5

Urbanization, Water Quality Degradation and Irrigation for Agriculture in Nhue River Basin of Vietnam

Mai Van Trinh and Do Thanh Dinh
Institute for Agricultural Environment, Vietnam

1. Introduction

The economic develope with a number of different agricultural, industrial productions, services and comercial activities, but at the same time river basins are highly populated. Because of that, environmental issues in these rivers are very important and many people care about waste, pollution and environmental protection. Pollution from animal waste, for example, Karr et al. (2003) used radio-active isotope ^{15}N to study the transportation and contribution of pollutants from high populated graizing lands to environmental quality of Neuse river basin and showed that ^{15}N can be used well in ditermining the sources of nitrate pollution. Gardi (2001) used Geographic Information System (GIS) and observed data on water discharge, sediment, plant protection chemical and nitrate conentration in the watershed near by Bologna. By simulating agricultural activities, the use of chemicals and fertilizers research found a residue of chemical within the watershed higher than European standard. Research also found that increasing the area of row planting crops increasing the chemical residue in the watershed water. Kraft and Stites (2003) reported that at the tropical regions the light soil texture and shallow ground water table conditions cause high vulnerability of nitrate pollution. It is recommended that people in the region need to have a management and monitoring system for production activities and minimize the input factors to mitigate nitrate pollution. Studying the pathway and pollution of phosphorus at a watershed in the western USA, McDowell and Sharpley (2003) concluded that they need to apply integrated measures on management of manures, agricultural farming and developing natural filters and strengthen production management to mitigate environmental pollution. Using Nutrient Transport and Transformation (NTT) to simulate the transpotation of nitrogen at Muddy Brook watershed in north-west of Connecticut, USA, Nikolaidis et al. (1998) based on the research results to give a management guideline to choose suitable managements to improve water quality in the river and tream network. Modelling is a good trend to assess the current environment, validate the results of management and planning measures in the watershed, for example, mass of pollutants from Glumso lake, Denmark were also simulated (Zhang and Jorgensen, 2005) using Pamolare model; use of GIS and Agricultural Non-Point Pollution Source (AGNPS) to assess the water quality due to changing of land use (He, 2003).

Nhue is a small river with a length of 76 km meandering flows from North to the South through Hanoi city and Ha Nam province. The river starts from Liem Mac Bridge to take water from Red River at Hanoi and ends at Phu Ly city before joining with another river to make a bigger watershed. Area of Nhue watershed is about 107,530 ha covering 20030ha of Hanoi city , 67727 ha of Ha Tay province (now merged to Hanoi) and 19710 ha of Ha Nam province. The watershed size in wide is about 20km.

Nhue River is a branch of Red River and connected to each other through a bridge. When bridge is opened, fresh water from Red river fill Nhue river. Because of that the river can be re-clean. However, there are a big amount of pollutants from many point pollution sources spilt in recent years reduce self-clean ability and degrade water quality of the river.

Water quality became a hot issues and attracted many researches for a long time, for example, the research by Dang Duc Nhan et al. (2001) showed high level of DDT in the mud of river bed and in water; Nhue water quality project done by National center of natural sciences and technology with many valuable outputs (Trinh Anh Duc et al., 2006, Trinh Anh Duc et al., 2007 and Thi Thuy Duong, 2007); and water quality monitoring done by Environmental Protection Department. Most of the researches showed that Nhue water quality was heavily degraded with many parameters lower than the standard level for irrigation. Nevertheless, Nhue River is still the irrigation and drainage river for more than 100000 ha. Therefore it is valuable to have research to contribute on improving the water quality and environment.

Objectives of research are to study: the irrigation capacity of the river for crop production; degradation of river water quality; and accumulation of pollutants in the field.

2. Methodology

Maps of watershed

The river and its watershed was delineated on the GIS software with all layers of information of topography, administrative, soil, land use, irrigation and drainage systems.

Irrigation water

Irrigation water is calculated based on the water balance equation, mostly in the root zone layer (Pham Ngoc Hai et al., 2006)

$$\Sigma W=(ETc+W_s)-(W_o+\Sigma P_o+\Delta W) \quad (1)$$

$$W_s=A.\beta_k.H \text{ (mm)} \quad (2)$$

Ws is limited by condition of

$$W_{\beta min}\leq W_s\leq W_{\beta max} \text{ (mm)} \quad (3)$$

$$W_{max}=A.\beta_{max}.H; \text{ (mm)} \quad (4)$$

$$W_{min}=A.\beta_{min}.H \text{ (mm)} \quad (5)$$

$$W_o=A.\beta_o.H \text{ (mm)} \quad (6)$$

$$\Sigma P_o=\Sigma \alpha CP \text{ (mm)} \quad (7)$$

$$\Delta W= W_H+W_m \text{ (mm)} \quad (8)$$

$$W_H = A\ \beta_o.(H-H_{add})\ (mm) \quad (9)$$

$$C=1-\sigma$$

where:
Σm: Total required water need for irrigation (mm)
ETc: Evapotranspiration (mm)
W_s: Water need to be stored in the soil at the end of period (mm)
γ_k:Soil bulk density (ton m^{-3})
β_k **:** Soil moisture content at the end of period, analogue % of soil bulk density
W0: Available water at the begining of period
βmax, βmin: minimum and maximum soil moisture content
$W_{\beta max}$, $W_{\beta min}$: water at minimum and maximum soil moisture content (mm)
A: Soil porosity (%)
H: depth of root zone layer (mm)
ΣP_o: Water that plants use during the period:
P: Real precipitation (mm)
C: Fraction of precipitation go into the soil
σ: Flow factor in practice
α: Rainfall use factor
ΔW: The addition water that plant used during the period (mm)
W_H: Water that plant used thank to incrementof root (mm)
H_{add}: increment depth of root (mm)
W_m: Ground water that plant can use through capilary rise, this depends on ground water table and soil characteristics

Irrigation water for rice

Paddy rice is a case because rice growing in the flooding condition with a hardpan at the bottom of cultivated layer. Therefore there is a typical irrigation procedure for paddy rice. Irrigation water for rice was calculated based on the water requirement and water balance for whole crop duration and can be described as follow:
Water requirement for whole rice crop (M) in equation 1:

$$M=M1 + M2 \quad (10)$$

Where: M1: irrigation water for land preparation; M2: irrigation water for rice.
Irrigation water for land preparation is calculated in equation 11

$$M_1=W_1+W_2+W_3+W_4-CR \quad (11)$$

$$W_1=A.H(1-\beta_o) \quad (12)$$

$$W_3 = K\frac{H+a}{H}(t_a - t_b) \quad (13)$$

$$W_4=ET_o.t \quad (14)$$

where:
W_1: water volume to saturate cultivated layer
W_2: water volume need to make a layer of water

W_3: Stable infiltration water in land preparation period
W_4: Evaporation during land preparation period
C: Rainfall effective factor
R: Rainfall (mm)
A: soil porosity
H: depth of soil cultivated layer (mm)
β_o: soil moisture content before irrigation (%)
H: depth of soil cultivated layer (mm)
t_a: Land preparation time (day)
t_b: Time to saturate the cultivated layer (day)
Water balance in the field is described in equation 15

$$W = (W + R + F_{in} + Cap) - (ETc + F_{out} + Per) - (S_{lim} - S_{ini}) - (G_{lim} - G_{ini}) \tag{15}$$

where
W: Current soil water
R: Rainfall in observed period
F_{in}: Inflow from higher fields
Cap: Capillary rise
ETc: Evapo-transpiration (ETc) calculated by Penman – Monteith method (FAO, 1998)
F_{out}: Surface outflow
Per: Percolation to ground water
S_{lim}; G_{lim}: limited surface and ground water due to using condition
S_{ini}; G_{ini}: Initial available surface and ground water
Irrigation will be set on when $\Delta<0$ and vice versa

Water quality assessment

Water samples were taken at three locations along the river length, the upstream, middle and the downstream, in dry and rain seasons using a litter plastic sampler. A liter of sub-sample of sub-sample was collected from a mixed three sanmples at three depths of surface, middle and bottom. Samples were treated by HNO_3 0.1M and stored in a cool condition of 4 degree census. Water samples were analyzed pH_{H2O}, EC, COD, BOD_5, total phosphorus, total nitrogen, total E. coliform, Hg, Cd, Pb and Cu. Data were analyzed by SPSS software and compared with national water quality standard.

Estimation of pollutant mass

Pollution mass was estimated as a product of irrigation volume and concentration of pollutant at location, and time of irrigation

3. Results

3.1 Study area

Nhue River located at coodinate from $20^0 30'40''$ to $21^0 09'$N and from $105^0 37'30''$ to $106^0 02'$E, within Red River Delta and bounded by Red River in the north, Day river in the west and Chau Giang river in the south. The river orginirated from Red River (Figure 1).

Topography

Whole watershed is located within Red River Delta with an elevation ranges from 1 to 10 m above sea level and lowered from north to south and from Red river, Day river to Nhue river.

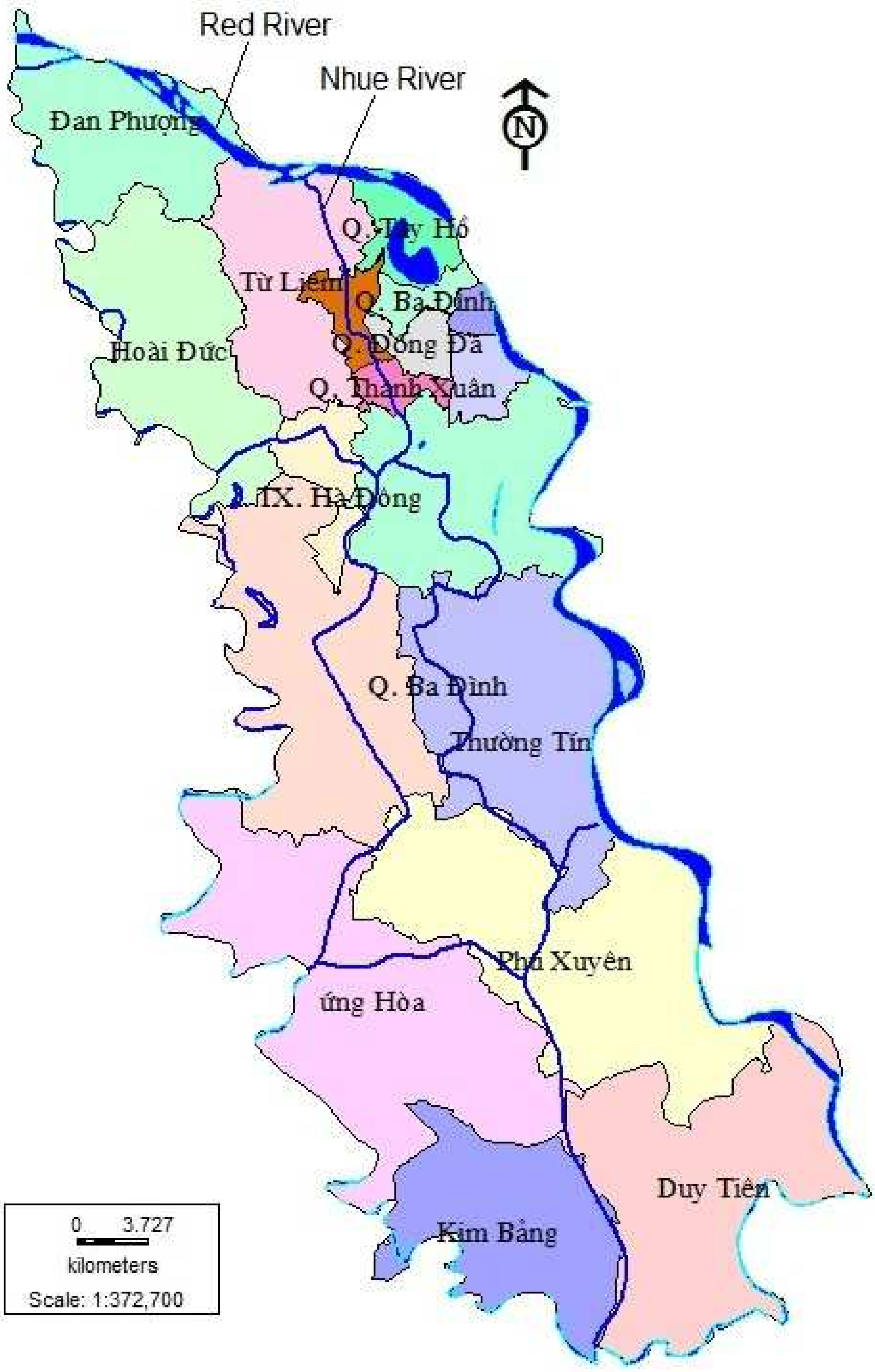


Fig. 1. Map of Nhue river and Nhue watershed with districts

Climate and hydrograph

The watershed is located in the sub-tropical region with 4 distinction seasons of spring, summer, autumn and winter. Average temperature is about 23 degrees. Annual rainfall in the watershed is from 1600 to 1700 mm (Table 1) and distributed unequally makes two different seasons, dry season from November to April and rain season from May to October. Very high rainfall concentrated from May to October causes exceeding water while very low rainfall in dry season, not enough water for some crops. Monthly evaporation ranges from 40 to 270 mm. In dry season, water balance can be negative because evaporation is exceeds rainfall while irrigation requirement for winter crops and young states of spring rice were very high.

	Month												Yearly
	1	2	3	4	5	6	7	8	9	10	11	12	
Phu Ly station													
Temperature (^{0}C)	16.7	18.0	20.4	24.5	26.9	29.0	29.1	28.1	27.0	24.8	21.4	17.8	23.6
Rain fall (mm)	20.6	27.6	47.0	44.4	243.0	175.6	307.2	315.2	376.0	174.5	36.8	48.0	1815.9
Relative humidity (%)	85.4	90.4	89.4	90.2	87.4	83.0	84.0	74.0	88.0	84.3	83.5	83.8	85.3
Evaporation (mm)	63.4	42.3	59.8	54.7	69.4	271.2	100.1	59.8	63.9	89.1	90.6	76.1	1040.4
Sunshine hour (hour)	64.0	150.2	47.6	94.8	175.6	172.2	180.6	158.4	155.4	140.8	140.8	96.8	1577.1
Ha Dong station													
Temperature (^{0}C)	16.8	16.6	20.7	24.3	27.0	29.0	29.0	28.1	27.1	25.0	21.5	17.9	23.6
Rain fall (mm)	18.0	28.2	43.6	59.2	226.4	250.8	317.8	328.2	196.6	87.8	30.0	29.0	1615.6
Relative humidity (%)	83.2	87.4	85.8	89.0	87.4	83.8	85.0	74.6	88.0	82.8	81.3	81.8	84.2
Evaporation (mm)	66.2	56.6	69.4	57.9	74.8	261.4	96.6	70.0	65.3	88.6	87.1	75.4	1069.3
Sunshine hour (hour)	62.0	46.6	45.4	83.8	145.4	142.4	157.6	145.2	148.6	136.3	137.0	97.3	1347.5

Table 1. Climate characteristic at Ha Dong (upper end) and Phu Ly station (lower end of river).

Ha Dong station is located at the upper end of the river Phu Ly station is located at the lower end of the river

River networks

Nhue River is bounded by three rivers: Red River, Day River and Chau River, flows from north to south with a distant of 76 km and has both functions of irrigation and drainage. The river takes water from Red river to irrigate for about 75-80% total water requirement of the basin and drainage for about 50-54% of the system

Ground water

Ground water in the basin strongly depends on the surface water sources, especially the water level in the Red River, the biggest river in the north and goes along the north east side of Nhue River. Ground water level and potential are fluctuated up and down as results from up and down of Red River water level. Ground water quality is also polluted because of receiving pollutants from surface water (ICEM, 2007).

Soil

Soil in the watershed can be classified as three main types of rusty spotted fluvisols distributed at the high locations, e.g. along the western parts with significant high content of ion and mangan that lateritic process happening, rusty spots can be formed with lower pH when dry; Eroded and impoverished soils distributed at the high level along Red River that can easily be eroded fine materials and nutrients; Red River old gleyed fluvisols distributed in the lower part in the south of the watershed that gley process can easily happen if drainage system is poor (Figure 2). The main characteristics of the soils are presented in Table 2

Soil properties	Soil types		
	Rusty spotted fluvisols	Eroded and impoverished	Old alluvial gleyed fluvisols
Soil depth (cm)	50	50	50
pH	5.5	5.5	6
OC (%)	2.04	1.72	2.43
Soil texture	Loam	Silt loam	Silty clay
Porosity (%)	46.3	50.1	46.4
Bulk density (kg cm^{-3})	1.32	1.34	1.30
Initial soil moisture content (%)	58	55	60
Infiltration Index	0.35	0.3	0.4
Initial infiltration rate (mm day^{-1})	145	72	32
Stable infiltration rate (mm day^{-1})	7.9	4.7	2

Table 2. Soil characteristics

Population

The population of the watershed is 4032884 in 2010 including 2527695 in the urban and 1505189 in the rural area. Very high population is in Hanoi capital with 2445861 (2194433 in the urban area and 251428 in the rural area). Because of quickly urbanization and industrialization in these provinces population of the watershed is increasing very fast. This increasing population strongly influences into the watershed water balance because a lot of surface water, ground water extraction and a huge amount of waste water contributed to the system, especially the big capital city with a lot of residential areas, industry, hospital, craft villages and agriculture activities (ICEM, 2007).

Land use

Detail land use types for three provinces are presented in Table 3. Dominated crop in the watershed is paddy rice (Figure 2) which grew in spring and summer season. Crops are grown in the rotation that can be a double crop as spring rice – summer rice; peanut – summer rice, can be a triple crop as spring rice – summer rice – winter maize; spring rice – summer rice – vegetable, can be year round non-rice annual crops (Table 4) as multi-vegetables that the farmer can have from three to seven harvests per year.

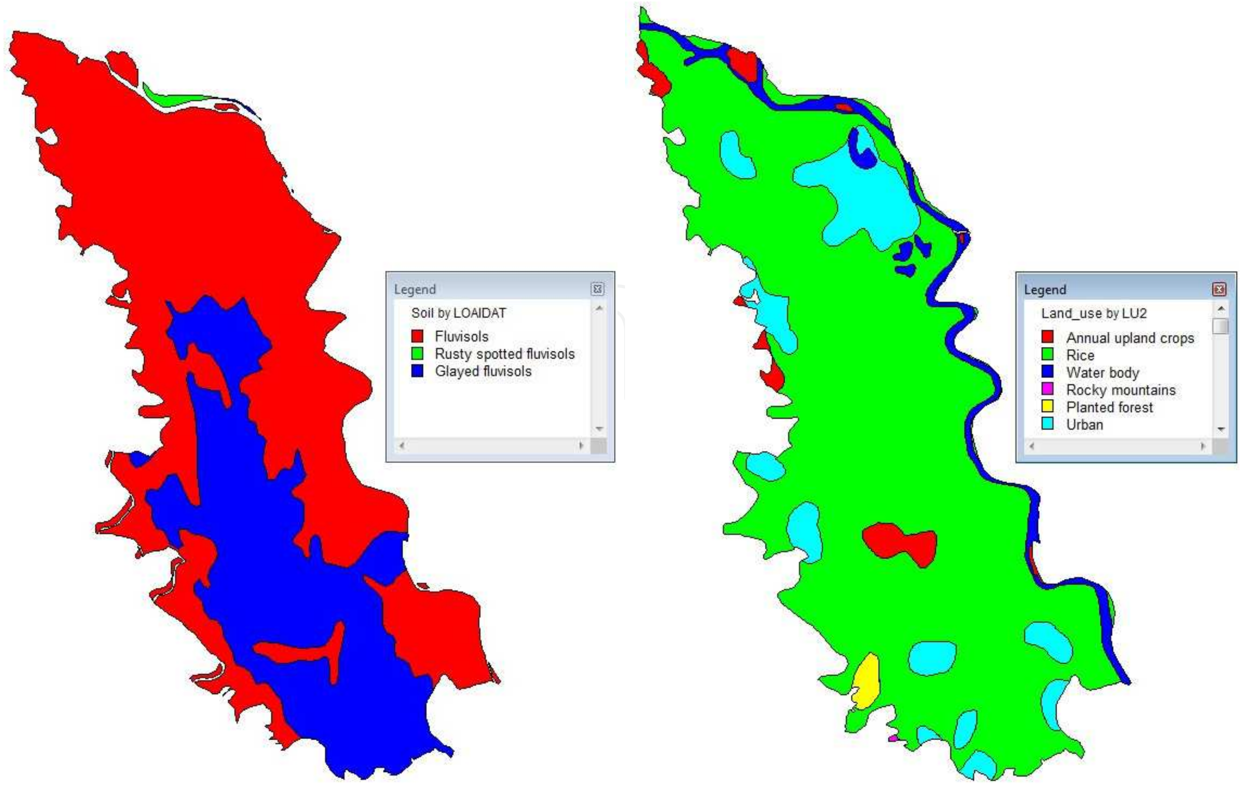


Fig. 2. Soil map (left) and land use map (right) of study area that many short non-rice annual crops hidden in the rice land use type

TT	**Land use**	**Provincial and total area (ha)**			
		Ha Noi	**Ha Tay**	**Ha Nam**	**Total**
	Natural area	25777.3	81315.1	22937.9	130030.35
1	*Agricultural land*	*7958.1*	*44779.6*	*13091.4*	*65829.1*
1.1	*Agricultural production*	5317.5	40140.7	10943.1	56401.4
1.1.1	Annual crops	4546.9	37361.7	9908.7	51817.4
1.1.1.1	Rice	2426.6	33188.1	9827.3	45441.9
1.1.1.2	Non-rice annual crops	2120.4	4173.6	281.5	6575.5
1.1.2	Perennial tree	770.6	2779.0	1013.6	4563.2
1.2	*Forestry*	0.0	0.0	0.0	0.0
1.3	*Aquaculture*	2508.5	3444.4	1808.1	7761.1
1.4	*Salt production*	0.0	0.0	0.0	0.0
1.5	*Other agricultural lands*	132.0	1194.5	1.0	1327.6
2	*Residence and special land*	*17557.5*	*35335.5*	*9803.7*	*62696.8*
3	*Non-cultivated land*	*261.7*	*1200.0*	*42.8*	*1504.4*

Sources: planning data from Hanoi city and Ha Nam province

Table 3. Main land uses in the watershed in 2010 (ha)

Sub-watershed	Irrigation unit	Province	District	Meteorology station	Spring rice (ha)	Maize (ha)	Soybean (ha)	Peanut (ha)	Sweet potato (ha)
1	Thanh Tri	Hanoi	Thanh Tri	Hanoi	1628	411	53	85	17
2	Hanoi center	Hanoi	NTHN	Hanoi	788	1365	0	0	0
3	Hong Van	Ha Tay	Thuong Tin	Hà Dong	6093	806	2255	161	262
4	La Khe	Ha Tay	TX Ha Dong	Hà dong	1841	88	44	41	74
			Thanh Oai	Ha Dong	6941	355	937	116	614
5	Phu Xuyen	Ha Tay	Phu Xuyen	Hung Yen	8544	742	8392	291	136
6	Ung Hoa	Ha Tay	Ung Hoa	Hung Yen	10869	827	3375	238	297
7	Dan Hoai Tu	Ha Tay	Dan Phuong	Hanoi	2049	1294	1602	2	155
		Ha Tay	Hoai Duc	Hanoi	3337	984	115	95	414
		Ha Tay	Tu Liem	Hanoi	1234	16	0	0	0
8	Huu Day	Ha Nam	Phu Ly	Phu Ly	1156	374	196	179	110
		Ha Nam	Kim Bang	Phu ly	5942	1730	514	337	338
		Hà Nam	Duy Tien	Phu Ly	6542	829	1014	277	181

Table 4. Distribution of annual crops in some districts in Nhue watershed

Current irrigation

Base on current topography and infrastructure, irrigation in the watershed can be classified as two types: irrigation by pumping to service of 16653 ha and semi pumping, that water can be free flow from the river to the field when river water level is higher than the field elevation and is pump to irrigate when river water level lower than the field elevation, with 55527 ha.

3.2 Irrigation

3.2.1 Irrigation for spring rice

Water requirements for spring rice are presented in Figure 3. Spring rice starts from the beginning of February and ends in the first and second weeks of June. The season before the spring rice season is the winter season that soil can be in many different land uses as fallow (for the double rice rotation, farmer plows the soil after harvesting summer rice); maize (in the rotations of rice-rice-maize), soybean, beans, and vegetables. The fallow soil is very dry before spring rice season but for triple rotation winter crops are harvested just before spring rice and soil still moist due to the irrigation during the crop. Because of that, soil moisture content is varied from soil to soil and crop to crop and a lot of irrigation water is needed for saturated and establish a water layer during land preparation before transplanting of spring rice.

Water balance and irrigation water were calculated and showed in Figure 4. The long dry period in the first half of season and high stable field water level require high irrigation in this period. Evapo-transpiration increases in the second half of season. ETc is highest at the flowering time, the last week of April and the first week of May when plant has maximum leaf area index. ETc is lowered in the maturing period until harvest time because of leaf elder, dying of the old leaf. However, rainfall in this period increases with some high rainfall events. As a result, irrigation is lowered with longer intervals. Figure 4 also shows that at some events with either high rainfall or high field water level. Water is succeeded and runs over the bunds (e.g. on the events of April 17, June 1 and June 14).

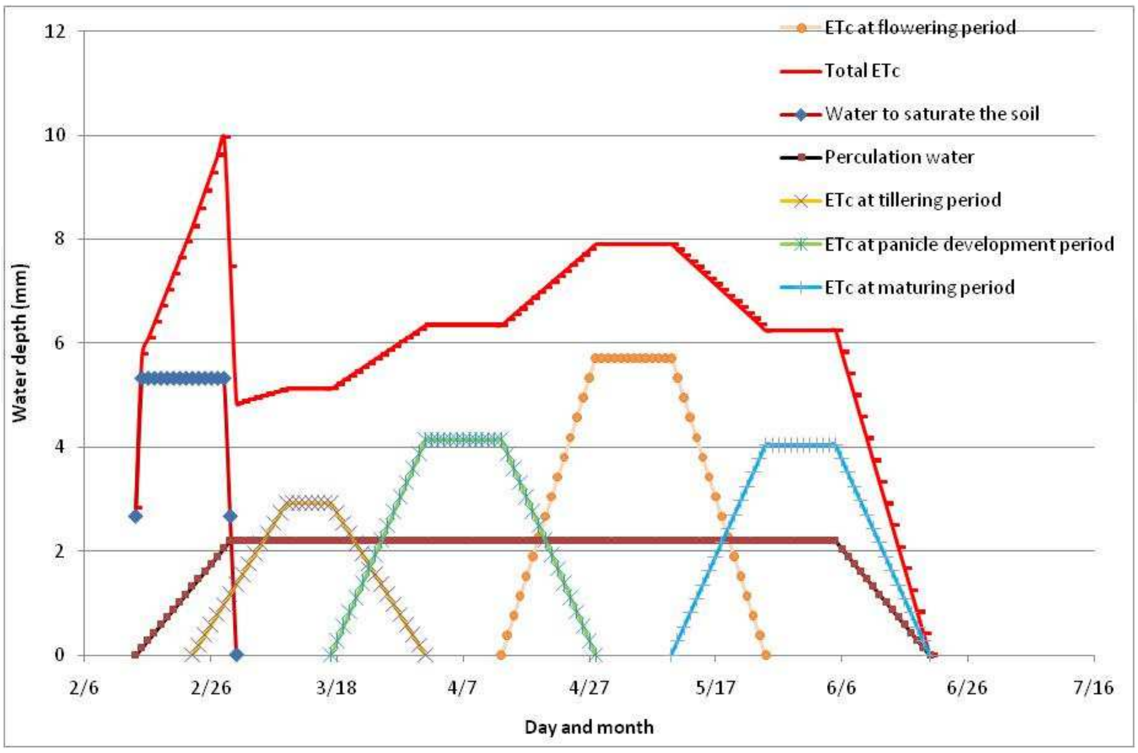


Fig. 3. Water losses for land preparation, percolation, and evapotranspiration of sping rice

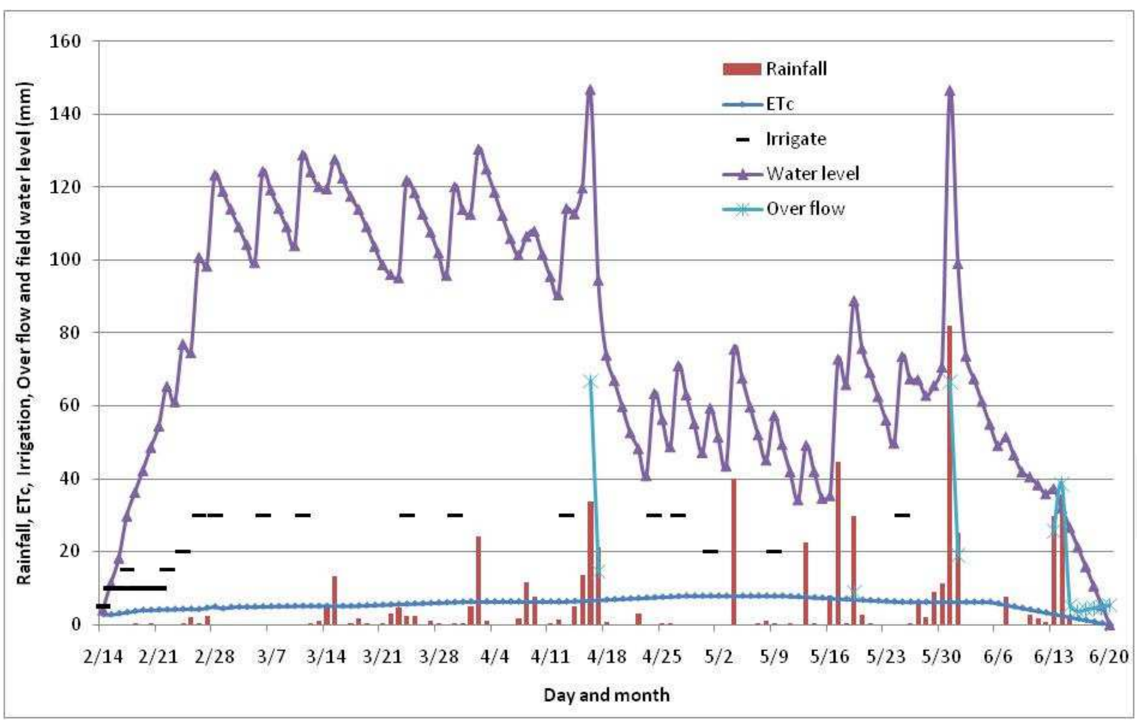


Fig. 4. Rainfall, ETc, irrigation water, field water level and overland flow for spring rice

Because summer rice is transplanted at an early in July, the intercrop time from harvesting spring rice to summer rice is shortness than a month. The longer this period the better for land preparation and decomposition of fresh organic matter from spring rice residue. Therefore, agronomists want to lengthen this period by shortening spring rice ripening period. Also, spring rice late ripening period, the time after silk ripening or about 10 days before harvesting, requires less and less water because of ending development. Farmer usually draws water out of the field in order to: shorten crop duration for harvesting on time; strengthen rice plant to avoid falling down in the heavy rain or storm/typhoon; harden the field surface easier for transportation (Pham Ngoc Hai et al., 2006).

3.2.2 Irrigation for summer rice

After harvesting spring rice in June land is plowed and harrowed immediately for summer rice. Because soil is already wetted and excessive rain water in this period, water for saturating the soil and creating flooded water layer is very low. Summer rice is transplanted in July and harvested at the end of September and early of October. This growing period is coin side with highest rainfall period of the year (about 30-40% of the annual rainfall during July-September period), soil is usually saturated and the field is usually flooded, because of that irrigation volume and intensity in summer rice is lower than the one in spring (Figure 5) rice.

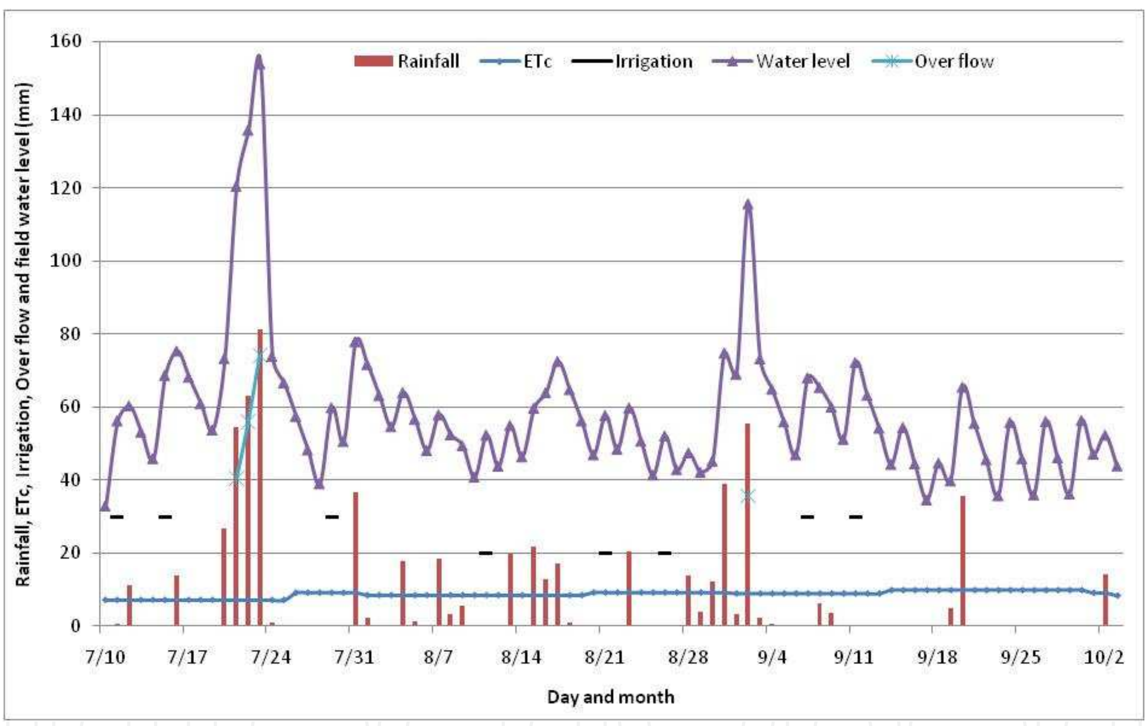


Fig. 5. Rainfall, ETc, irrigation water, field water level and overland flow for summer rice

3.2.3 Irrigation for non-rice annual crops

Non-rice annual crops or the upland crops, not planted in flood condition. However these crops need moist soil to grow.

Representative for these crops are soybean, sweet potato and maize grown in different seasons with different rainfall, Kc values and ETc (Figure 6). The condition for applying irrigation commands are soil moisture content drops lower than 65% of field capacity and soil moisture content should be best within 70 and 90% of field capacity. This parameter is measured by loggers at the hydrological stations, but in practice, it can be estimated and irrigation is considered after group discussion of water resource people, agronomist/extensionist and local management people.

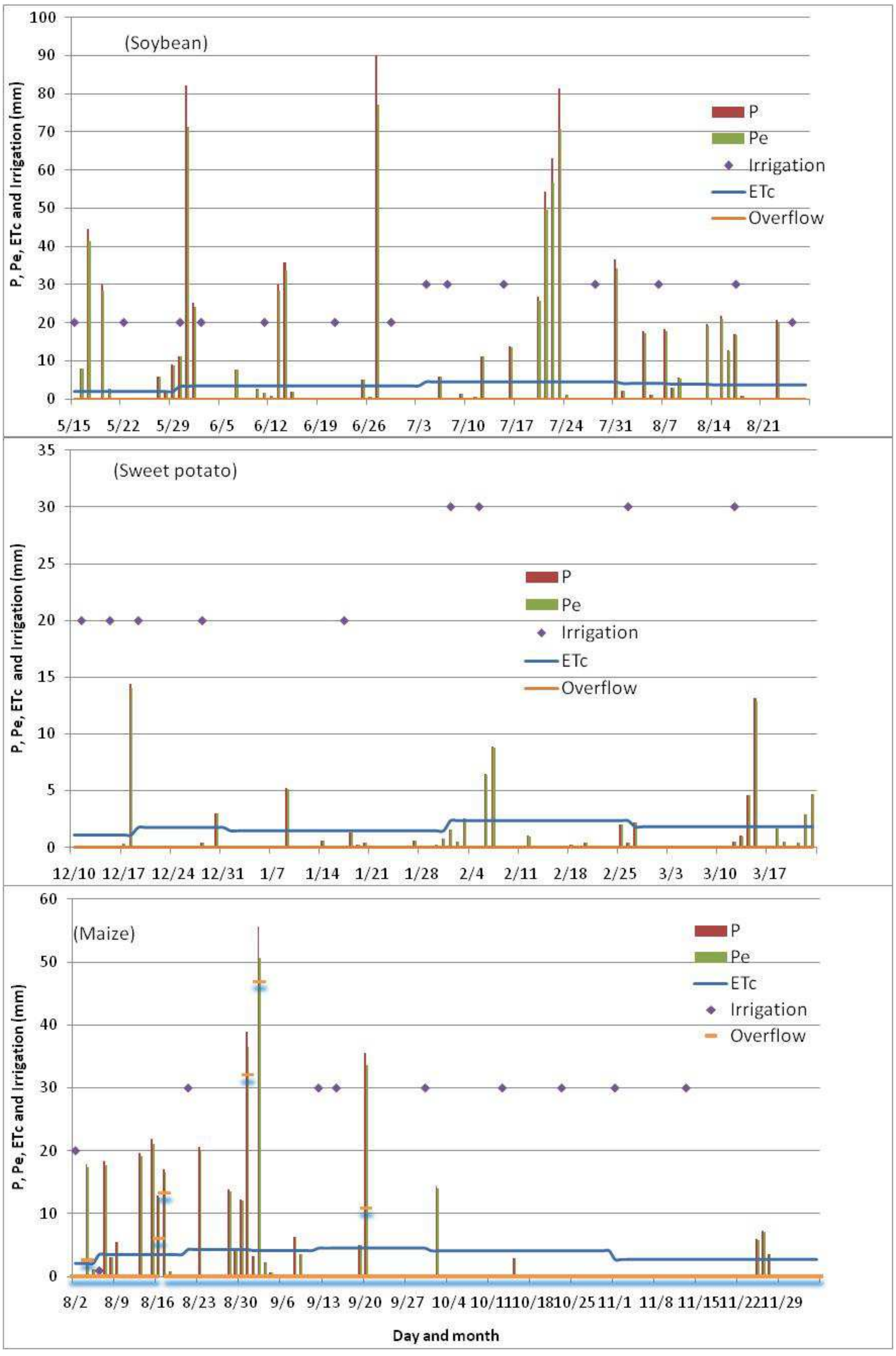


Fig. 6. Irrigation scheme for soybean, sweet potato and maize

3.2.4 Seasonal crop irrigation water

This water is summarized from all irrigation time during crop growing season, for example, total irrigation water of spring rice is summarized from water needed to saturate the soil, water needed to make a field water layer, for percolation, and water for evapo-transpiration. Summarizing the volume of irrigation water for whole crop is presented in Table 5.

Crop	Growing time	Water volume (m^3 ha^{-1})
Spring rice	Feb-Jun	4800
Summer rice	Jul-Oct	3400
Maize	Aug-Dec	2600
Sweet potato	Oct-Mach	2200
Soybean	May-Aug	1300

Table 5. Water needed for whole crop production (m^3)

3.3 Water quality

Physically, Nhue River takes fresh water from Red River, therefore, the river can re-clean itself after each irrigation time. However, the river flows through the capital and cities and many towns, villages, industrial factories, hospitals and craft villages containing strong point pollution sources. Especially, in recent two decades the increase of urbanization and industrialization in this basin rapidly increase the amount of pollutants to the river. Water quality becomes worse and worse (Trinh Anh Duc et al., 2006; Trinh Anh Duc et al., 2007; Thi Thuy Duong et al., 2007; and ICEM, 2007). The average daily discharge of waste water into the river is estimated as 2,554,000m^3 from agriculture and animal husbandry, 636,000 from industry, 619,000 from resident, and 15,500 from hospital, and especially waste water from To Lich river comes from the Hanoi city center with daily discharge of about 300,000-350,000m^3, excluding the disposal from cities and river side slowing down the river flow (ICEM, 2007).
There is a big different in water quality in spatial and temporal. In dry season concentration of all elements are very high because very low fresh water comes from Red river that can not help to clean polluted water in the river. pH from Table 6 also shows the tends it increases in rain season as a result from dilution. Many pollutants have concentration higher than Vietnamese standard line of water quality, for example, pH, Coliform, total nitrogen, total P in dry season. However, measurements results showed that concentration of all heavy metals are lower than the standard line in both dry and wet seasons.

3.4 Estimation the mass of pollutants to the field

A mass of pollutants was calculated as product of total discharge and pollutant concentration. Pollutant concentration is complicated to determine because it varies spatially and temporally. It can be diluted by fresh water from Red River and rain water but it can also be more concentrated because of contribution of pollutants from many pollution sources as urban, industries, hospitals, craft villages and other activities. Dynamically, pollutants can easily be transported from upstream to downstream and always high concentration at the downstream of the watershed. Water in the river can be re-cleaned after rainfall but it will quickly be high concentration because of ever flows from pollution sources in industrialized and urbanized centers. In practice, irrigation is take place when only the soil is dried or long time after raining; it means the dilution effect is very small or insignificant. Because of that pollutant concentration for mass calculation in this study is distinguished as concentration in dry season and the one in rain seasons as presented in Table 6. Then the mass of pollutants will be calculated as product of total irrigation water and pollutant concentration (either in dry or rain season depend on the crop calendar, dry season from October to April and the rain season from May to September) and shown in Table 7.

Position	pH	EC* µS cm^{-1}	BOD_5 mgl^{-1}	COD mgl^{-1}	Coliform MPN/ 100ml	N_{tot} mgl^{-1}	P_{tot} mg l^{-1}	Cu mg l^{-1}	Pb mg l^{-1}	Hg mg l^{-1}	Cd mg l^{-1}
March 2010											
Lien Mac	7.5	4.15	9.6	22.4	110000	20.16	12.104	0.0154	0.0013	<LOD	0.00021
To bridge	7.31	6.46	70.4	51.2	460000	12.32	13.699	0.0058	0.0012	<LOD	0.00013
Nhat Tuu	7.17	5.32	16	26.4	1500	22.4	7.965	0.0192	0.0044	0.00013	<LOD
July 2010											
Lien Mac	8.94	178	4.8	8.6	90	4.81	0.60	0.0058	0.0012	<LOD	0.00013
To Bridge	10.56	252	32	56	210	5.6	0.86	0.0154	0.0013	<LOD	0.00021
Nhat Tuu	10.39	324	44	64	4600	7.20	1,35	0.0192	0.0044	0.00013	<LOD
TCVN: A	6-9		30	50	3000	5	4	2	0.1		0.005
B	5.5-9		50	80	5000	10	6	2	0.5		0.01

Note: March in dry season, July in rain season. Lien Mac, To bridge and Nhat Tuu are upstream, middle and downstream points along Nhue river, TCVN 5945-2005 is Vietnamese water standards for drinking (A) and irrigation (B). * Electrical conductivity

Table 6. Spatial and seasonal water quality of Nhue river

Position, crop	BOD_5	COD	Coliform	N_{tot}	P_{tot}	Cu	Pb	Hg	Cd
Lien Mac (upstream)									
Spring rice	46.08	107.52	5280000	96.768	58.0992	0.07392	0.00624	NS	0.001008
Summer rice	16.32	29.24	306	16.35	2.04	0.01972	0.00408	NS	0.000442
maize	12.48	22.36	234	12.506	1.56	0.01508	0.00312	NS	0.000338
Sweet potato	21.12	49.28	2420000	44.352	26.6288	0.03388	0.00286	NS	0.000462
Soybean	6.24	11.18	117	6.253	0.78	0.00754	0.00156	NS	0.000169
To (middle)									
Spring rice	337.92	268.8	1008	26.88	4.128	0.07392	0.00624	NS	0.001008
Summer rice	108.8	190.4	714	19.04	2.924	0.05236	0.00442	NS	0.000714
maize	83.2	145.6	546	14.56	2.236	0.04004	0.00338	NS	0.000546
Sweet potato	154.88	123.2	462	12.32	1.892	0.03388	0.00286	NS	0.000462
Soybean	41.6	72.8	273	7.28	1.118	0.02002	0.00169	NS	0.000273
Nhat Tuu (down stream)									
Spring rice	76.8	307.2	22080	34.56	6.48	0.09216	0.02112	0.000624	NS
Summer rice	149.6	217.6	15640	24.48	4.59	0.06528	0.01496	0.000442	NS
maize	114.4	166.4	11960	18.72	3.51	0.04992	0.01144	0.000338	NS
Sweet potato	35.2	140.8	10120	15.84	2.97	0.04224	0.00968	0.000286	NS
Soybean	57.2	83.2	5980	9.36	1.755	0.02496	0.00572	0.000169	NS

NS: not significant

Table 7. Mass of pollutant from irrigated water to the field (kg ha^{-1}season^{-1}) at upstream, in the middle and downstream positions

There are quite high mass of BOD_5, COD, coliform, total nitrogen, total phosphorus from Nhue river applied to the field in the watershed throughout irrigation as results from polluted sources. Adding of BOD_5, COD and coliform are the negative to the soil environment but nitrogen and phosphorus may have some positive effects because they provide more nitrogen and phosphorus nutrients to the soil for plant to grow. At some locations and time very high N and P was irrigated e.g. spring rice and sweet potato in the upstream of the river or rice, maize and potato in the downstream of the river where pollutants accumulated most of the time at the downstream of the river. There are about 0.02 to 0.09 kg ha^{-1} of Cu irrigated to the field in each crop (with highest amount in spring rice field in Nhat Tuu); from 0.002 to 0.02 kg ha^{-1} of Pb irrigated to the field (with highest amount of 0.02 in spring rice in Nhat Tuu; amount of irrigated Hg is insignificant at the upstream and middle but significant at the downstream. In contrast to Hg, amount of Cd irrigated to the field is significant at the upstream and middle but insignificant at the downstream. Because heavy metal concentration is lower than standard line for irrigation water, so that its amount can be considered that safe to the environment. However, the long term accumulation of these elements can be harmful to the soil, environment, product and people.

5. Conclusions

Nhue river is one of the important river and watershed in Vietnam because it irrigates and drains for more than 100000 ha of agricultural land of three provinces and drains most of the waste water for Hanoi capital and two other provincial towns with hundred of industrial, urban area, hospital, craft villages and intensive agriculture. From research results we can draw some conclusion follow:

Water quality of the river is degrading very strong with high content of BOD_5, COD and Coliform that threatening soil and water quality and people health of the whole watershed. Heavy metal concentration in the river water is still lower than the standard line. However, river water strongly impact on environment because it relates to people activity and agricultural production. Mass pollutant calculation showed that on the other side of positive effects of providing nitrogen and phosphorus from polluted irrigation water there are many negative impacts of long term accumulation of BOD, COD, coliform and heavy metal in the soil and water that can be serious problems in the future. One of the reason is there are many continuous pollution sources from urban and industry to release pollutants to the river water and spreading to the field causing soil and water degradation. The Government should have strong action to control the pollution sources and clean the environment for sustainable development.

6. References

Dang Duc Nhan, F.P. Carvalho, Nguyen Manh Am, Nguyen Quoc Tuan, Nguyen Thi Hai Yen, J.-P. Villeneuve, C. Cattini, 2001, Chlorinated pesticides and PCBs in sediments and molluscs from freshwater canals in the Hanoi region, *Environmental Pollution*, Vol.112, pp. 311- 320

FAO, 1998, Crop evapotranspiration - Guidelines for computing crop water requirements - *FAO Irrigation and drainage paper 56*. Food and Agriculture Organization of the United Nations, Rome.

Gardi, C. (2001). "Land use, agronomic management and water quality in a small Northern Italian watershed." *Agriculture, Ecosystems & Environment, Vol.* 87 No.1, pp. 1-12

He, C. (2003). "Integration of geographic information systems and simulation model for watershed management." *Environmental Modelling & Software* Vol. 18, No. 8-9, pp. 809-813.

ICEM, 2007, Day/Nhue river basin pollution sources study. Improving Water Quality in the Day/Nhue River Basin, Vietnam: Capacity Building and Pollution Sources Inventory, ministry of natural resources and environment, 155 pp.

Karr, J. D., W. J. Showers, et al. (2003). "Low-level nitrate export from confined dairy farming detected in North Carolina streams using 15N." *Agriculture, Ecosystems & Environment,* Vol. 95 No.1, pp. 103-110.

Kraft, G. J. and W. Stites (2003). "Nitrate impacts on groundwater from irrigated-vegetable systems in a humid north-central US sand plain." *Agriculture, Ecosystems & Environment,* Vol.100, No.1, pp. 63-74.

McDowell, R. W., A. N. Sharpley, et al. (2003). "Modification of phosphorus export from an eastern USA catchment by fluvial sediment and phosphorus inputs." *Agriculture, Ecosystems & Environment* Vol. 99, No. 1-3, pp. 187-199.

Nikolaidis, N. P., H. Heng, et al. (1998). "Non-linear response of a mixed land use watershed to nitrogen loading." *Agriculture, Ecosystems & Environment, Vol.* 67, No.2-3, pp. 251-265.

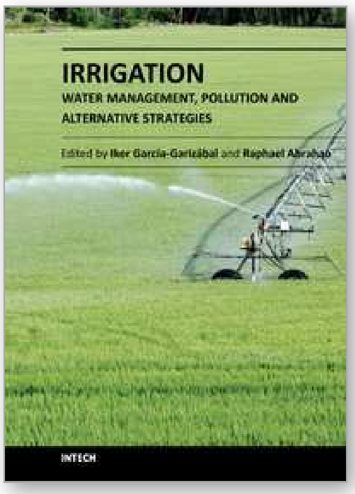
Pham Ngoc Hai, Tong Duc Khang, Bui Hieu and Pham Viet Hoa, 2006, irrigation and irrigation regimes for crops, *plan and projection of irrigation systems*, Construction Publishing House, pp. 46-93 (in Vietnamese)

Thi Thuy Duong, Agne`s Feurtet-Mazel, Michel Coste, Dinh Kim Dang, Alain Boudou, 2007, Dynamics of diatom colonization process in some rivers influenced by urban pollution (Hanoi, Vietnam), *Ecological Indicators* Vol. 7, pp. 839–851

Trinh Anh Duc, Marie Paule Bonnet, Georges Vachaud, Chau Van Minh, Nicolas Prieur, Loi Vu Duc, Le Lan Anh, 2006, Biochemical modeling of the Nhue River (Hanoi, Vietnam): Practical identifiability analysis and parameters estimation, E*cological Modelling*, Vol. 193, pp. 182–204.

Trinh Anh Duc, Georges Vachaud, Marie Paule Bonnet, Nicolas Prieur, Vu Duc Loi, Le Lan Anh, 2007, Experimental investigation and modelling approach of the impact of urban wastewater on a tropical river; a case study of the Nhue River, Hanoi, Viet Nam, *Journal of Hydrology*, Vol. 334, pp. 347– 358

Zhang, J. and S. Erik Jorgensen (2005). "Modelling of point and non-point nutrient loadings from a watershed." *Environmental Modelling & Software* Vol. 20, No. 5, pp. 561-574.



Irrigation - Water Management, Pollution and Alternative Strategies
Edited by Dr Iker Garcia-Garizabal

ISBN 978-953-51-0421-6
Hard cover, 234 pages
Publisher InTech
Published online 28, March, 2012
Published in print edition March, 2012

Irrigated agriculture is the most significant user of fresh water in the world and, due to the large area occupied, is one of the major pollution sources for the water resources. This book comprises 12 chapters that cover different issues and problematics of irrigated agriculture: from water use in different irrigated systems to pollution generated by irrigated agriculture. Moreover, the book also includes chapters that deal with new possibilities of improving irrigation techniques through the reuse of drainage water and wastewater, helping to reduce freshwater extractions. A wide range of issues is herein presented, related to the evaluation of irrigated agriculture impacts and management practices to reduce these impacts on the environment.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821