International Journal of GEOMATE, March., 2021, Vol.20, Issue 79, pp. 9-15
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2021.79.6165
Geotechnique, Construction Materials and Environment

NITROGEN FLOW ANALYSIS FROM DIFFERENT LAND-USE OF THE CHI RIVER BASIN (MAHA SARAKHAM REGION, THAILAND)

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*Corresponding Author, Received: 03 Nov. 2020, Revised: 12 Jan. 2021, Accepted: 27 Jan. 2021

ABSTRACT: This paper aims at assessing the effect of land use on nitrogen flows from a significant land-use area in the Chi River basin (Maha Sarakham region) in Thailand. The Chi River is one of the main rivers, and many land use categories affect the quality of the river. Statistical data and referred data was collected as the secondary data from credible sources to identify the flows. The data show a strong effect of land use on nitrogen with the highest load dominated by paddy field (66,597.51 tonne/year), and the lowest value in the community (1,005.71 tonne/year). Nitrogen flow increased with the fertilizer application in paddy field and farm plants (34,834.07 tonne/year). Paddy field discharged nitrogen to the Chi River 47 tonne/year in form of surface runoff. Also, the community without wastewater collection system takes part in a non-point source (NPS) of nitrogen to the Chi River at 299 tonne/year. The management's suggestion is to control fertilizer application, burning of agricultural residue such as rice straw, and wastewater treatment before disposal.

Keywords: Nitrogen; Chi River; Substance Flow Analysis (SFA); Land-Use

1. INTRODUCTION

Pollution from natural phenomena or human activities and living things actions affects water quality in any water resource. Water quality disturbs the environment, natural resources, human activities, and human health [1, 2]. Pollution can be categorized into point source (PS) and non-point source (NPS) pollution. PS pollution mainly comprises of industrial and domestic wastewater loads, which can be identified through the discharging point or pipe [3]. NPS pollution usually comes from unidentified sources, such as agriculture land, street runoff, and the deposition of atmospheric pollutants [4]. The pattern of NPS pollution leads to the effect of land use on water quality.

Nutrient load is one of significant problems for water resource management, the interaction of nutrient, water and pathways has been traced and tracked by much research in the past. Nutrient load in water is a result of several interacting processes in the basin, including an exchange between cycles in the terrestrial, aquatic, geological, and atmospheric environment. These processes can be characterized into: (1) nutrient release (e.g., through mineralization, weathering, fertilization, atmospheric deposition, sewage effluents); (2) water transport (conducting, e.g., transit time and flow paths); and (3) transformation and immobilization (e.g., denitrification, sedimentation, and adsorption).

Nutrient problems can be magnified by the improper land-use that discharges nutrients to water bodies [5, 6]. Concentrated agricultural activities and rapid urbanization created immense pressure on water quality. The percentage of agricultural land is significantly positive correlated with water pollution due to fertilizer application entering surface water through runoff [7].

Urbanization is associated with changes in land- uses through infrastructure development, population density, and community. The increase in impervious areas (i.e., roads, rooftops, impermeable pavement, and parking lots) results in NPS pollution increase in runoff and transportation of NPS pollutants to receiving waters [8]. The Forest area was considered as net sinks of nitrate [9]. Land-use category is relevant to water quality within a watershed, and landscape alignments may be more sensitive predictors of water quality.

The Chi River is the longest river in Thailand. It is 765 km long. In wet seasons there are often flash floods in the floodplain of the Chi River basin. The river originates in the Phetchabun mountains and then flows to the east part through the central Isan provinces of Chaiyaphum, Khon Kaen, and Maha Sarakham, then turns south in Roi Et and runs through Yasothon and joins the Mun River in the Kanthararom district of Sisaket Province. The Chi River carries approximately 9.3 km^3 of water per annum [10]

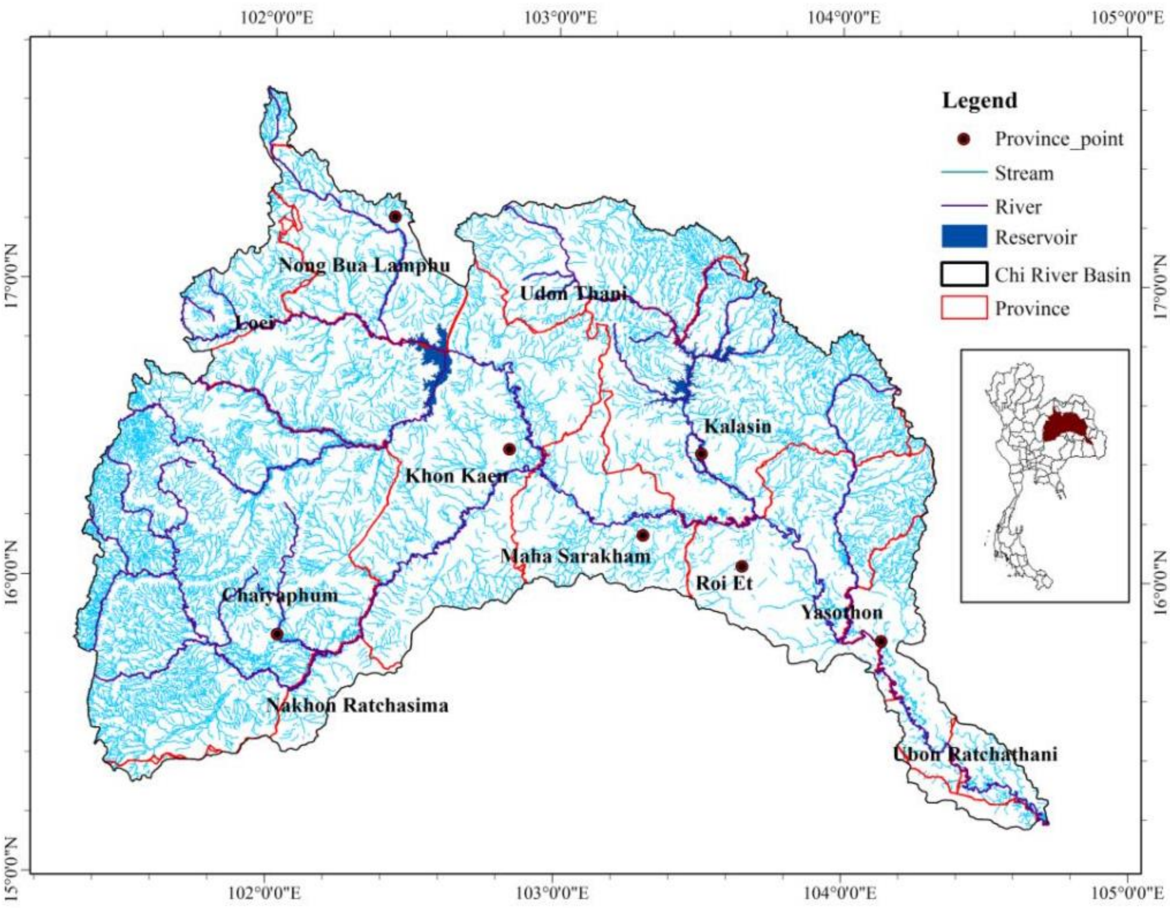

Fig.1 Chi River Basin [12]

Substance Flow Analysis (SFA) is an environmental accounting tool used to trace and track environmental problems. SFA is an appropriate method to answer the questions of substance flows from input transformation processes until discharging in system boundary [11]. Therefore, this study aimed to analyze nitrogen flows by SFA quantitatively, and propose implemented solutions in the system boundary.

2. METHODOLOGY

2.1 Substance Flow Analysis (SFA)

Substance Flow Analysis (SFA) is an environmental accounting tool based on the concept of mass balance in a specific area and time. SFA for nitrogen provides a systematic assessment of flows and stocks within a defined system in space and time. It was undertaken to quantify nitrogen flows from different land-use area (as a process) in the Chi river basin (Maha Sarakham region).

2.2 System Boundary

The Chi river basin covers the middle part of the northeastern region (Fig.1). The area of the basin in Maha Sarakham province was selected to be the specific system boundary (Fig 2) Maha Sarakham is the fast-growing city located along the Chi River. It has undergone rapid urbanization. Chi River is used as a water resource of tap water supply, agriculture and fishery.

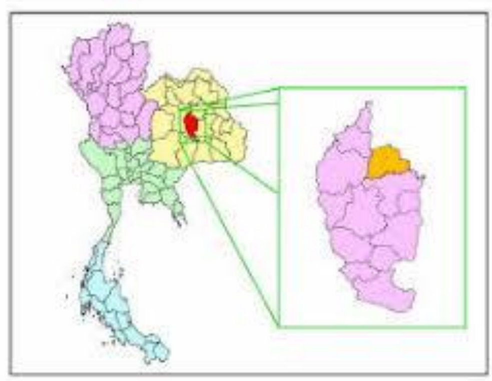

Fig. 2 Maha Sarakham province Location [13]

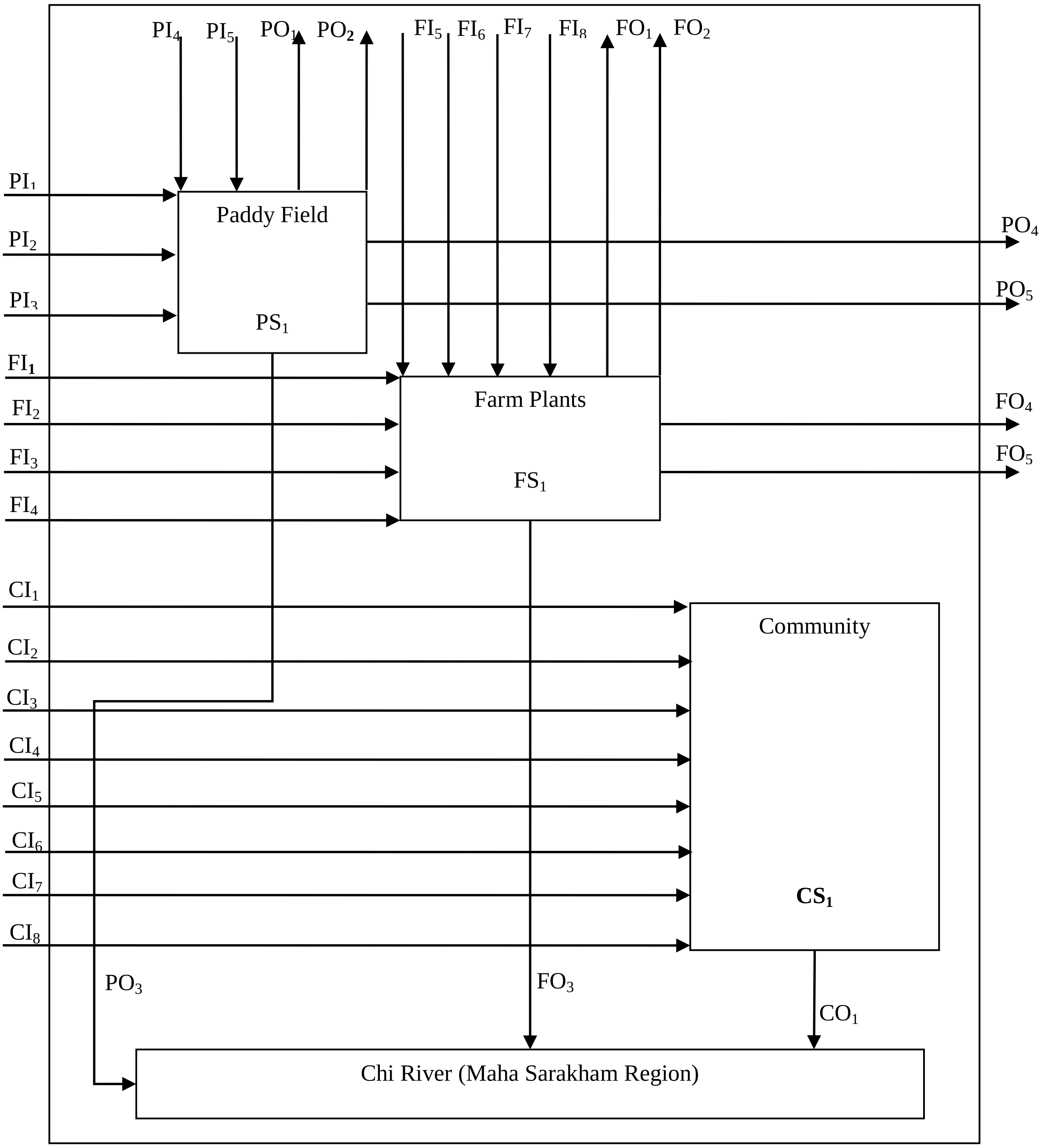

Fig.3 Nitrogen flows

The Chi River basin area is 53.18% of Maha Sarakham province which was 2,998 km^2. The land-use area in the system boundary was categorized into community along the Chi River 6.83% (205 km^2), agriculture 82.88% (2,484 km^2), forestry 3.94% (118 km^2) and miscellaneous 2.63% (79 km^2). The activities that have an impact on the Chi River were only community and agriculture along the Chi River. The major agriculture included paddy field 62.17% (1,864 km^2), corn 0.01% (0.3 km^2) and cassava 11.28% (338 km^2). The period of data collection was in the year of 2018 (one year period).

2.3 Data Collection

Nitrogen flows in the system boundary were traced to define quantity and pathway through relevant processes until discharge to the environment. The nitrogen flow diagram of the system boundary is shown in Fig 3.

In order to know the nitrogen flows through the various land use categories, secondary data was obtained from official reports by related organizations and relevant literature review [14-29]. Details of data acquisition were described as follows:

2.1.1 Statistical Data

Official reports from governmental organizations such as Department of Land Development, National Statistical Office, Department of Irrigation, and Office of Regional Environment.

2.1.1 Reference Data

Due to unavailable data in the system boundary, secondary data (nitrogen concentrations) was obtained from a nearby area, which has similar management based on literature review was applied to the nitrogen flows.

2.3 Calculation

The calculations basically multiplied the flows (which is recognized as activity) of input, output, and stock of each land-use area in the system boundary with their nitrogen concentration ([N], mg N/L). Finally, the results of nitrogen flows were shown in the unit of tonne N/year. Nitrogen flows were calculated based on mass balance over the processes. Determination methods for nitrogen flows were summarized in Tables 1-3.

Table 1 Data acquisition and calculation for paddy field

Flows	Material	Calculation
Input	Fertiliser (PI_1)	N in fertilizer × area × loops
	Irrigation (PI_2)	N in irrigated water × area × water consumption × days
	Rain water (PI_3)	N in rainwater × area × loops
	Seed (PI_4)	N in seed × area × loops
	Atmospheric fixation (PI_5)	N in atm × area × loops
Output	Burning (PO_1)	N in input × % burning
	Evaporation (PO_2)	N in input × % evaporation
	Surface runoff (PO_3)	N in input × % burning
	Rice production (PO_4)	N in rice × area
	Rice straw (PO_5)	N in rice straw × area × rice straw
Stock	Infiltration (PS_1)	N in input × % infiltration

Table 2 Data acquisition and calculation for farm plants

Flows	Material	Calculation
Input	Fertiliser corn (FI_1)	% N in fertilizer × area × fertilizer consumption × loops
	Fertiliser cassava (FI_2)	% N in fertilizer × area × fertilizer consumption × loops
	Irrigation corn (FI_3)	N in irrigated water × area × water consumption × loops
	Irrigation cassava (FI_4)	N in irrigated water × area × water consumption × loops
	Rain water corn (FI_5)	N in rainwater × area
	Rain water corn (FI_6)	N in rainwater × area
	Atmospheric fixation corn (FI_7)	N in atm × area × loops
	Atmospheric fixation cassava (FI_8)	N in atm × area × loops
Output	Burning (FO_1)	N in input × % burning
	Evaporation (FO_2)	N in input × % evaporation
	Surface runoff (FO_3)	N in input × factor of runoff
	Corn production (FO_4)	N in corn x area × loops
	Cassava production (FO_5)	N in cassava × area × loops
Stock	Infiltration (FS_1)	N in input × % infiltration

Table 3 Data acquisition and calculation for community

Flows	Material	Calculation
Input	Water supply (CI_1)	N in water supply × water consumption × population
	Rice consumption (CI_2)	N in rice × consumption × population
	Beef consumption (CI_3)	N in beef × consumption × population
	Pork consumption (CI_4)	N in pork × consumption × population

Table 3 continue

	Chicken consumption (CI_5)	N in chicken × consumption × population
	Milk consumption (CI_6)	N in milk × consumption × population
	Egg consumption (CI_7)	N in egg × consumption × population
	Fresh water animals consumption (CI_8)	N in fresh water animals × consumption × population
Output	Wastewater (CO_1)	N in wastewater × wastewater generation rate × population
Stock	Infiltration (CS_1)	N in input × % stock

3. RESULTS AND DISCUSSION

3.1 SFA of the Current Situation (2018)

Three processes included in the system boundary were traced to the nitrogen flow and calculated the flows as detailed in the previous section. The results from each process are shown in Tables 4-6 as follows.

Table 4 Nitrogen flows in paddy field process

Flows	Material	Flows (Ton/year)
Input	Fertilizer	32,611
	Irrigation	0.11
	Rainwater	1.4
	Seed	18,588
	Atmospheric fixation	15,397
Output	Burning	5,228
	Evaporation	799
	Surface runoff	47
	Rice production	21,524
	Rice straw	14,629
Stock	Infiltration	1,590

From the calculation above, it showed that the nitrogen flows in the input depend on the activity in paddy field and vary to the area. The major input was fertilizer application, seed and naturally atmospheric fixation. These input flows were then transformed to the composition of rice and straw as the output flows. Therefore, the stock (infiltration) had little flow comparing to the output (rice production and straw). It also indicated the output flow in form of surface runoff was the lowest flow.

Table 5 Nitrogen flows in farm plant process

Flows	Material	Flows (Ton/year)
Input	Fertilizer corn	4.21
	Fertiliser cassava	2218.86
	Irrigation corn	0.25
	Irrigation cassava	291.62
	Rain water corn	0.17
	Rain water corn	196.53
	Atmospheric fixation corn	0.24
	Atmospheric fixation cassava	84.52
Output	Burning	214.20
	Evaporation	68.23
	Surface runoff	1.96
	Corn production	10.92
	Cassava production	3,943.23
Stock	Infiltration	279.64

The results of farm plant process had the same trend as the paddy field process. The nitrogen flows in the input depend on the activity in paddy field and vary to the area. The major input was fertilizer application for cassava production as the cassava is the main farm plant in the system boundary. The major output flow was the cassava product.

Table 6 Nitrogen flows in community process

Flows	Material	Flows (Ton/year)
Input	Water supply	10.10
	Rice consumption	510.84
	Beef consumption	22.69
	Pork consumption	32.68
	Chicken consumption	142.70
	Milk consumption	7.74
	Egg consumption	41.18
	Fresh water animals consumption	237.78
Output	Wastewater	299.09
Stock	Infiltration	100.57

The activities in the community process included typical food consumption, water supply and wastewater generation. Therefore, the population affected the amount of flows. In the system boundary, there were population of 256,074 people. Moreover, the latent population of 30,000 people were the students in Mahasarakham University living in the dormitories located in the community. The old houses and dormitories did not have septic tank. This was the main nitrogen in the output flow to the Chi River.

3.2 Overall Discussion

The calculation of the flows was done to compare to the calculation above. It was found that the paddy field had over the inflow of 66,597.51 tonne/year. This amount of nitrogen input could be transformed to rice and straw and adsorbed to the soil, whereas the farm had lower input flow than output flow and stock. This could have resulted from mechanisms of cassava planting. The modeled consumption of the community roughly showed that the input was more than stock and output.

The major input flow of nitrogen into the system boundary was from the paddy field, which was similar to research done in China [4,7]. People living the Chi river basin were mostly farmers and reach irrigation during drought season and plentiful rainwater in the rainy season. Therefore, farmers in the system boundary planted rice all year round and leaded to high nitrogen input flow. However, people who live far from the Chi River but still in the range of the catchment plants corn and cassava, which were the primary farm plants in the northeastern region. Therefore the main land-use area, affecting the nitrogen input in agriculture. The nitrogen flow from the community affected the Chi River due to a non-point source of wastewater discharge. Therefore the suggestion was to control the fertilizer application in the paddy field and burning of agricultural residue. Community should reduce the flow of wastewater discharging into the river by installing wastewater treatment unit.

4. CONCLUSION

Land-use area and activities influence the flow of nitrogen into the Chi River according to the application of fertilizer and other post-harvesting activities. The communities along the Chi River also take responsibility for NPS of nitrogen in terms of wastewater discharge. The strategy could apply to agriculture management and wastewater collection and treatment.

5. ACKNOWLEDGMENTS

This research was financially supported by Mahasarakham University (Grant Year 2019) and Faculty of Engineering, Mahasarakham University.

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