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Original Research Paper

Assessing Agricultural Non-point Source Pollution Load of Nitrogen and Phosphorus in Hangzhou, China

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ABSTRACT

Agricultural non-point source pollution is important environmental problem in China. In this study, the export coefficient model is applied to assess the agricultural non-point source pollution load of total nitrogen (TN) and total phosphorus (TP) based on the main pollution sources. The results showed that the agricultural non-point source pollution load of TN in Hangzhou was 18166t, and the TN load exported from animal husbandry accounted for the highest share. The agricultural non-point source pollution load of TP was 1668t, and the TP load exported from rural living accounted for the highest share. Then the spatial distribution of TN load and TP load was analysed. It revealed that the minimum TN load and TP load existed in central district in Hangzhou. The maximum TN load and TP load existed in Xiaoshan, Yuhang and Fuyang which surrounded the central district. The TN load and TP load in Chun'an, Jiande and Lin'an had a close relationship with local ecological protection and landforms. This assessment will offer effective support to policy makers for reducing TN load and TP load.

INTRODUCTION

Agricultural non-point source pollution is an important environmental problem in China (Guo et al. 2014, Kouhsari & Nagaraju 2015). Since the intensive farming practices and a great rise in the production of live stocks which are adopted widely in rural regions to produce more agricultural production and improve farms' living (Shen et al. 2013, You 2015), the pollutants exported from agricultural non-point source pollution rise sharply (Sun et al. 2012, Buckley & Carney 2013). It is a phenomenon that the excessive inputs of nitrogen (N) and phosphorus (P) in water from agricultural non-point pollution sources cause eutrophication in China (Domagalski et al. 2007, Jin et al. 2005). Therefore this study calculates the TN load and TP load exported from agricultural non-point pollution sources to analyse the level of agricultural non-point pollution.

The export coefficient model is widely used to assess the non-point pollution load for its ease of application (Ding et al. 2010, Mattikalli & Richards 1996). The export coefficient model whose procedures include, model construction, export coefficient selection and model validation aims to calculate the non-point pollution load based on the sum of the pollution discharge quantity from different pollution sources (Johnes 1996). Therefore, the export coefficient model is applied in this study to assess the TN load and TP load exported from agricultural non-point pollution sources.

MATERIALS AND METHODS

Johnes (1996) put forward the export coefficient model for assessing agricultural non-point source pollution load of TN and TP based on the main sources of N and P. The equation is defined as follows:

$$L_j = \sum_{i=1}^{m} E_{ij} A_i + Z_j \quad ...(1)$$

where, L_j is the emission of pollutant j; i is the pollution source i; A_i is the land area, or number of livestocks, or of farmers; E_{ij} is the export coefficient of pollution source i for pollutant j; Z_j is input of pollutant from precipitation, and it is small enough to be neglected in this study.

The agricultural non-point source pollution comes from many different sources. The land use, animal husbandry (including livestocks and fowls) and rural living are considered as the main pollution sources of agricultural non-point source pollution (Johnes 1996a, Johnes et al. 1996b, Guo et al. 2014). According to previous studies (Wesström et al. 2014, Liu et al. 2012, Ma et al. 2011, Zhou et al. 2014, Ma et al. 2012), the land use types that were selected to assess agricultural non-point source pollution included paddy land, dry land and orchard land. The animal husbandry included pigs, cattle, sheep and fowls. The export coefficients indicate the rates of N or P exported from pollution sources. The export coefficients selected in this study and their sources

Fig. 1: Location of Hangzhou, China

are presented in Table 1.

CASE STUDY

Study area: Hangzhou, the capital of Zhejiang province in eastern China, is the local political, economic and cultural center (Fig. 1). Hangzhou is described as a land flowing with milk and honey since it is endowed with mild temperature and sunlight as well as plentiful rain. Though the farmers and local economy benefit from high agricultural productivity in Hangzhou, the agricultural non-point source pollution from intensive farming and animal husbandry poses a serious threat to the environment. Therefore, Hangzhou is selected as an empirical case for analysing agricultural non-point source pollution load.

Data gathering: The data in 2011 of 5 indicators including, pig, cattle, sheep, fowl and rural population can be found in Hangzhou Statistical Yearbook 2012. The data in 2011 of paddy land, dry land and orchard land were collected from the Hangzhou Municipal Bureau of Land and Resources. The descriptive statistics of indicators for pollution sources are provided in Table 2.

RESULTS AND DISCUSSION

Results of pollution load: Based on the export coefficient model, using the export coefficients and related indicators for pollution sources, the agricultural non-point source pollution load of TN and TP in Hangzhou were computed (Tables 3, 4, and 5).

The agricultural non-point source pollution load of TN in Hangzhou was 18165827.01kg. The TN load exported from land use accounted for 28.28% of overall TN pollution load. The TN load exported from animal husbandry accounted for the highest share of the overall TN pollution load at 36.82%. In addition, the TN load exported from rural living accounted for 34.40% of overall TN pollution load. Therefore, the three agricultural pollution sources had a similar impact on TN load.

The agricultural non-point source pollution load of TP in Hangzhou is 1668496.74kg. The TP load exported from land use accounted for 28.26% of overall TP pollution load. The TP load exported from animal husbandry accounted for 30.70% of the overall TP pollution load. In addition, the TP load exported from rural living accounted for the highest share of the overall TP pollution load at 41.04%. Consequently rural living was the most important agricultural pollution source for TP load.

Spatial distribution of pollution load: The minimum TN load and TP load existed in central district in Hangzhou. The tertiary sector is now the largest sector of the economy in the central district in Hangzhou, and the proportion of agricultural sector is very small in the central district. Meanwhile the urban proportion of the population in the central district has been increasing, since the rapid speed of urbanization. Accordingly the TN load and TP load exported from agricultural non-point sources are a relatively small amount. The maximum TN load and TP load existed in Xiaoshan, Yuhang and Fuyang which surrounded the central district. The large area of agricultural land is distributed over Xiaoshan, Yuhang and Fuyang which have good transport facilities, and the land currently is under agricultural production and animal husbandry. Therefore the press of TN load and TP load are serious in Xiaoshan, Yuhang and Fuyang.

Chun'an is the largest country in Hangzhou. However, the TN load and TP load, especially the TP load, are relatively smaller than those in Jiande and Lin'an. The main

Table 1: Export coefficients of agricultural pollution sources.

Pollution source		Unit	Export coefficient		Source
			TN	TP	
Land use	Paddy land	$kg \cdot hm^{-2} \cdot a^{-1}$	26.00	1.80	Liu et al. (2012)
	Dry land	$kg \cdot hm^{-2} \cdot a^{-1}$	11.20	3.30	Liu et al. (2012)
	Orchard land	$kg \cdot hm^{-2} \cdot a^{-1}$	3.10	0.15	Liu et al. (2012)
Animal husbandry	Pig	$kg \cdot head^{-1} \cdot a^{-1}$	2.67	0.14	Zhang et al. (2013)
	Cattle	$kg \cdot head^{-1} \cdot a^{-1}$	11.37	0.22	Zhang et al. (2013)
	Sheep	$kg \cdot head^{-1} \cdot a^{-1}$	0.45	0.12	Zhou et al. (2014)
	Fowl	$kg \cdot head^{-1} \cdot a^{-1}$	0.05	0.01	Zhang et al. (2013)
Rural living	Rural population	$kg \cdot person^{-1} \cdot a^{-1}$	1.9547	0.2142	Ma et al. (2011)

Table 2: Statistical description of indicators of pollution sources.

Indicators	Unit	Obs.	Min.	Max.	Mean	Std. dev.
Paddy land	hm^2	8	5602.49	47544.74	21082.37	12889.10
Dry land	hm^2	8	1806.38	8775.31	5764.23	2028.59
Orchard land	hm^2	8	2353.86	45584.98	13147.92	14048.34
Pig	10^4 heads	8	2.67	95.99	25.33	29.17
Cattle	head	8	14.00	3528.00	1976.75	1157.12
Sheep	10^4 heads	8	0.25	4.28	2.21	1.36
Fowl	10^4 heads	8	19.20	874.88	254.79	283.22
Rural population	person	8	9.20	72.23	39.96	18.02

Table 3: Agricultural non-point source pollution load of TN and TP exported from land use.

	Paddy land (kg)		Dry land (kg)		Orchard land (kg)	
	TN	TP	TN	TP	TN	TP
Center district	145664.74	10084.48	20231.46	5961.05	7296.97	353.08
Xiaoshan	1236163.24	85580.53	63429.63	18689.09	7991.80	386.70
Yuhang	783604.38	54249.53	54395.94	16027.37	30030.01	1453.07
Tonglu	407879.42	28237.81	64999.54	19151.65	29298.41	1417.67
Chun'an	310849.24	21520.33	63843.25	18810.96	141313.44	6837.75
Jiande	453851.84	31420.51	98283.47	28958.52	55469.01	2683.98
Fuyang	455596.96	31541.33	84592.14	24924.47	18724.87	906.04
Lin'an	591522.10	40951.53	66699.14	19652.42	35943.88	1739.22
Total	4385131.92	303586.06	516474.56	152175.54	326068.39	15777.50

Table 4: Agricultural non-point source pollution load of TN and TP exported from animal husbandry.

	Pig (kg)		Cattle (kg)		Sheep (kg)		Fowl (kg)	
	TN	TP	TN	TP	TN	TP	TN	TP
Center district	71289.00	3738.00	159.18	3.08	16020.00	4272.00	9600.00	1920.00
Xiaoshan	2562933.00	134386.00	25753.05	498.30	11025.00	2940.00	190840.00	38168.00
Yuhang	340158.00	17836.00	8095.44	156.64	19260.00	5136.00	164920.00	32984.00
Tonglu	344697.00	18074.00	27367.59	529.54	6615.00	1764.00	46455.00	9291.00
Chun'an	471789.00	24738.00	23183.43	448.58	1125.00	300.00	21525.00	4305.00
Jiande	541476.00	28392.00	20193.12	390.72	4635.00	1236.00	437440.00	87488.00
Fuyang	528660.00	27720.00	40113.36	776.16	13455.00	3588.00	101675.00	20335.00
Lin'an	550020.00	28840.00	34940.01	676.06	7245.00	1932.00	46705.00	9341.00
Total	5411022.00	283724.00	179805.18	3479.08	79380.00	21168.00	1019160.00	203832.00

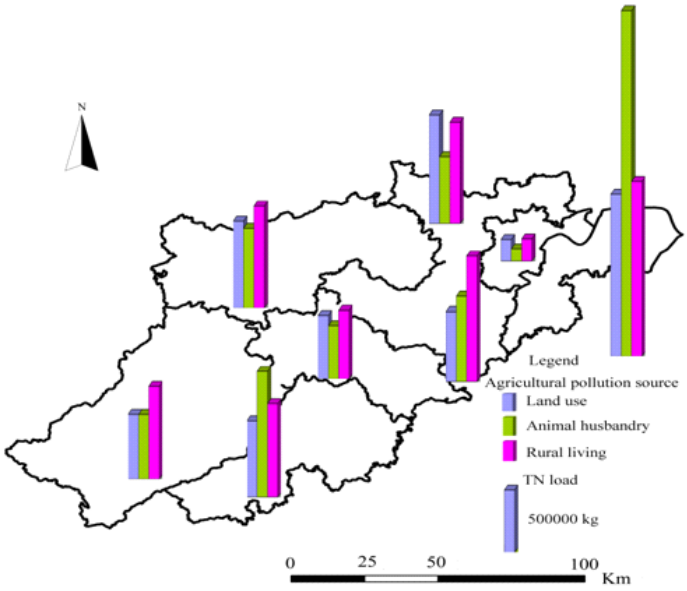

Fig. 2: Spatial distribution of TN load in Hangzhou, China

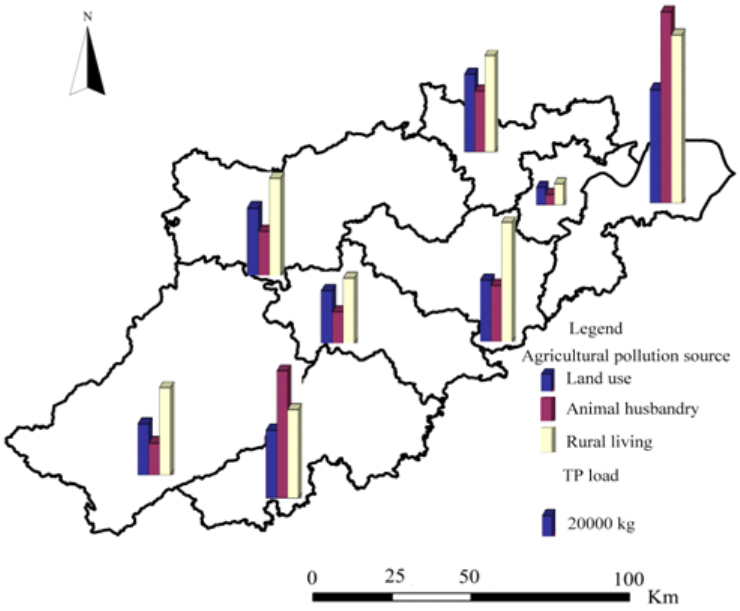

Fig. 3: Spatial distribution of TP load in Hangzhou, China

reason is that the Hangzhou government established the water source protection region in Chun'an to protect drinking water source from pollutants. Consequently, the development of agricultural production and animal husbandry is limited at reasonable speed. The TN load and TP load exported from rural living account for the largest proportion in Chun'an now. The TN load and TP load in Tonglu, Jiande and Lin'an are at medium level in Hangzhou. The landform in west part and middle part of Hangzhou is the hill. The areas where hills encompass are difficult for people farming and raising pigs, cattle, sheep and fowls.

CONCLUSIONS

The agricultural pollution has become a huge environmental and social problem in China. Agriculture is the leading cause of non-point source pollution, especially excess N and

Table 5: Agricultural non-point source pollution load of TN and TP exported from rural living.

	Rural population (kg)	
	TN	TP
Center district	179832.40	19706.40
Xiaoshan	1411879.81	154716.66
Yuhang	806900.16	88421.76
Tonglu	547511.47	59997.42
Chun'an	737703.78	80839.08
Jiande	745718.05	81717.30
Fuyang	1004715.80	110098.80
Lin'an	814523.49	89257.14
Total	6248784.96	684754.56

P exported from agriculture have negative environmental consequences. In this study, the export coefficient model is applied to assess the agricultural non-point source pollution load of TN and TP based on the main sources of N and P. The results showed that the agricultural non-point source pollution load of TN in Hangzhou was 18165827.01kg, and the TN load exported from animal husbandry accounted for the highest share. The agricultural non-point source pollution load of TP is 1668496.74kg, and the TP load exported from rural living accounted for the highest share. Then the spatial distribution of TN load and TP load was analysed. It revealed that the minimum TN load and TP load existed in central district in Hangzhou. The maximum TN load and TP load existed in Xiaoshan, Yuhang and Fuyang which surrounded the central district. The TN load and TP load in Chun'an, especially the TP load, are relatively smaller than those in Jiande and Lin'an since water resource protection region. The TN load and TP load in Tonglu, Jiande and Lin'an are at medium level since their landform. The export coefficient model provides a useful tool for assessing agricultural non-point source pollution load. This assessment will offer effective support to policy makers for reducing TN load and TP load.

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