The effect of nutrients discharged from agricultural watershed upon the eutrophication of reservoirs in Korea

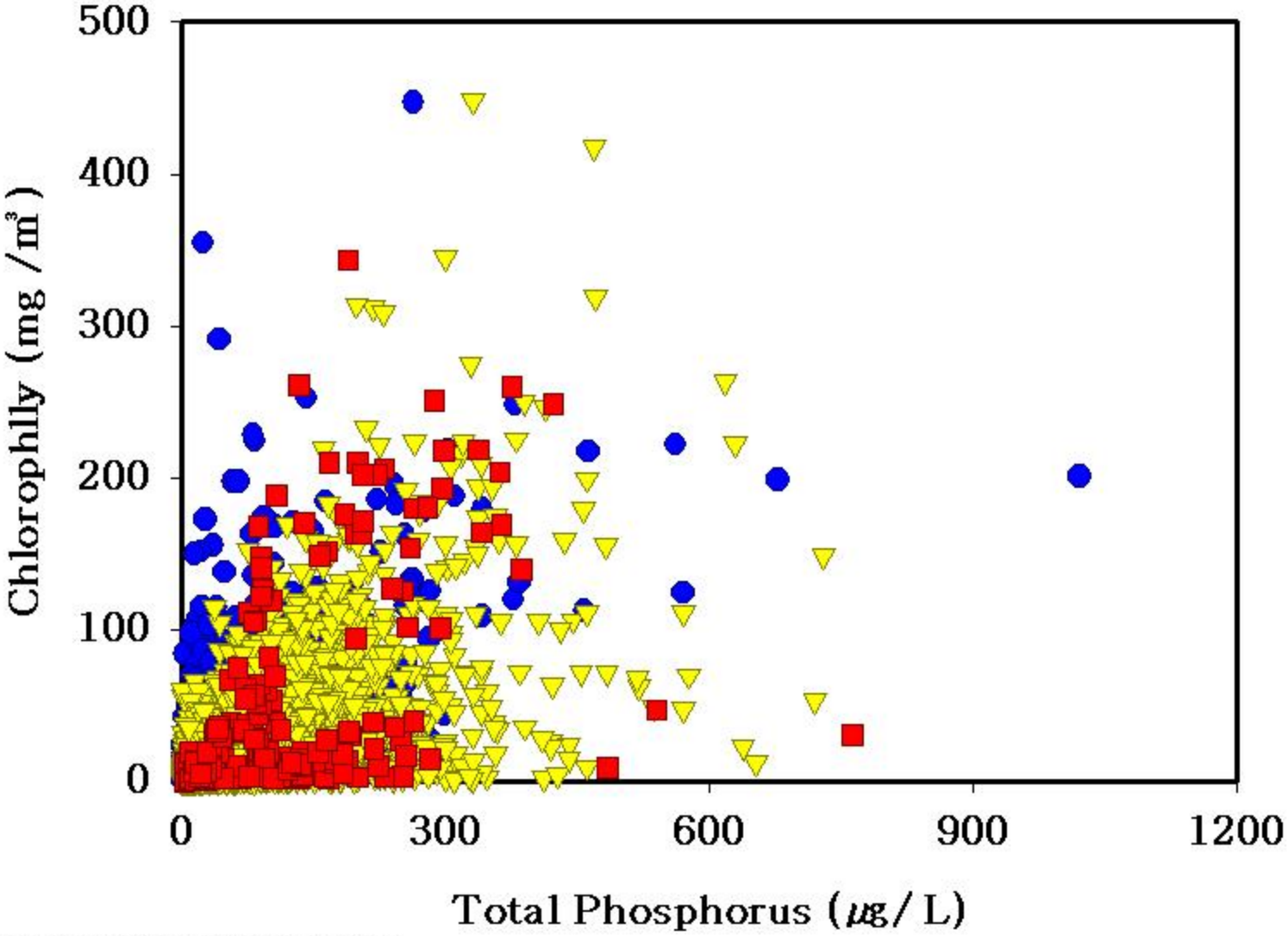
Bomchul Kim
Kangwon National University

Trophic state of major reservoirs in Korea

(Kim et al, 2000)

Upstream Reservoirs	Rank	Z_m	V_{max}	SD	TP	TN	N/P	Chl	P.P.	TSI	TS
Soyang	1	100	16.8	2.8	0.016	1.35	102	12.5	435	50	meso-eu
Choongju	2	70	14.4	3.1	0.015	2.22	157	4.6	183	47	meso
Daechong	3	60	9.1	2.9	0.017	1.79	103	9.5	211	50	meso-eu
Andong	4	50	6.0	2.5	0.018	2.39	163	4.8	387	49	meso
Hapchon	6	60	3.2	2.1	0.022	1.07	51	10.5	606	54	eu
Okjong	8	50	1.8	1.8	0.029	2.03	76	9.4	419	55	eu
Juam	9	40	3.4	3.4	0.015	0.77	59	6.6	310	48	meso
Paldang	12	20	0.9	0.9	0.074	1.97	38	9.4	654	63	eu
Jinyang	-	7	1.4	1.4	0.034	1.28	40	7.9	428	57	eu
Euiam	-	15	2.3	2.3	0.024	1.41	65	7.4	472	52	eu
Estuarine Reservoirs											
Yongsan	10	12	1.8	0.8	0.111	3.20	29	20.3	389	68	eu
Kum	-	8	1.2	0.9	0.132	2.31	18	48.7	466	71	eu
Nakdong	-	10	0.5	0.9	0.109	3.19	29	41.9	935	70	eu

Status of trophic state in 500 Korean reservoirs



Sources of phosphorus in Korea

- Most of reservoirs are eutrophic.
- Approximately 85% of phosphorus discharge in Korea is known to be from agricultural activity
- Fertilizer is the largest source of generation
- Manure or compost is the second source
- The export coefficient of phosphorus from agricultural field is high.

❖ Amount of N and P in fertilizer produced, imported, exported, and utilized in Korea

	produced	imported	exported	utilized
N(ton/yr)	992,153	46,400	239,963	467,778
P(ton/yr)	231,976	1,106	114,689	133,407

(Kim et al, 2000)

- Total national budget of nitrogen and phosphorus discharge from fertilizer, animal feed, and man in Korea. (13 gN/ca/day, 2.0 gP/ca/day assumed)

	amount of use	Nitrogen discharge (tN/yr)	Phosphorus discharge (tP/yr)
fertilizer	2,100,000 t/yr	467,778	133,407
animal feed	15,783,000 t/yr	381,317	70,936
human discharge	pop. 43,000,000	204,035	31,390

High rate of fertilizer application in Korea

The rate of fertilizer application is 5 – 10 times higher than OECD average.

Application of organic compost

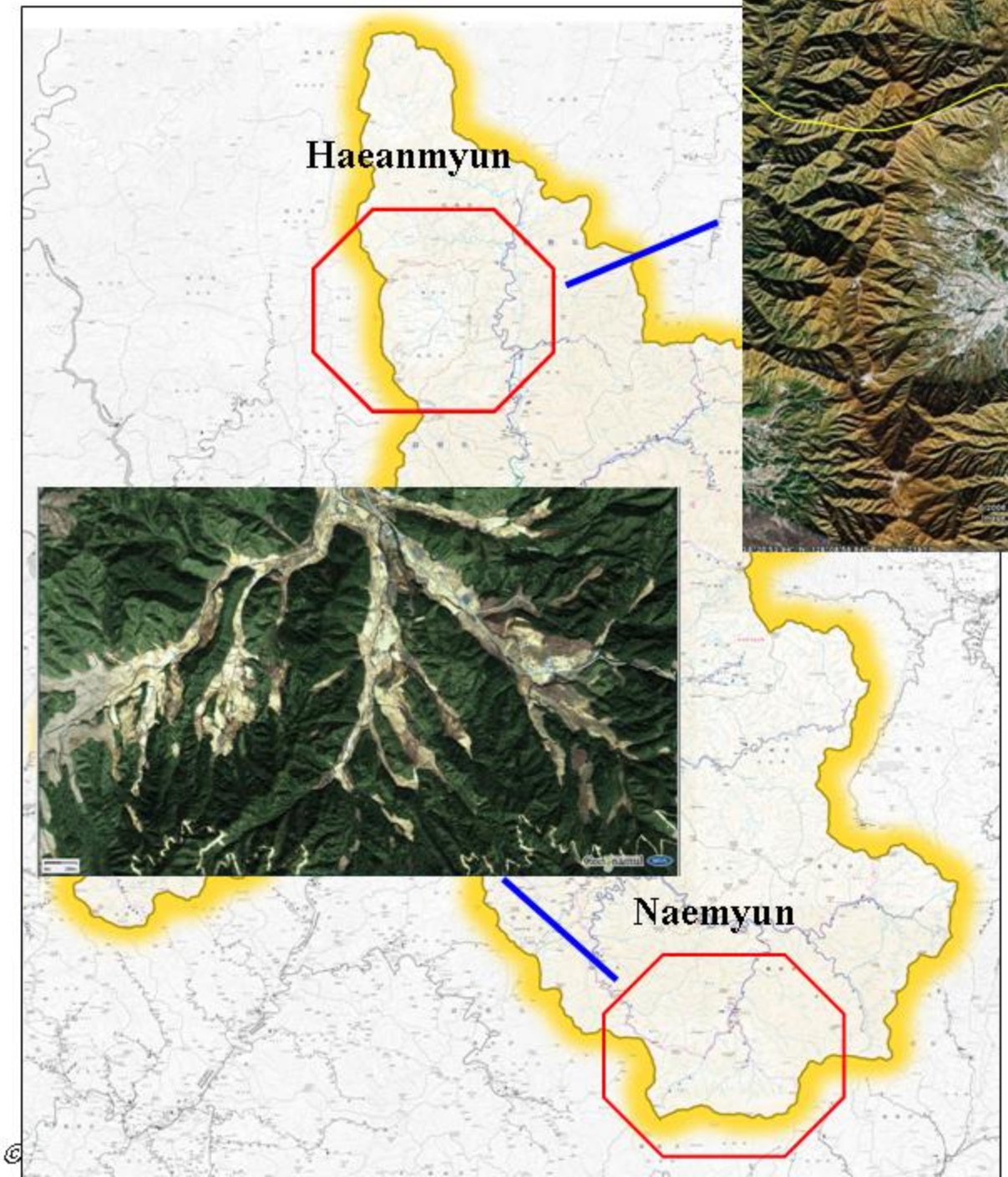
High P content

Low N/P ratio

Excessive P fertilization

Examples of intensive agricultural watershed

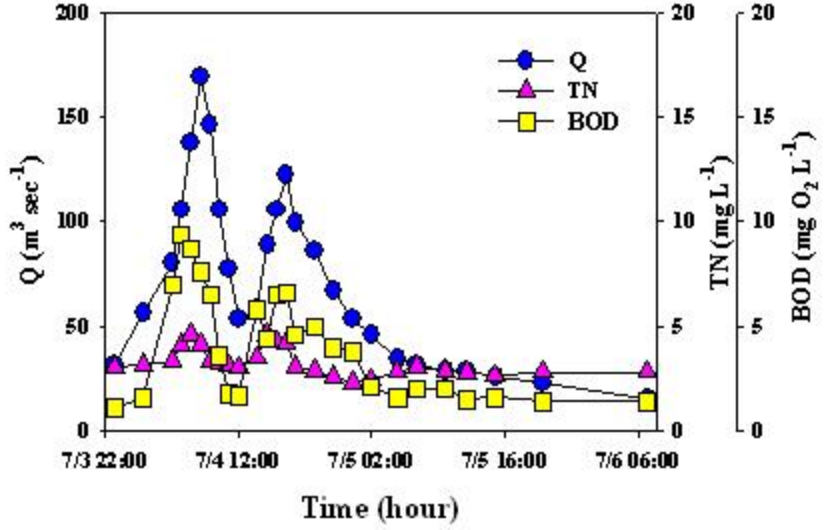
- Two hot spot of agricultural nonpoint pollution in the watershed of Lake Soyang
  - Lake Soyang is the largest reservoir in Korea
  - Tributaries of the Han River
  - The Mandae Stream and the Jawoon stream
- Districts of intensive agriculture of vegetables
- 3-5 times more fertilizer is applied to dry fields than paddy fields

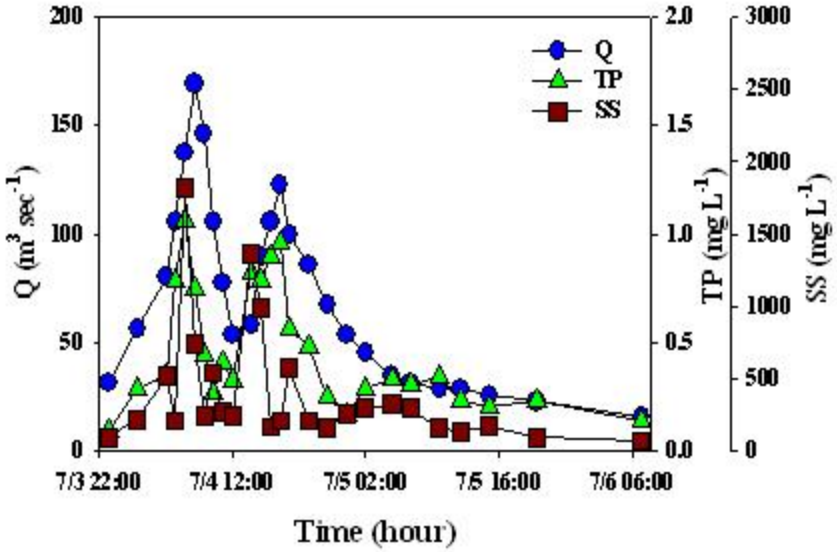


Two districts of intensive agriculture.

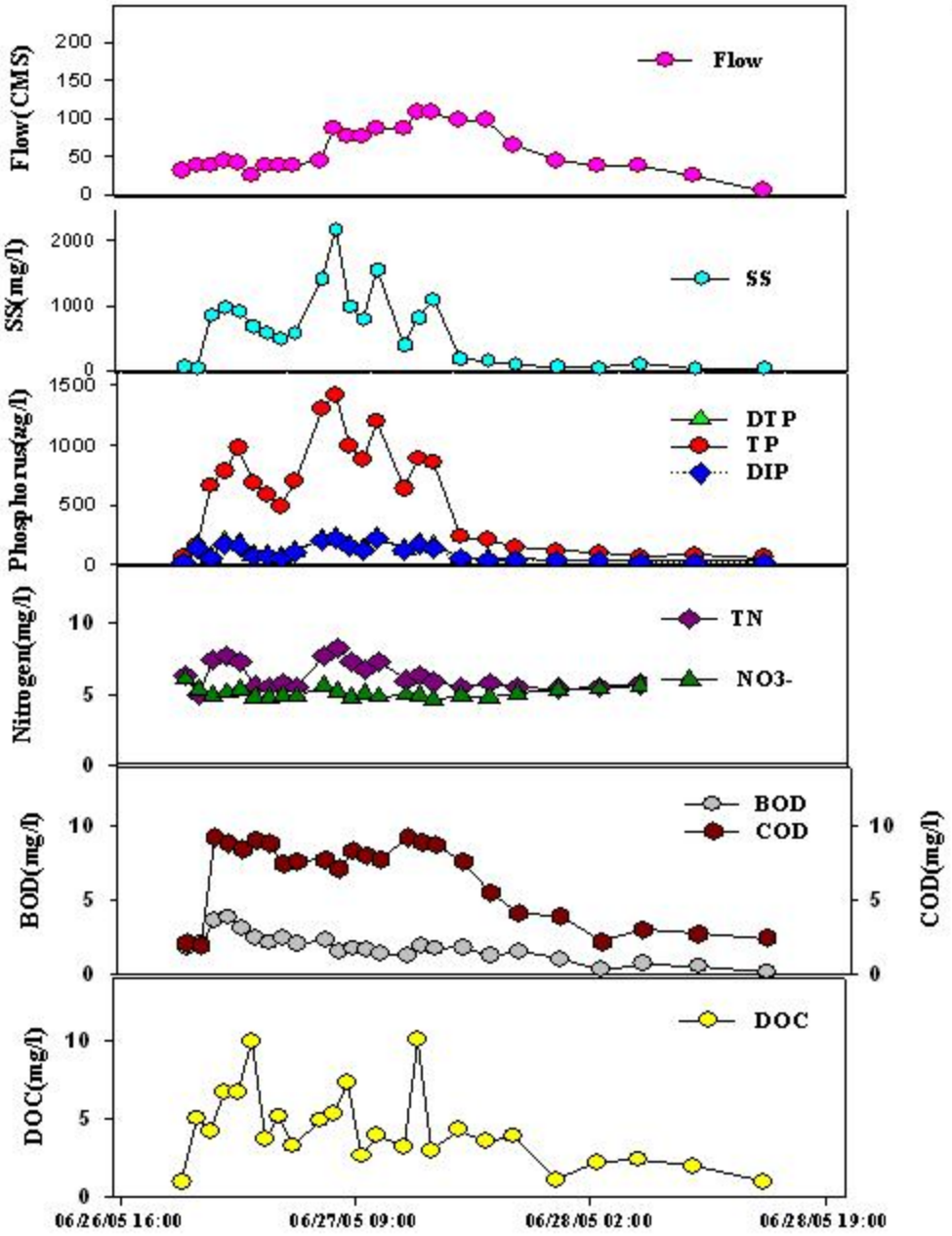
❖ Land use in the studied watershed

Watershed		Upland	Paddy	Forest	Others	Total
Mandae	km^2	41.1	4.9	13.3	1.0	60.3
	(%)	(68.1)	(8.1)	(22.1)	(1.7)	(100)
Jawoon	km^2	20.1	0.9	111.5	0.8	133.4
	(%)	(15.1)	(0.7)	(83.6)	(0.7)	(100)
Soyang	km^2	167.2	12.8	1606.7	65.3	1,852
	(%)	(9.0)	(0.7)	(86.8)	(3.5)	(100)





Water quality variation on a rain event in the Mandae Stream (July 3~6, 2004)



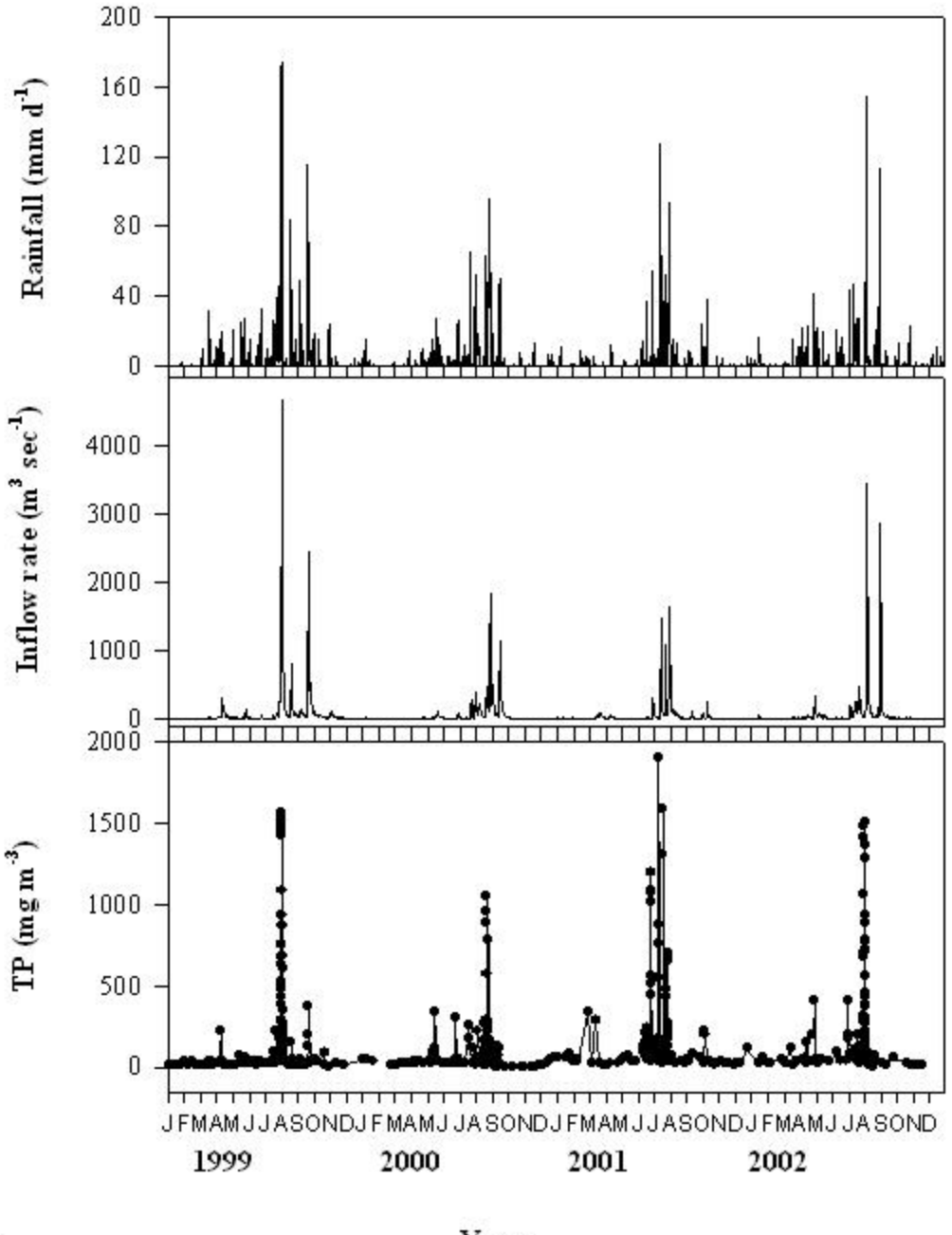
The Jawoon Stream (June 26 ~28, 2006)

❖ The annual average of rain event mean concentrations(EMC) of water quality in the Mandae Stream (mg · L^{-1})

Year	BOD	SS	TN	TP
2003	3.7	544	2.85	0.522
2004	2.7	349	3.28	0.361

❖ The comparison of export coefficients from agricultural land in different watersheds ($kg \cdot yr^{-1} \cdot km^{-2}$).

Watershed	BOD	TN	TP	Reference
The North Han River	1930	680	53	Lee et al.(2001)
The South Han River	1890	680	52	
The Kyung-an Stream	1980	700	54	
Standard export coefficient of paddy field	2081	1949	193	Korean Ministry of Environment(1996)
Standard export coefficient of dry field	1570	2201	113	
The Palmi-ri Stream (paddy field watershed)	-	2920	292	Shim(1998)
The Palmi-ri Stream (dry field watershed)	-	6205	146	
The Young-san River	2592	894	80	Cha et al.(1999)
Virginia, USA	-	270	30	Ritter(1988)
The Mandae Stream in 2003	7156	4785	1318	This study
The Mandae Stream in 2004	6437	8794	1120	This study

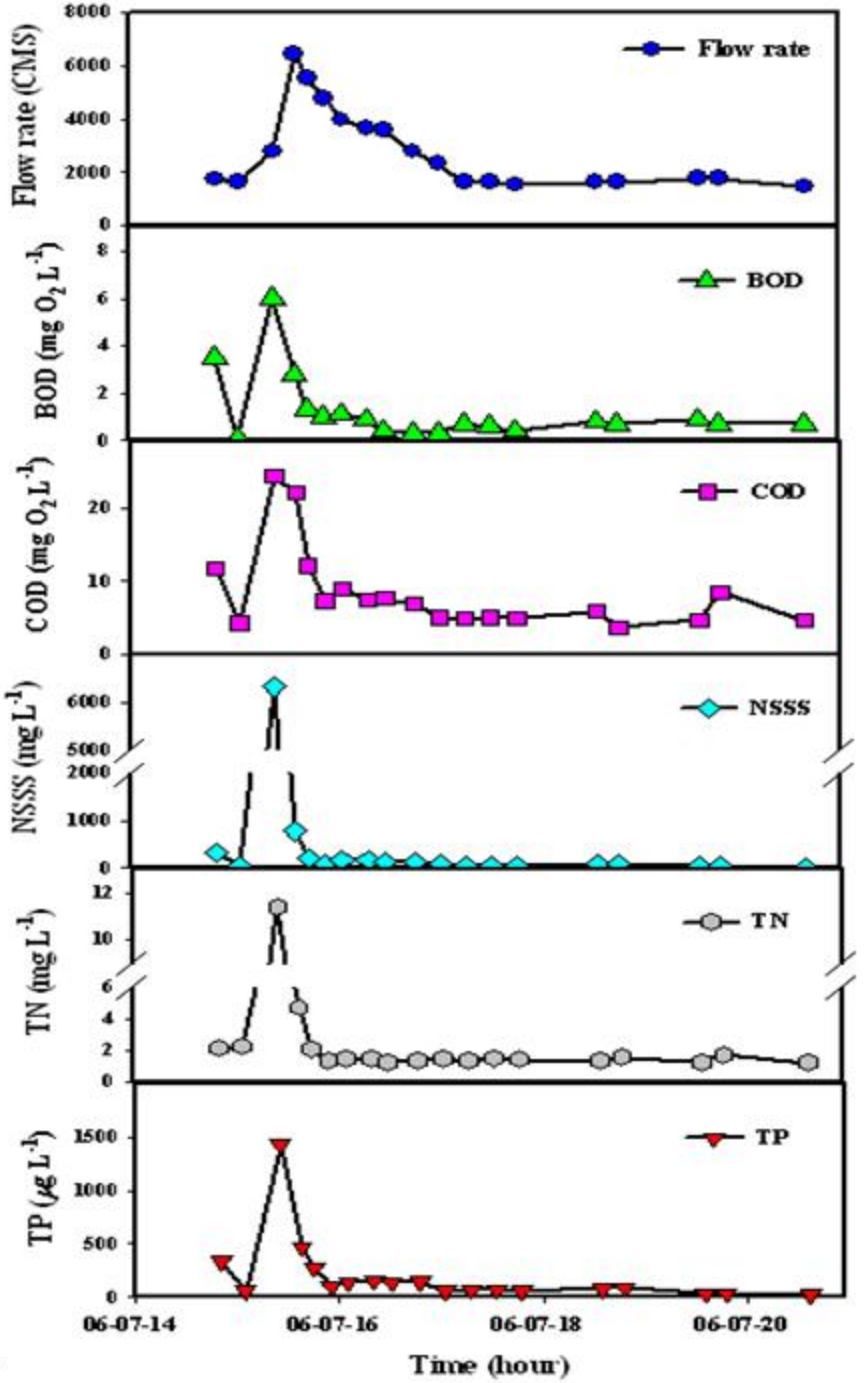


The case of the Soyang River

Watershed is mainly forest and agricultural field

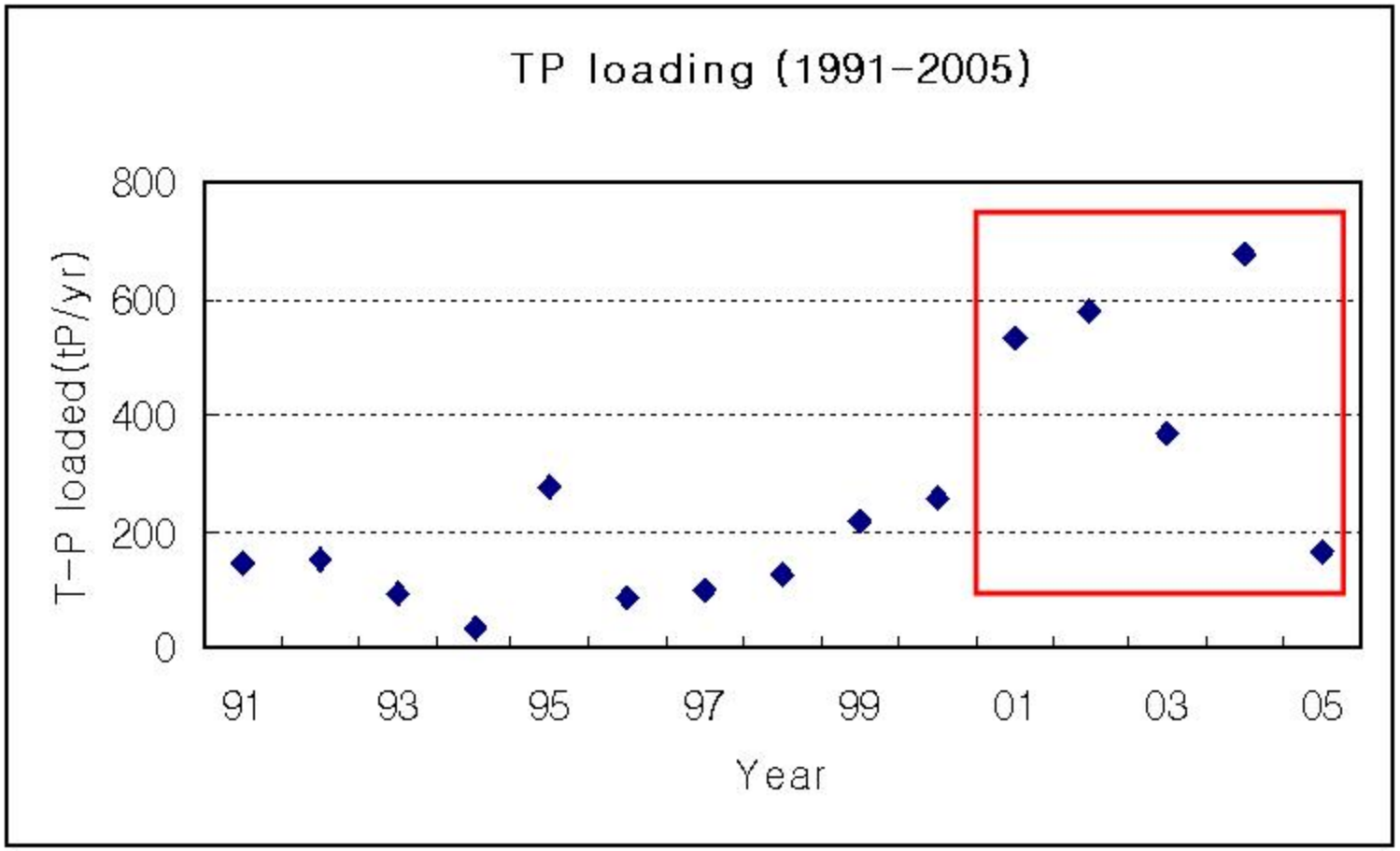
Daily variations of flow rate and TP in the Soyang River

Turbid water runoff into Lake Soyang on a stormy day (July 15, 2006)



Variations of the water quality in the Soyang River during a rain event.

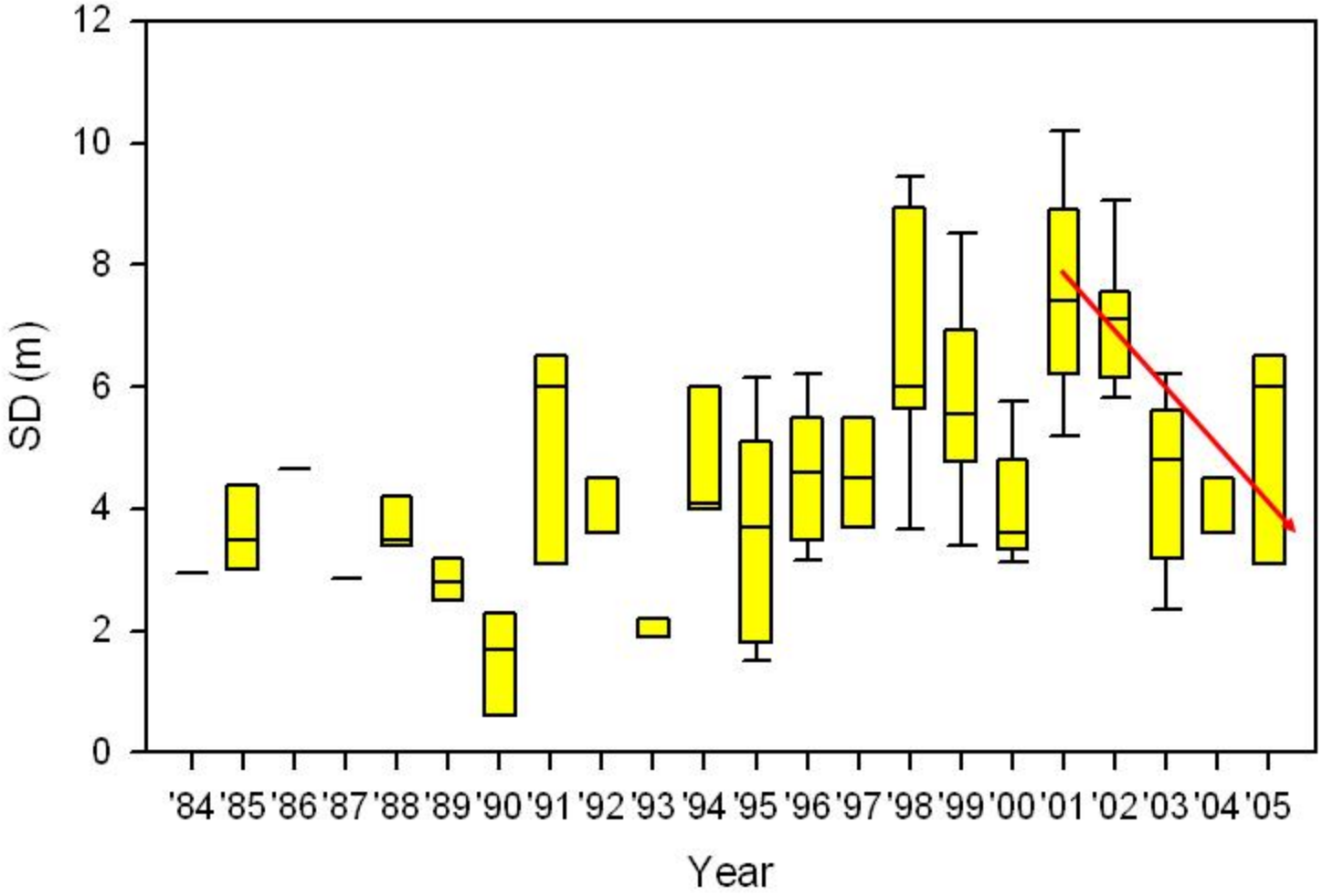
❖ Long term variations of TP loading into Lake Soyang



(data : Korean Ministry of Environment)

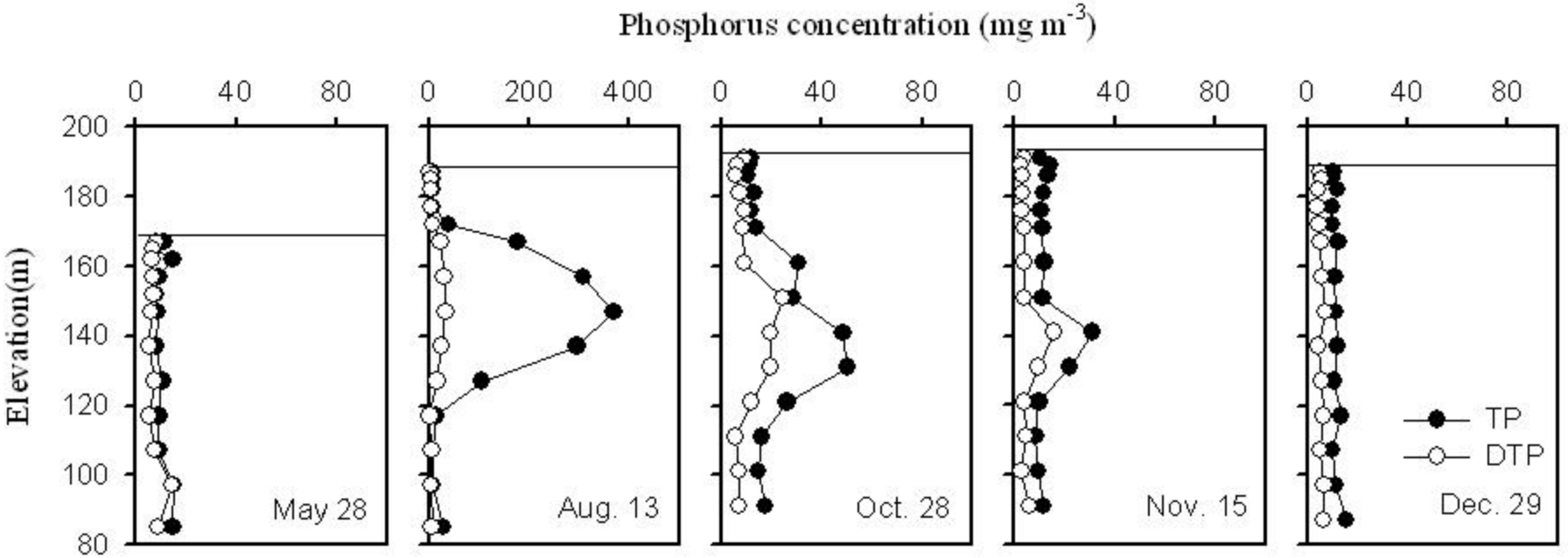
❖ **Increasing trend in recent years without increase of population or industrialization.**

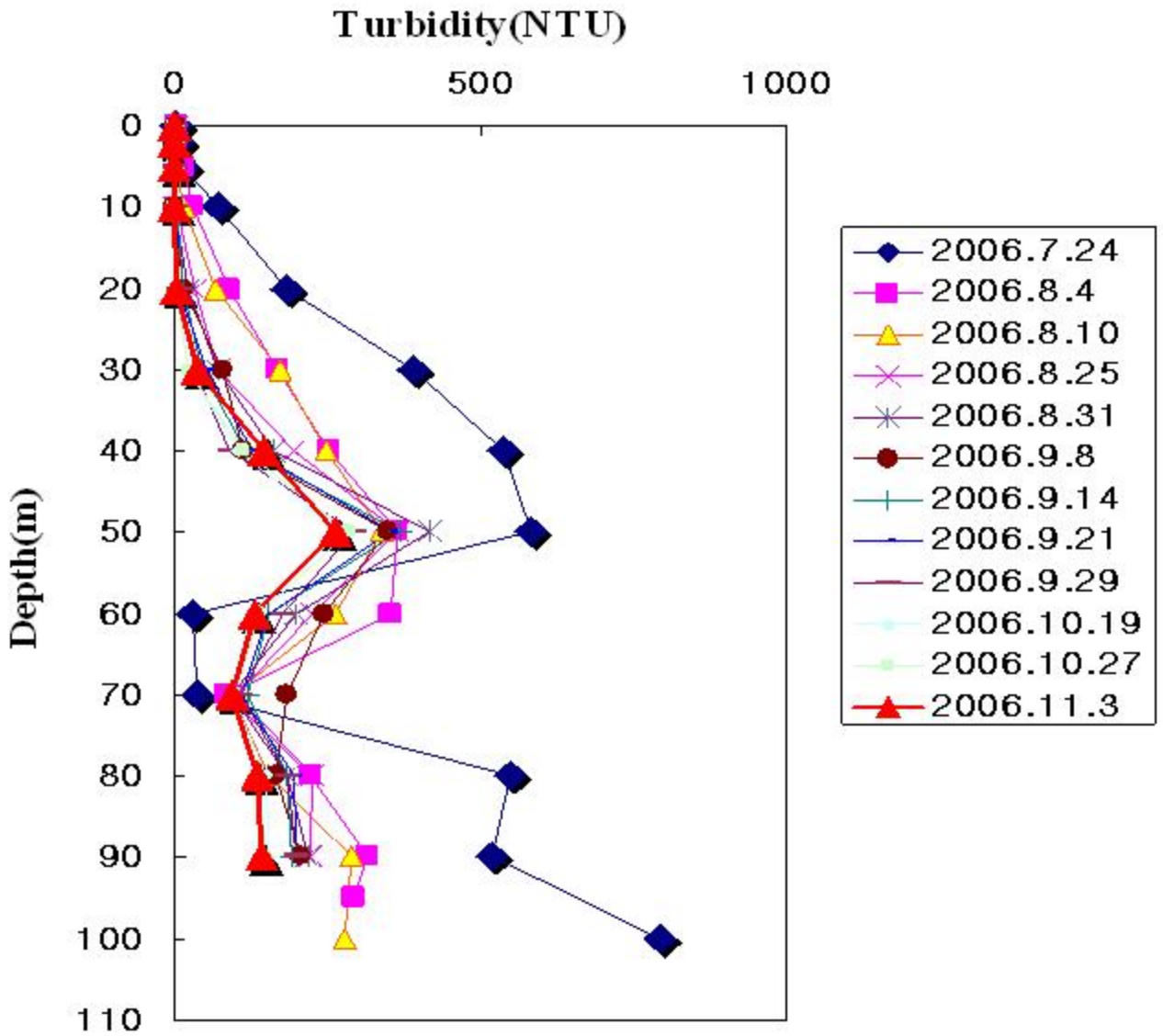
Long term trend of transparency in Lake Soyang



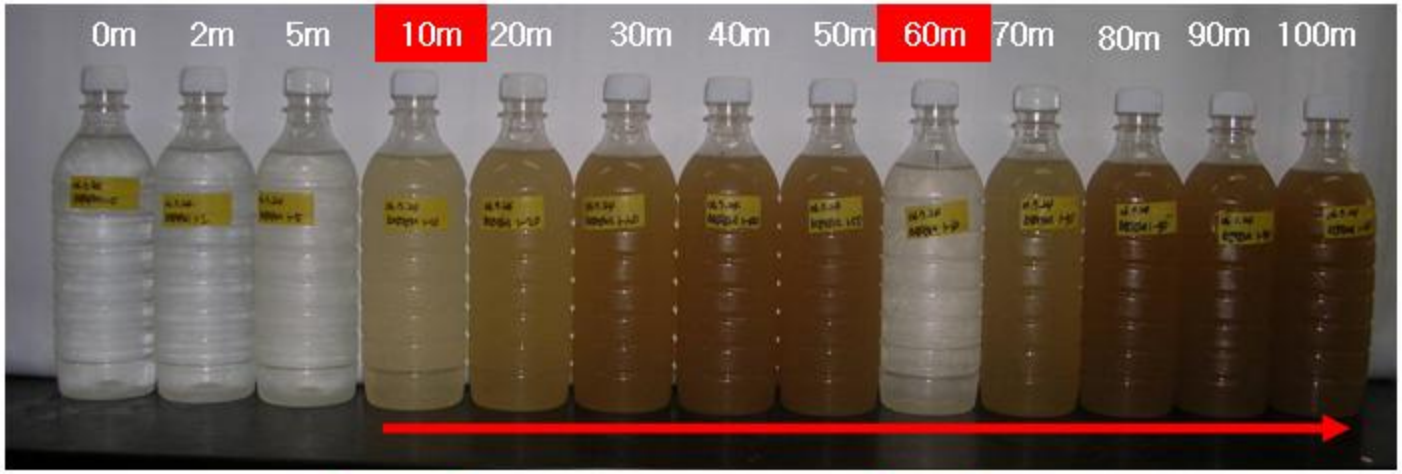
High phosphorus concentration in the middle layer after summer monsoon.

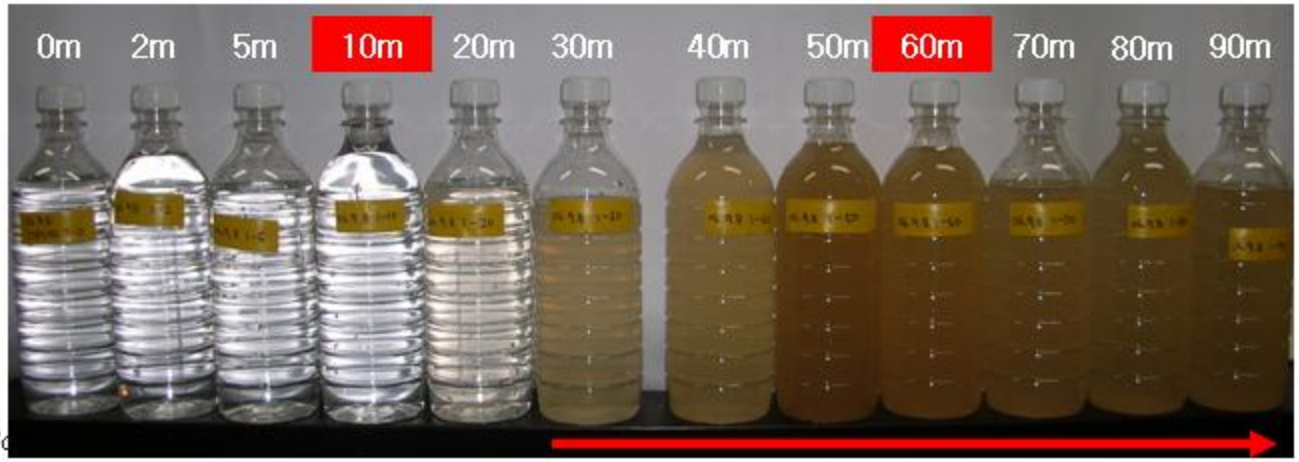
High turbidity = high TP





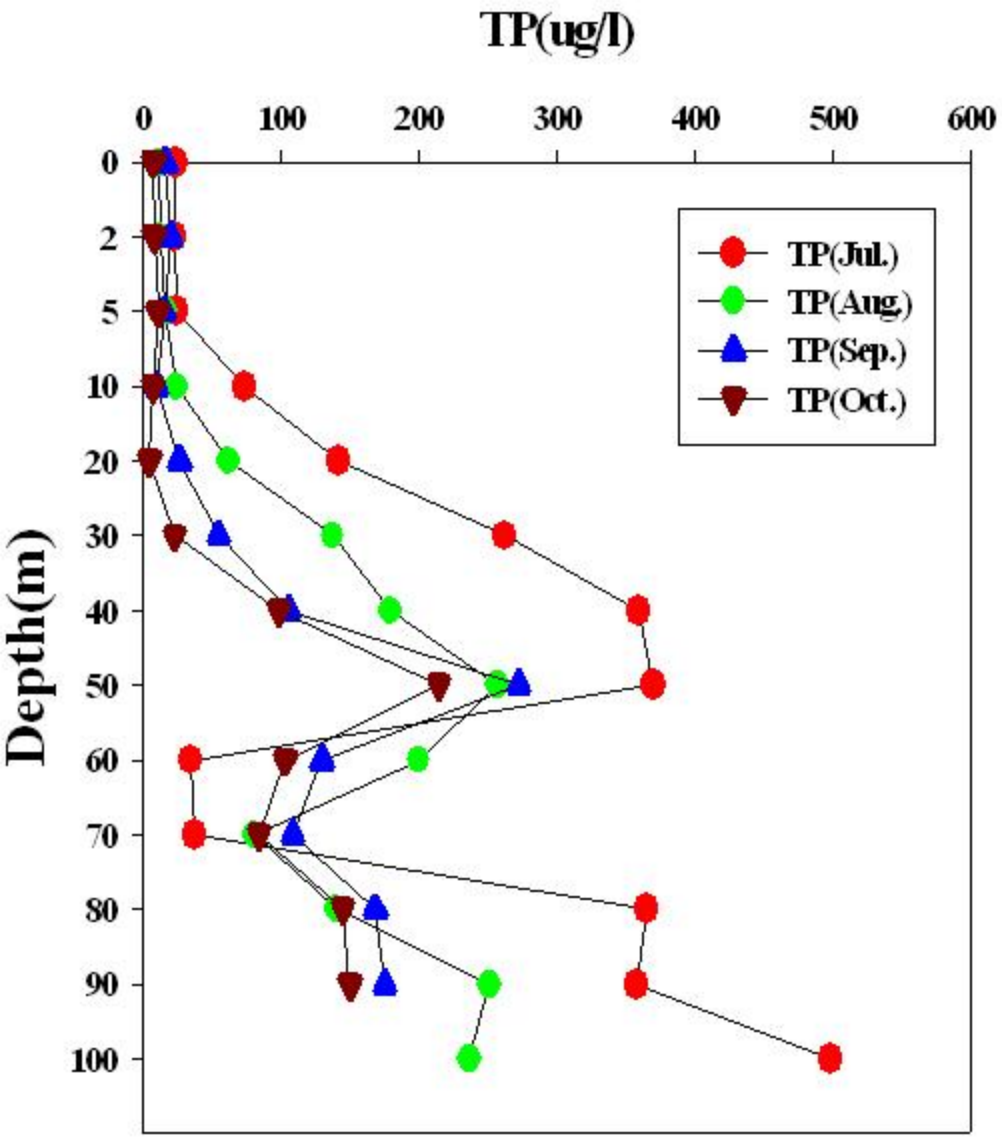
Vertical distribution of turbidity in Lake Soyang after monsoon in 2006.





Photos of the vertical distribution of turbid water in Lake Soyang

upper- 2006.7.24
middle- 2006.8.10
lower- 2006.9.8



Vertical distribution of TP after monsoon in Lake Soyang(2006)

❖ DOC and POC in dry days and rainy days

Stream	Dry days		Rainy days	
	DOC	POC	EMC(DOC) $mg \cdot L^{-1}$	EMC(POC) $mg \cdot L^{-1}$
Mandaechon	1.25 (±0.40)	0.39 (±0.52)	2.17	25.59
Jawoonchon	1.29 (±0.17)	0.58 (±0.16)	2.17	18.82
Soyang	1.68 (±0.58)	0.80 (±0.38)	1.95	5.74

❖ POC discharge rate is high on rainy days.

Conclusion

- Most of reservoirs are eutrophic.
- Major source of phosphorus loading in reservoirs is agriculture.
  - Fertilizer and compost
- Export rate of nutrients from agricultural field is much higher in Korea than other countries.
- Topsoil erosion occurs together with P discharge, causing turbidity and eutrophication problems.
- Agricultural nonpoint source pollution should be a major target for water quality management in Korea.