Supplement of Biogeosciences Discuss., 12, 3577–3615, 2015
http://www.biogeosciences-discuss.net/12/3577/2015/
doi:10.5194/bgd-12-3577-2015-supplement

Biogeosciences
Discussions
Open Access

Supplement of

Anthropogenic point and non-point nitrogen inputs into Huai River Basin and their impacts on riverine ammonia-nitrogen flux

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Part I Watershed characteristics

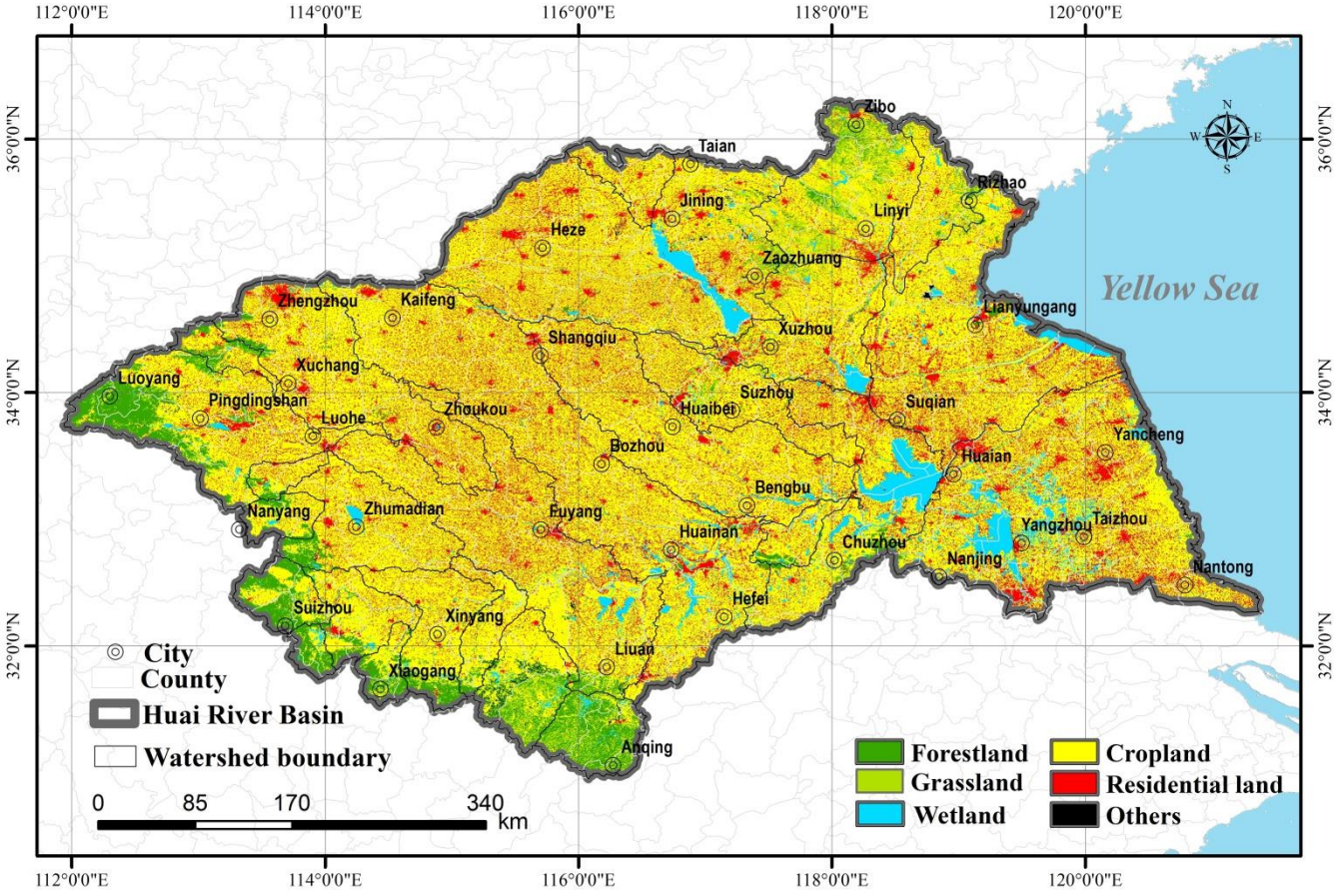

Fig. 1A Distribution of land use types in Huai River Basin (30m×30m resolution)

Table 1A Basic characteristics of 27 watersheds in Huai River Basin (HRB)

Watershed ID	Area (km^2)	Cropland	Forest	Wetland	Residential land	Precipitation (mm)	Temperature (℃)	Slope (%)	Population density (km^{-2})
				(%)					
1	3,042	41.31	53.60	2.12	1.90	1,090	15.88	5.60	236.24
2	1,095	22.46	70.50	6.28	0.29	1,127	16.30	10.10	144.44
3	1,686	46.49	47.92	1.73	2.25	1,171	16.45	6.26	266.14
4	9,770	64.41	45.96	3.55	5.70	1,100	15.98	4.57	310.01
5	15,771	60.67	29.13	2.78	6.55	1,123	16.09	4.48	350.80
6	30,201	67.42	20.18	2.63	9.14	1,081	15.79	3.19	455.01
7	11,534	73.57	10.75	2.46	12.81	1,003	15.38	1.98	583.58
8	1,914	68.96	23.38	2.02	5.45	982	15.36	4.27	367.65
9	1,308	70.55	14.81	1.42	12.98	962	15.20	3.00	635.44
10	13,867	57.11	26.77	1.67	10.36	826	14.84	5.36	597.05
11	1,753	50.99	27.44	0.88	9.37	720	14.75	6.64	595.20
12	29,375	65.13	15.80	1.44	14.30	802	14.90	3.47	773.17
13	89,674	64.25	18.48	2.63	12.07	1,033	15.52	3.61	611.28
14	5,625	49.91	38.83	2.39	2.91	1,461	16.29	8.70	325.29
15	4,349	16.49	67.68	2.66	0.78	1,642	16.59	13.64	150.93
16	121,817	67.12	13.91	3.11	13.67	1,006	15.49	2.82	640.65

17	123,861	67.08	13.85	3.25	13.64	1,006	15.50	2.80	636.78
18	16,981	77.74	0.35	3.26	17.73	945	15.32	0.59	608.62
19	7,126	71.40	2.20	2.28	18.04	949	15.17	1.40	718.01
20	160,460	67.82	11.19	4.53	14.33	1,000	15.49	2.38	616.78
21	2,577	77.58	2.03	1.36	16.13	761	13.59	0.71	788.45
22	31,708	70.99	2.63	5.58	16.89	818	14.13	1.16	738.07
23	10,566	57.31	11.35	2.92	8.31	873	13.71	5.67	507.47
24	4,585	74.89	8.19	2.98	9.62	864	13.67	2.67	582.95
25	52,023	67.73	4.48	5.25	15.09	854	14.14	2.12	706.05
26	21,467	68.47	2.17	7.63	18.76	988	14.40	1.09	607.20
27	30,312	62.77	0.64	14.76	20.23	1,050	15.47	0.54	532.95
HRB	268,846	68.72	9.81	6.06	13.49	973	15.10	2.00	623.26

Part II Calculation of $NANI_n$

2.1 Fertilizer N (N_{chem})

Table 2A Data used to calculate fertilizer N

Watershed ID	Single N fertilizer (ton yr^{-1})	Compound fertilizer (ton yr^{-1})	N_{chem} (kg N $km^{-2}yr^{-1}$)
1	23,761	5,780	8,477
2	3,491	650	3,397
3	9,235	2,084	5,908
4	76,919	36,451	9,179
5	152,548	71,298	11,255
6	342,361	296,002	14,766
7	134,026	208,843	17,957
8	19,165	20,498	13,759
9	19,132	26,402	21,697
10	173,483	159,339	16,532
11	10,699	17,582	9,612
12	460,324	341,956	19,745
13	1,108,964	886,781	15,828
14	38,261	14,200	7,686
15	6,645	6,683	2,066
16	1,624,618	1,257,525	16,950
17	1,647,838	1,281,490	16,925
18	251,212	267,585	20,309
19	94,579	84,286	17,412
20	2,138,062	1,736,144	17,111
21	47,013	33,570	22,803
22	561,600	456,553	22,751
23	70,743	86,362	9,556
24	47,400	66,397	15,407
25	848,566	670,567	20,823
26	431,913	195,881	23,314
27	547,242	218,842	20,581
HRB	4,013,184	2,887,832	18,687

2.2 Biological nitrogen fixation (N_{fix})

Table 3A Data used to calculate biological N fixation

Watershed ID	Peanuts	Soybeans	Paddy	Upland	N_{fix}
			(ha)		(kg N $km^{-2}yr^{-1}$)
1	13,436	3,986	31,311	18,877	1,095
2	1,316	364	7,820	765	411
3	3,254	1,317	27,917	3,777	853
4	52,496	11,249	150,148	77,544	1,381
5	96,016	21,383	317,168	144,625	1,653

6	218,197	66,032	424,577	788,190	1,951
7	113,497	39,548	17,472	621,969	2,447
8	12,856	7,295	1,206	73,746	1,824
9	4,708	4,381	411	64,737	1,535
10	54,080	42,941	3,219	521,806	1,369
11	3,601	5,559	2	66,385	1,135
12	150,570	117,277	15,298	1,395,871	1,769
13	415,071	376,433	799,439	2,968,838	1,760
14	7,086	4,890	95,540	11,208	784
15	649	1,672	24,999	7,224	253
16	565,695	671,569	1,087,820	4,422,085	1,936
17	573,669	684,288	1,123,742	4,468,617	1,937
18	96,097	250,333	66,805	910,389	3,059
19	28,041	91,556	32,972	295,603	2,495
20	735,598	1,068,811	1,421,409	5,942,017	2,047
21	21,582	10,371	21,137	100,969	2,295
22	198,354	78,386	110,234	1,205,158	1,715
23	81,090	10,258	27,201	282,888	1,558
24	52,918	7,162	17,841	157,188	2,264
25	318,003	119,428	250,302	1,829,949	1,677
26	100,750	47,875	388,546	576,671	1,762
27	18,111	96,416	843,331	424,446	1,426
HRB	1,225,380	1,339,692	2,921,429	8,930,272	1,900

2.3 Atmospheric N deposition (N_{dep})

Table 4A Data used to calculate atmospheric N deposition

Watershed ID	NO_y (ton)	N_{dep} (kg N $km^{-2}yr^{-1}$)
1	3,434.12	1,129
2	703.98	643
3	1,803.86	1,070
4	13,343.97	1,366
5	28,712.84	1,821
6	110,998.08	3,675
7	68,734.58	5,959
8	7,026.62	3,670
9	15,753.73	12,047
10	101,157.90	7,295
11	10,000.56	5,704
12	227,528.89	7,746
13	454,445.23	5,068
14	8,455.65	1,503
15	4,088.36	940
16	629,446.48	5,167

17	635,032.03	5,127
18	66,490.21	3,916
19	46,341.14	6,503
20	774,292.88	4,825
21	23,921.20	9,283
22	328,422.81	10,358
23	28,514.66	2,699
24	13,634.75	2,974
25	428,236.43	8,232
26	89,399.69	4,165
27	167,771.24	5,535
HRB	1,473,334.99	5,480

2.4 Net food and feed import in rural area ($N_{r\text{-}im}$)

Table 5A Data used to calculate food and feed N

Watershed ID	Paddy	Wheat	Potatoes	Corn	Peanut	Soybean	Cabbage	Fruits
	(10^3 ton yr^{-1})							
1	178.1	91.4	8.3	16.0	44.8	5.2	295.1	12.9
2	42.2	13.4	1.6	3.0	5.1	0.7	79.2	1.2
3	233.8	40.9	5.7	0.4	8.7	2.4	167.6	3.5
4	981.7	466.2	30.0	82.9	158.0	17.2	1,197.0	29.2
5	1,886.5	1,099.5	51.4	157.2	277.6	31.7	2,013.7	50.0
6	2,507.0	4,046.8	130.8	1,397.5	620.0	92.9	5,456.4	137.4
7	80.1	2,686.9	63.7	1,211.1	319.1	55.4	2,968.3	72.9
8	8.1	278.6	14.3	123.3	33.2	9.6	206.3	14.5
9	0.0	298.5	8.1	207.8	16.0	6.4	415.8	8.7
10	12.0	1,821.0	299.0	1,118.2	174.4	80.4	4,249.8	156.3
11	0.0	177.1	47.7	125.3	7.2	9.3	243.9	24.2
12	28.7	5,442.4	544.6	2,833.8	519.6	213.7	12,709.0	604.8
13	4,958.1	13,366.9	897.1	5,497.4	1,261.1	587.2	25,532.2	954.6
14	665.5	98.2	12.7	14.2	21.7	8.2	641.8	22.0
15	144.5	9.3	5.2	8.7	1.6	3.3	101.0	0.9
16	6,838.8	20,095.2	1,201.7	7,453.6	1,770.5	1,035.8	40,626.7	1,826.2
17	7,089.6	20,300.0	1,212.9	7,487.5	1,792.4	1,050.2	40,977.3	1,841.6
18	420.1	3,822.0	200.8	1,407.8	350.9	367.4	7,325.7	1,282.6
19	148.1	1,184.8	105.2	500.2	87.9	129.7	2,485.5	605.4
20	9,025.2	26,410.5	1,629.0	9,681.1	2,329.6	1,614.6	53,156.6	3,806.9
21	18.9	578.2	20.1	418.6	96.6	26.5	2,136.7	66.0
22	592.3	5,824.2	395.6	3,459.6	743.7	188.7	24,889.7	2,114.7
23	111.7	573.8	334.0	582.1	297.8	24.5	2,923.3	1,678.9
24	122.3	427.8	151.7	332.7	224.9	19.5	1,288.8	222.1
25	1,354.8	7,668.7	830.3	4,724.0	1,175.7	279.4	35,820.1	4,154.4
26	2,951.7	2,508.3	255.7	694.8	388.5	106.4	7,865.0	432.6
27	5,510.2	3,028.6	91.3	533.0	53.8	284.7	10,822.1	380.0

HRB	18,964.2	40,044.0	2,958.0	15,965.7	4,172.5	2,304.5	108,952.5	8,996.0

Table 5A (continued):

Watershed ID	Rural population	Horses & cattle	Hogs & pigs	Sheep & lambs	Chickens & ducks	N_{selfo}	N_{selfe}	N_{harv}	N_{liv}	$N_{r\text{-}im}$
		(10^4 individuals)				(kg N km^{-2} yr^{-1})				
1	55.1	12.5	30.9	14.4	395.8	781	3,932	1,963	1,086	1,665
2	11.7	1.3	5.9	1.6	79.1	462	1,571	1,041	515	476
3	38.5	5.6	19.9	3.7	297.8	986	3,749	2,539	1,188	1,009
4	238.0	37.7	150.5	41.1	1,680.2	1,051	4,534	2,919	1,419	1,246
5	462.8	66.5	275.1	70.3	3,254.9	1,266	5,085	3,618	1,618	1,114
6	1,169.0	209.4	822.3	340.3	8,909.4	1,670	8,256	5,113	2,540	2,273
7	577.4	122.4	489.4	241.1	4,493.5	2,160	12,707	7,262	3,843	3,761
8	61.9	29.8	48.3	33.5	467.9	1,396	12,418	4,502	2,925	6,387
9	68.5	7.1	78.0	29.5	716.4	2,261	12,848	7,729	4,755	2,626
10	649.4	130.6	396.8	224.7	3,836.9	2,020	9,844	4,956	2,779	4,130
11	88.8	8.9	39.9	29.1	485.7	2,186	7,089	3,641	2,221	3,413
12	1,681.9	256.9	973.3	535.2	11,018.4	2,470	10,516	6,680	3,191	3,115
13	4,421.3	586.8	2,370.3	1,182.4	26,957.5	2,127	8,105	5,638	2,507	2,087
14	162.8	12.2	56.5	31.1	1,406.4	1,249	3,462	2,227	1,212	1,272
15	58.2	2.5	14.2	2.2	120.9	578	792	575	265	529
16	6,266.3	784.4	3,212.4	1,869.6	37,546.4	2,219	8,200	6,189	2,537	1,694
17	6,333.8	791.4	3,236.1	1,879.2	37,890.8	2,206	8,129	6,162	2,515	1,658
18	887.4	105.4	369.5	387.3	5,826.8	2,255	8,114	8,412	2,437	-480
19	374.7	20.8	152.3	167.9	2,006.9	2,268	6,281	6,572	2,103	-126
20	7,979.9	935.1	3,911.7	2,531.1	48,315.5	2,145	7,670	6,265	2,387	1,163
21	168.4	18.6	76.8	79.0	1,397.5	2,820	10,721	10,005	3,398	138
22	1,906.6	142.3	784.9	1,396.9	16,008.3	2,594	9,439	8,090	3,045	898
23	440.2	20.0	142.9	168.5	3,099.7	1,797	4,484	3,587	1,576	1,119
24	225.6	12.6	114.0	66.3	2,038.2	2,122	6,674	5,090	2,499	1,208
25	2,917.3	183.7	1,103.0	1,691.0	23,113.6	2,419	7,676	6,984	2,555	557
26	1,018.3	37.3	413.9	129.2	5,881.0	2,046	4,426	5,853	1,716	-1,096
27	1,152.4	4.7	575.4	256.4	14,358.1	1,640	4,500	5,747	2,031	-1,639
HRB	13,293.4	1,173.3	6,117.9	4,674.0	93,706.4	2,133	7,064	6,293	2,328	576

Part III Calculation of $NANI_p$ and AN_p

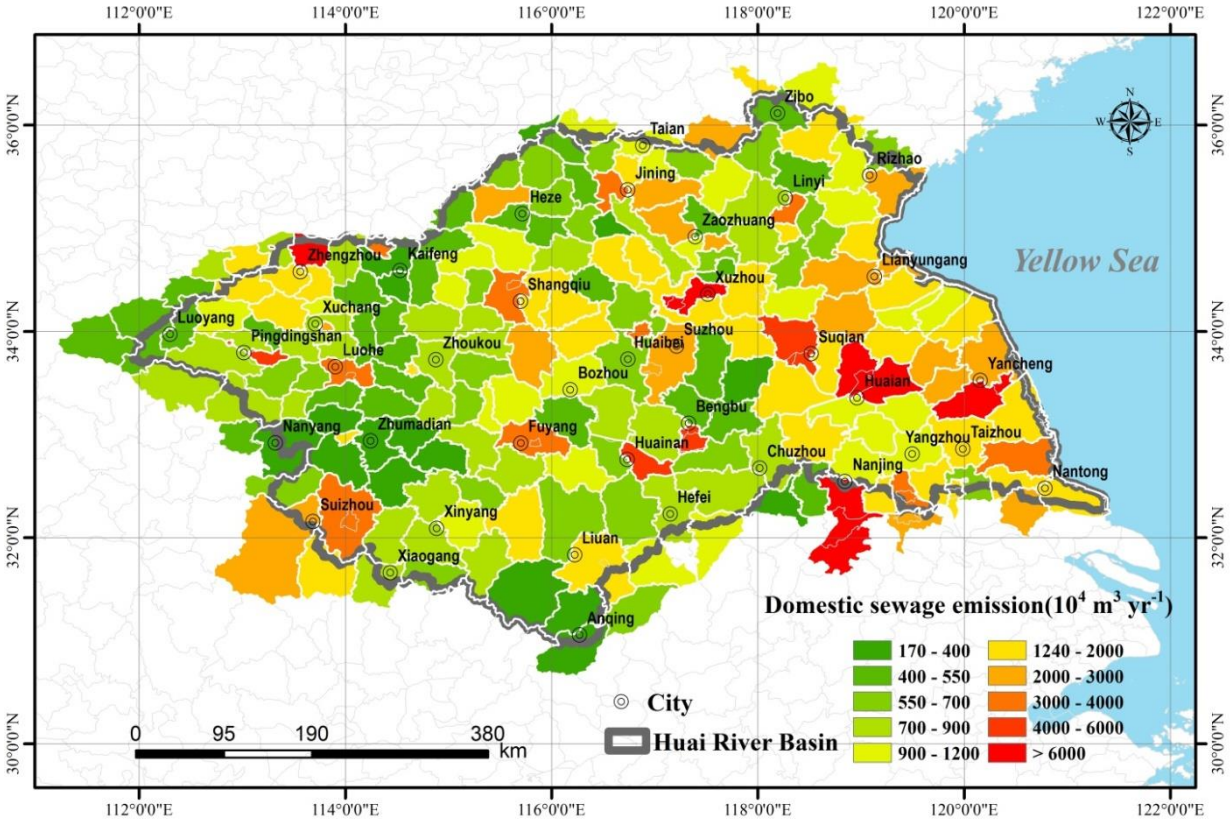

Fig. 2A Average amount of domestic sewage (W_{urban}) for 2003-2010

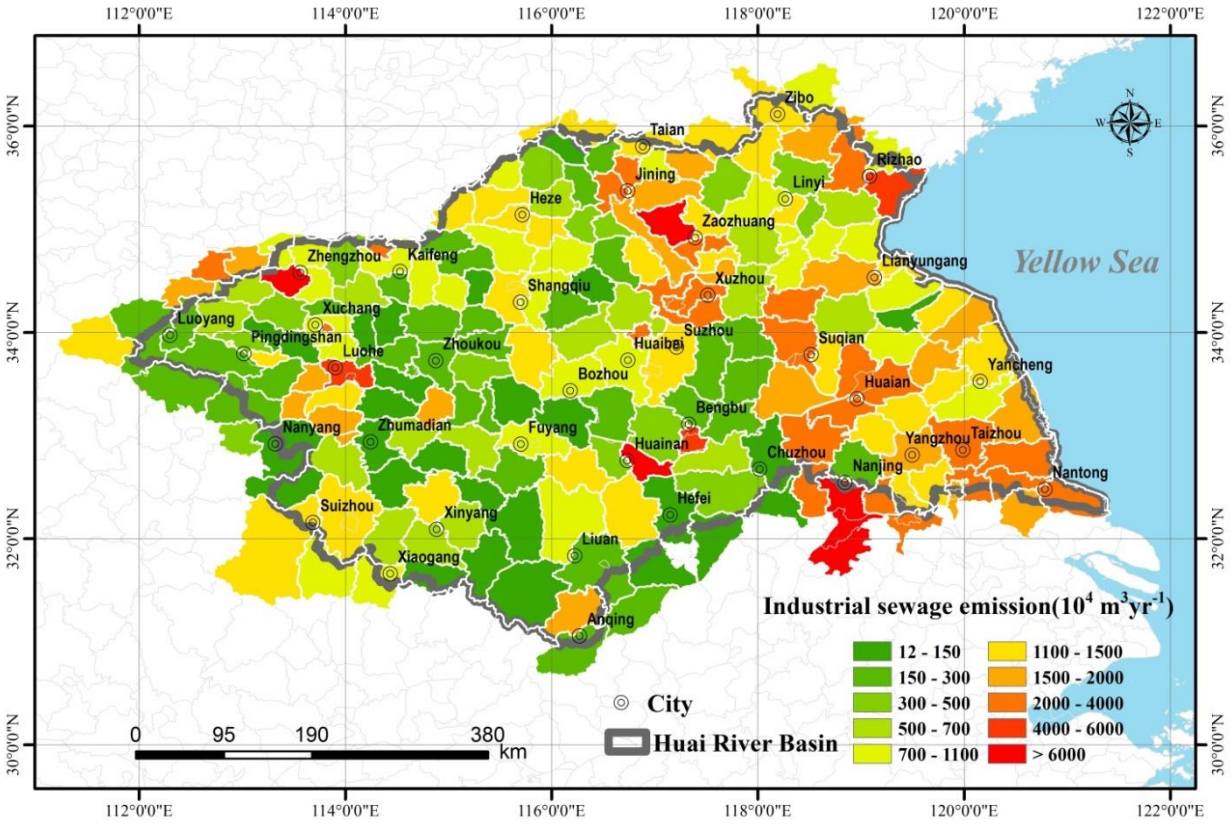

Fig. 3A Average amount of industrial sewage (W_{ind}) for 2003-2010

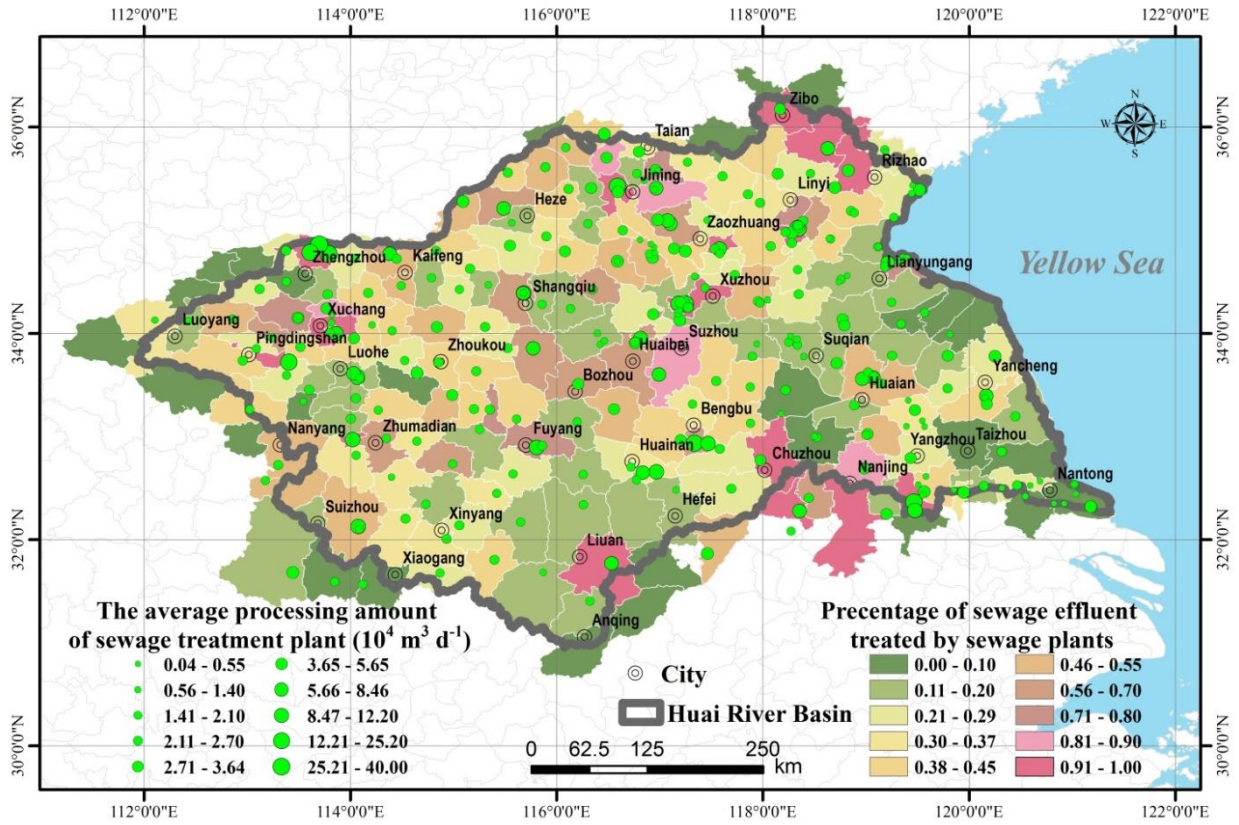

Fig. 4A Location and average daily processing amount of sewage treatment plants, and average percentage of sewage effluent treated by sewage plants (I_{sew}) for each county (2003-2010)

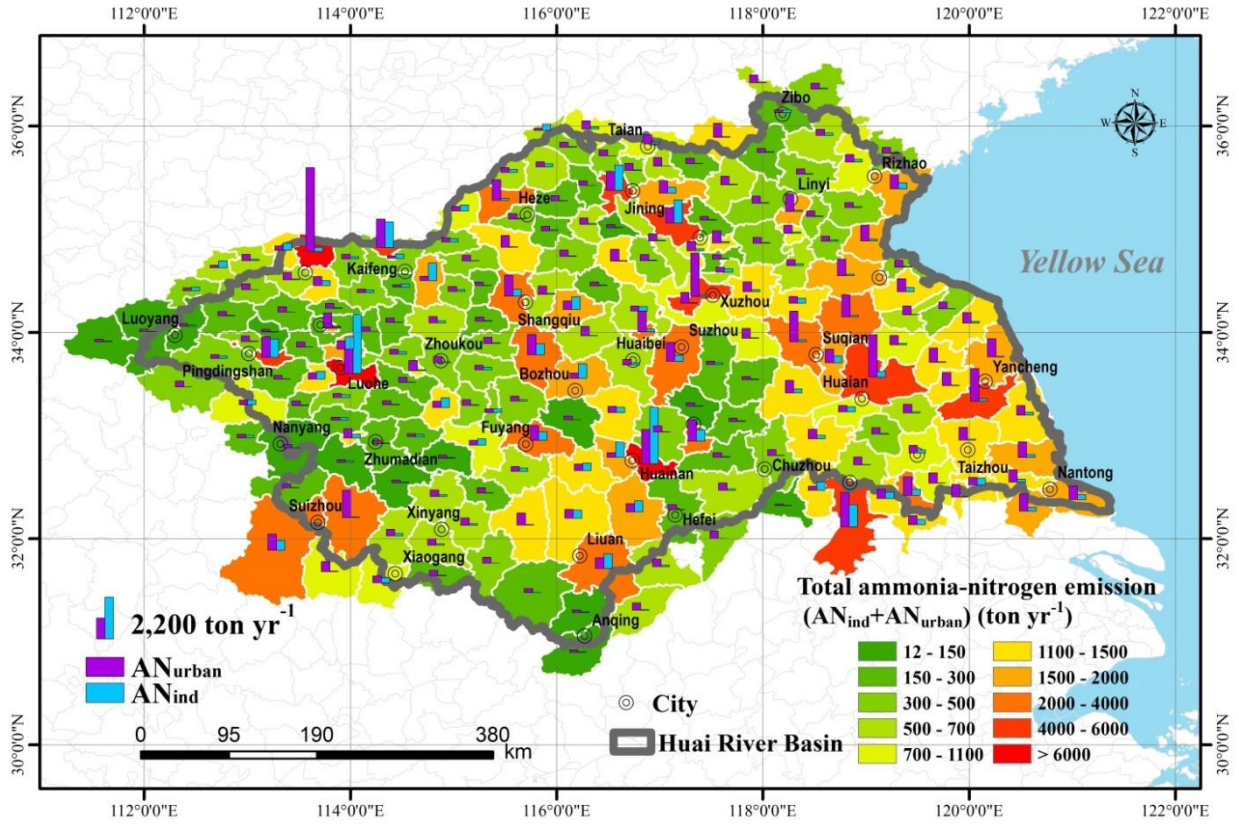

Fig. 5A Average ammonia-nitrogen emission from urban inhabitants (AN_{urban}) and industrial production (AN_{ind}) (2003-2010)

Table 6A Data used to calculate point N input ($NANI_p$) and point AN input (AN_p)

Watershed ID	AN_{urban} (ton yr^{-1})	AN_{ind} (ton yr^{-1})	$W_{urban}+W_{ind}$ (10^4 ton yr^{-1})	W_{sew} (10^4 ton yr^{-1})	I_{sew}	N_{urban} (kg N km^{-2}yr^{-1})	$NANI_p$ (kg N km^{-2}yr^{-1})	AN_p (kg N km^{-2}yr^{-1})
1	362.24	64.26	1,189.14	584.96	0.49	263.40	197.43	91.94
2	27.65	0.83	94.95	29.21	0.31	178.57	149.48	20.41
3	150.97	66.56	563.93	134.56	0.24	179.78	180.60	107.44
4	2,049.85	279.37	6,823.19	3,158.34	0.46	280.75	231.65	161.16
5	3,299.00	467.57	11,434.59	4,224.76	0.37	273.60	250.66	177.06
6	5,869.41	1,540.60	24,679.18	9,619.19	0.39	324.14	309.89	178.41
7	1,970.07	1,019.15	11,426.74	4,907.35	0.43	395.67	395.46	181.25
8	110.00	60.39	778.10	226.62	0.29	210.21	229.81	70.86
9	420.56	259.38	3,149.93	273.71	0.09	530.83	878.17	488.33
10	3,901.65	3,345.51	20,407.51	10,625.20	0.52	614.06	504.27	332.15
11	370.62	11.73	2,231.26	1,057.33	0.47	422.59	351.74	145.73
12	13,132.41	5,293.61	68,187.22	42,860.24	0.63	956.84	706.80	351.27
13	24,056.06	10,399.76	113,653.30	60,539.21	0.53	564.00	455.65	240.97
14	735.05	36.50	1,774.94	450.29	0.25	171.11	149.88	112.81
15	164.14	50.44	1,548.65	286.67	0.19	81.36	138.32	42.95
16	34,528.05	20,577.97	164,877.10	84,093.14	0.51	602.19	499.81	290.86
17	34,867.50	20,657.61	166,707.40	84,935.32	0.51	598.24	497.10	288.41
18	3,705.10	2,121.96	16,058.43	6,538.91	0.41	410.31	363.85	245.34
19	2,846.29	610.32	12,290.67	7,057.34	0.57	916.81	702.72	290.09
20	44,368.83	23,964.77	206,656.30	101,228.53	0.49	569.88	481.20	279.84
21	1,200.26	823.23	6,011.01	5,532.19	0.92	642.95	406.02	279.35
22	11,205.82	5,574.58	59,570.72	33,242.62	0.56	652.39	592.09	322.49
23	2,563.46	446.02	12,691.19	5,650.17	0.45	433.62	392.99	196.06
24	924.25	208.80	5,539.77	4,077.34	0.74	434.01	328.14	119.81
25	18,749.71	6,718.70	98,063.07	60,801.57	0.62	692.92	568.89	277.08
26	8,829.86	1,781.42	40,598.21	10,020.94	0.25	633.71	688.58	408.91
27	12,724.73	2,332.38	64,654.06	22,203.02	0.34	728.70	745.67	377.33
HRB	85,597.36	35,006.07	4,155,114.03	1,983,314.10	0.48	614.37	542.12	300.17

Part IV Nitrogen budget

Table 7A Nitrogen budgets for 27 watersheds of the Huai River basin

ID	Point N ($NANI_p$)	Non-point N ($NANI_n$)	Total N ($NANI$)	Riverine AN flux
	(kg N km^{-2} yr^{-1})			
1	197.43	12,365.82	12,563.25	190.87
2	149.48	4,927.00	5,076.48	115.97
3	180.60	8,839.25	9,019.84	188.26
4	231.65	13,171.55	13,403.21	266.87
5	250.66	15,842.69	16,093.35	163.14
6	309.89	22,664.96	22,974.85	219.29
7	395.46	30,124.53	30,519.99	235.89
8	229.81	25,640.15	25,869.96	253.64
9	878.17	37,904.70	38,782.87	655.50
10	504.27	29,325.21	29,829.47	372.57
11	351.74	19,863.76	20,215.50	
12	706.80	32,374.69	33,081.48	337.00
13	455.65	24,742.92	25,198.57	256.70
14	149.88	11,245.17	11,395.05	146.70
15	138.32	3,787.73	3,926.05	140.56
16	499.81	25,746.61	26,246.42	185.28
17	497.10	25,647.01	26,144.11	255.21
18	363.85	26,803.43	27,167.29	
19	702.72	26,283.55	26,986.27	272.20
20	481.20	25,146.97	25,628.17	
21	406.02	34,517.40	34,923.42	367.00
22	592.09	35,721.92	36,314.02	
23	392.99	14,930.88	15,323.87	192.59
24	328.14	21,852.40	22,180.54	201.40
25	568.89	31,288.09	31,856.98	
26	688.58	28,144.54	28,833.11	
27	745.67	25,902.24	26,647.91	
HRB	542.12	26,643.94	27,186.27	

Part V Relationship between ammonia-nitrogen and total nitrogen

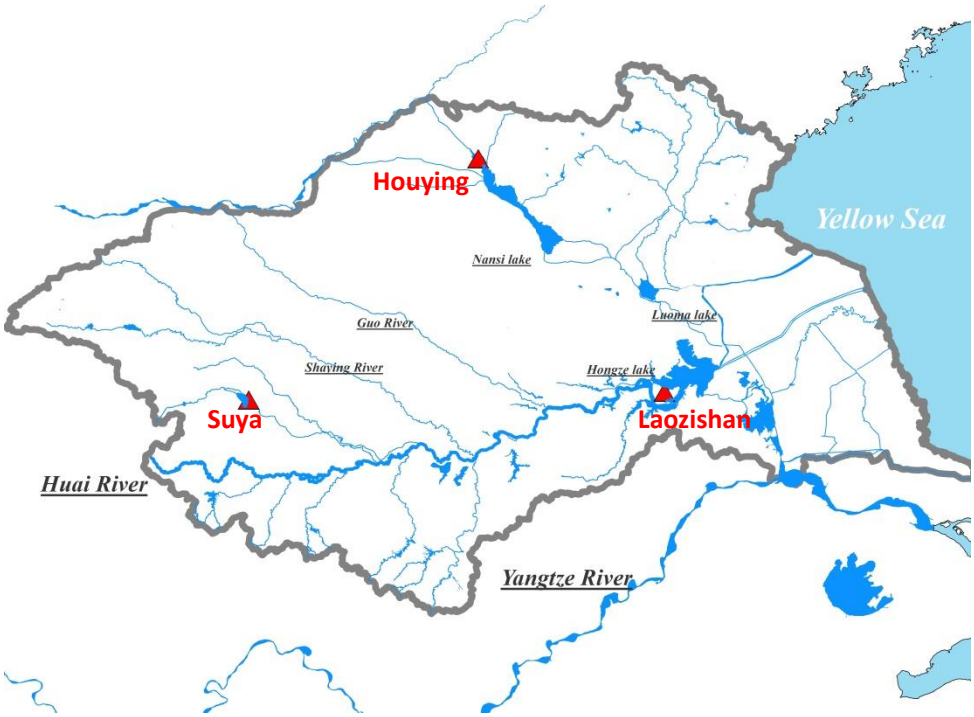

Fig. 6A Location of monitoring stations used to determine the proportional relationship between AN and total N

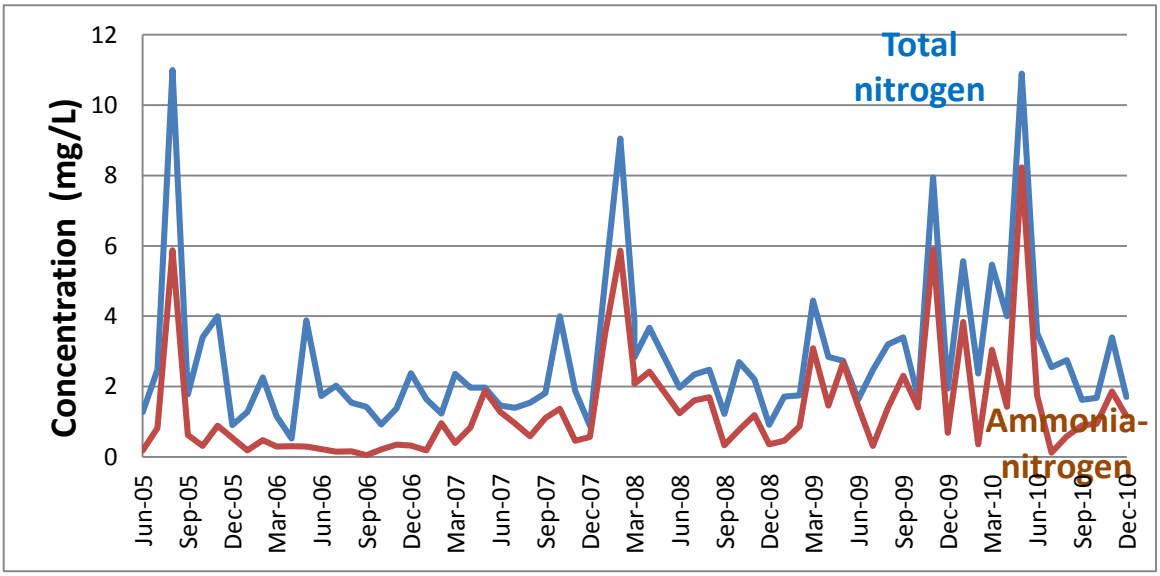

Fig. 7A Monthly variation of ammonia-nitrogen and total nitrogen concentrations at Suya station (Jun 2005 to DEC 2010). Ammonia-nitrogen concentration is well correlated with total nitrogen (AN=0.56*TN, R^2=0.78, P<0.001, N=67)

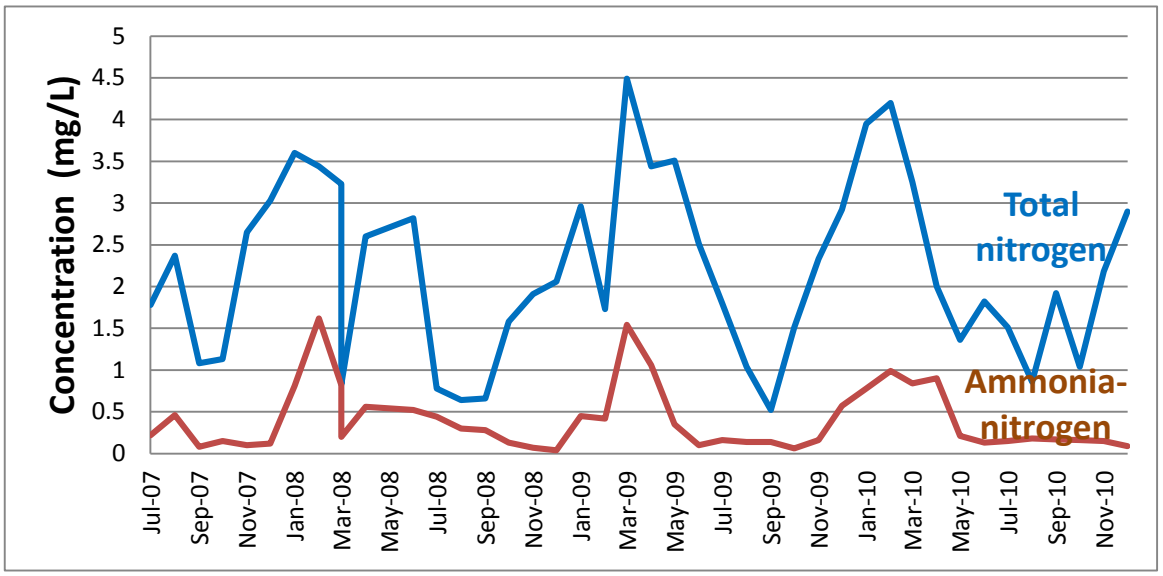

Fig.8A Monthly variation of ammonia-nitrogen and total nitrogen concentrations at Laozishan station (Jun 2007 to DEC 2010). Ammonia-nitrogen concentration is well correlated with total nitrogen (AN=0.20*TN, R^2=0.43, P<0.001, N=42)

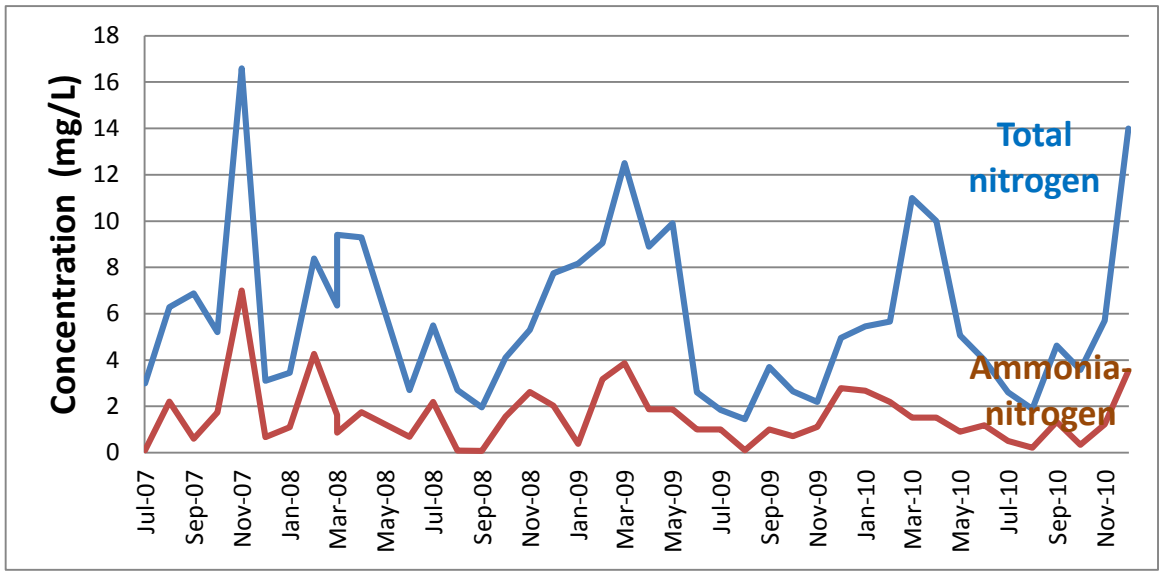

Fig.9A Monthly variation of ammonia-nitrogen and total nitrogen concentrations at Houying station (Jun 2007 to DEC 2010). Ammonia-nitrogen concentration is well correlated with total nitrogen (AN=0.23*TN, R^2=0.60, P<0.001, N=42)