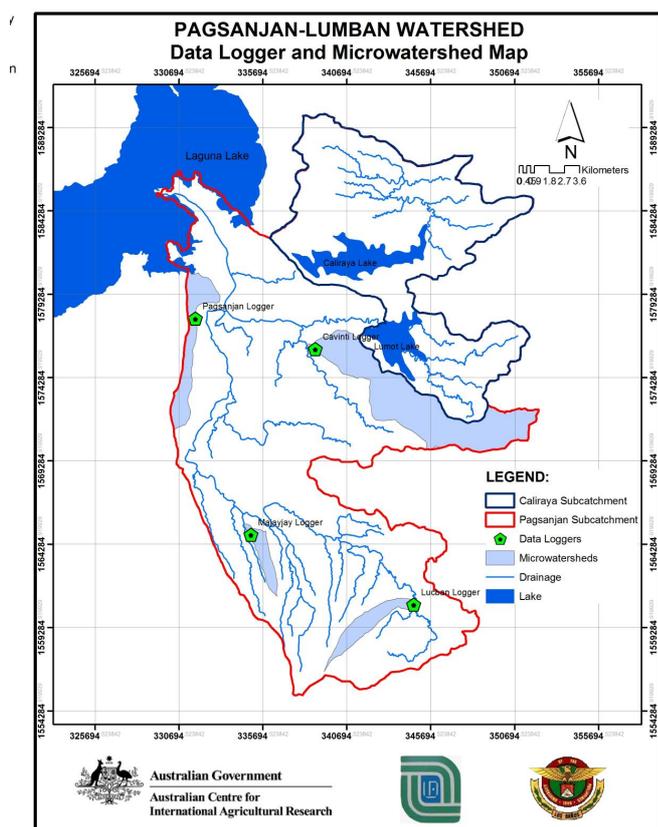


Figure 1. Pagsanjan-Lumban watershed map and location of automated water samplers and data loggers.

### *Sampling and laboratory analysis*

Water samples were collected every 6 hours during the day and the 7 samples each week were composited to provide one sample for the week. The daily water samples were stored at 4°C until they were composited and transported to the laboratory for analysis. Collection of water samples started in 2007 in Lucban and Cavinti while in Pagsanjan and Majayjay in 2008 and continued until 2009.

Total suspended solids (TSS) were measured by filtering a known volume of water through glass fibre filters (1.2 µm) that been conditioned by wetting with high quality water and drying at 40°C then weighed. The filter was then oven dried at 40°C and re-weighed and the mass of sediment in the known volume of water was determined. Total Kjeldahl nitrogen (TKN) was determined in both unfiltered and filtered (<1.2 µm) samples by digesting a known volume of sample in sulfuric acid with selenium mixture as a catalyst followed by colorimetric determination of ammonium using an autoanalyser. TKN in the filtered sample represented total dissolved nitrogen. The difference between TKN and total dissolved nitrogen was considered to be total colloidal (>1.2 µm) N. Total P (TP) was determined by digesting a known volume of sample with sulfuric acid and ammonium persulfate followed by colorimetric determinations. Total dissolved P and total colloidal P were calculated from P concentrations of the unfiltered and filtered samples.

## **Results and discussion**

### *Total suspended solids*

Cavinti had the lowest mean concentration of TSS (73 mg/L) throughout the monitoring period followed by Lucban (77 mg/L), Pagsanjan (399 mg/L) and Majajay (1716 mg/L) (Table 1). The predominant land use upstream of the sampling sites tended to influence TSS concentration particularly at Pagsanjan, Cavinti and Lucban. Pagsanjan, which is predominantly a rice production area, contributed more suspended solids as compared to Cavinti (coconut) and Lucban (vegetables). The rice areas were puddled and kept flooded most of the time and if proper soil and water management practices are not in place, large amounts of sediments may leave the rice fields with the irrigation water. Very high TSS concentrations were recorded in Majajay because of the piggery effluents draining straight into Initian Creek.

**Table 1. Total suspended sediments, total kjeldahl nitrogen and total P data in all sites.**

Site	Total suspended solids (mg/L)			Total Kjeldahl N (mg/L)			Total P (mg/L)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Cavinti	6	544	73	0.01	2.43	0.59	0.003	0.693	0.106
Lucban	13	312	77	0.01	3.15	1.01	0.003	2.236	0.292
Majayjay	12	7728	1716	0.33	135.00	67.9	0.180	132.570	23.920
Pagsanjan	81	2936	399	0.25	9.63	1.62	0.020	2.432	0.537
Balanac	2	29	11	0.23	1.53	0.54	0.018	0.345	0.015
Bonbongan	3	124	24	0.01	1.08	0.44	0.016	0.314	0.110

#### Total Kjeldahl N

The trend in TKN is similar to TSS with Cavinti having the lowest mean concentration (0.59 mg/L) and Majayjay, the highest mean concentration (67.9 mg/L) (Table 1). Rice growers in Pagsanjan use higher rates of N fertilizers which resulted in higher TKN concentrations when compared to Lucban (vegetable) and Cavinti (coconut). An additional source of N in Pagsanjan can be domestic waste. In Majayjay, very high TKN concentrations were recorded because of the manure, urine and excess feed in the effluents. The mean TKN concentrations in all the sites were higher than the eutrophication threshold of 0.5 to 1.0 mg/L (Pierzynski *et al.* 2005). In a summary provided by Zafaralla *et al.* (2005), a mean TKN concentration of 1.10 mg/L was recorded in the eastern bay of the lake from 1990 to 1999. The mean TKN mean concentrations in Balanac and Bonbongan, which drain into Laguna de Bay, are lower compared to the four sites located further upstream in the watershed suggesting that there is dilution of contaminants.

In addition to land use, TKN appeared to be influenced by TSS particularly in Pagsanjan where a linear relationship ( $r^2 = 0.94$ ) was obtained in 2008 and in Lucban ( $r^2 = 0.62$ ) in 2007. In the other sites and at different sampling periods, the relationship between TKN and TSS was not as obvious. In Lucban, Pagsanjan and Majayjay, nitrogen moved predominantly off-site in association with the colloidal ( $>1.2 \mu\text{m}$ ) fraction but in Cavinti, N was transported both as sediment ( $>1.2 \mu\text{m}$ )-bound and in the dissolved ( $<1.2 \mu\text{m}$ ) fraction.

#### Total phosphorus

The trend in TP was also similar to TSS and TKN and average concentrations over the sampling period was: Cavinti (0.106 mg/L) > Lucban (0.292 mg/L) > Pagsanjan (0.537 mg/L) > Majayjay (23.92 mg/L) (Table 1). Except in Balanac, mean TP concentrations exceeded eutrophication threshold of 0.02 to 0.1 mg/L (Pierzynski *et al.* 2005). Assessment of water quality in the eastern bay of the Lake from 1990 to 1999 gave a mean TP concentration of 0.23 mg/L (Zafaralla *et al.* 2005). Higher P applications in the rice growing areas contributed to higher P concentrations in Pagsanjan. Higher TSS concentration also increased P concentration as a large proportion of total P transported off-site associated with colloids ( $>1.2 \mu\text{m}$ ). Total P in Lucban, Cavinti and Pagsanjan was dominated by the colloidal ( $>1.2 \mu\text{m}$ ) fraction while in Majayjay, the soluble ( $<1.2 \mu\text{m}$ ) fraction dominated off-site transport.

#### Conclusion

Higher TSS, TKN and TP concentrations occurred in Pagsanjan, where rice production is the major agricultural activity compared with concentrations in sub-catchments dominated by vegetable (Lucban) or coconut (Cavinti) production. Total suspended solids, TKN and TP concentrations were extremely high in effluents draining from piggery farms and Majayjay is a major point source of contamination in the catchment. The colloidal ( $>1.2 \mu\text{m}$ ) fraction dominated the transport of N and P in Lucban and Pagsanjan but in Cavinti N transport was dominated by soluble ( $<1.2 \mu\text{m}$ ) fraction. In Majayjay, the soluble fraction ( $<1.2 \mu\text{m}$ ) dominated transport of TP. These results suggest that higher nutrient concentrations occur in surface drainage water in areas with greater fertilizer inputs and if proper soil, water and piggery effluent management practices are not implemented, large amounts of sediments and nutrients can be transported off-site into waterways.

#### Acknowledgement

This study is part of a joint project between University of the Philippines Los Banos (UPLB), Laguna Lake Development Authority (LLDA) and CSIRO funded by the Australian Centre for International Agricultural Research (ACIAR). The technical assistance of Dr Jim Cox and Mr Nigel Fleming of SARDI in site selection and setting up the autosamplers and data loggers is gratefully acknowledged as is the assistance of Mr Michael Pillas in providing the watershed map.

## References

- Pierzynski GM, Thomas Sims J, Vance GF (2005) 'Soils and Environmental Quality. 3<sup>rd</sup> edition'. (CRC Press: Boca Raton FL, USA).
- Zafaralla MT, Barril CR, Santos-Borja AC, Manalili EV, Dizon, JT, Sta Ana JG, Aguilar NO (2005) Water Resources. In 'Ecosystems and People, The Philippine Millennium Ecosystem Assessment, Sub-global assessment (Eds RD Lasco, MVO Espaldon) pp. 61-114. (EFP: CFNR, UPLB).