PROJECT OVERVIEW

Covering a catchment of over 117,000 km^2 populated by 20 million people, the Red River system is facing global change via competing interests - economic, agricultural, environmental and urbanization, especially in the context of the 'Open Policy' of transition economy. Today, the coastal zone of the system is in serious trouble.

- It has suffered from flooding, storm surges and extreme events, along with changing water quality and declining fish production.
- Habitats are declining; some native species are listed as endangered, especially migratory birds, e.g. Black-faced Spoonbill.
- Mangroves are effective as buffers for sea dyke protection, but continuous conversion of the mangrove to aquaculture continues, while there are many sea dykes structurally week and in a high risk of failure.

Reasons to care

- The Red River delta is the second largest river system in Vietnam, and is home to many aquatic and terrestrial plants and animals.
- The system is vulnerable to failure, especially due to flooding during the typhoon or monsoon season, which causes serious damage to people and properties.
- Thousand of shore birds migrate through and live in the coastal areas, and hundreds of fish species and valuable marine products are found there.
- The system contributes over 30 % of national' Gross Domestic Product (GDP)' in terms of agriculture, forestry and fishery.
- The Hoa Binh Dam which covers over 200 km^2, is the nations biggest hydroelectric power generator, but its impact has not been estimated for the Delta environment.

Relevance to LOICZ and SARCS

- Contributing directly to the goals of LOICZ focus 4 - 'to develop integrated models, scenarios and/or forecasts for a specific area or system, encompassing both natural and social driving forces of change'
- Contributing to the SARCS Immediate Objective 2 ' to integrate natural-social science assessment of changes in the coastal zones of the SACRS region'

Results of this study form the basis for future integrated management of the coastal areas and development of capacity building and regional/international contribution of local expertise.

A new approach

The SARCS/WOTRO/LOICZ program represents a new approach to model human-induced environmental change in the coastal zone. A basis for the linkage of the biogeochemical or budget models with the ecological process models and with the economic models has been provided by guidelines resulting from discussions of program's workshops. Two conceptualized interacting subsystems have been accessed into the framework. The environmental subsystem comprises the biogeochemical processes, whereas the economic subsystem comprises all the economic activities taken into consideration, as shown in the figure below.

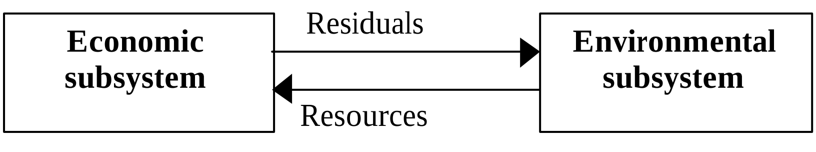


Figure 1. Conceptual integrated model for the coastal zone

Vietnam

We attempt to construct a regional Input-Output (I-O) table with the view of providing an appropriate and effective analytical device for I-O modelling approach, which can be usefully applied up to the scale of a regional I-O model. Residual generation could then be predicted (C, N and P) for a geographical set of economic activities and population settlements under a number of different economic growth scenarios (Turner 1997).

The economic subsystem is described on the basis of an economic input-output model, which relates final demand to production in the sectors under consideration. The final demand depends on, among other factors, household consumption, policy intervention, economic growth and demographic change. The impact of each economic sector is expressed in terms of its residual output. This forms the basis for the linkage between the economic and environmental models.

Main results

- A set of information on natural and socio-economic pressures to the coastal zone has been collected and collated in order to serve the multidisciplinary research and analysis of Pressures-Impacts-State-Responses.
- Water, salt, C, N and P generated from natural and economic activities have been estimated in terms of budgets and fluxes, and one-box models for seasonal and annual balance of the residuals have been developed using LOICZ methodology.
- The biogeochemically dynamic processes were modelled using the Stella 2 and computation methods.
- The regional Input-Output (I-O) table was constructed and economic-environmental coefficients were developed by using WHO rapid assessment method and national monitoring network for estimating economic residuals from eleven economic sectors and household consumption.
- The feedback of the residuals has been initially tested, and the increased rates of residuals along with three scenarios of economic growth by sectors have been simulated.

SYNTHESIS REPORT

1. DESCRIPTION OF THE SITE

1.1. Geological history and coastal morphology

1.1.1. Sediment features: The coastal zone of Red River Delta (RRD) stretches from Do Son to Lach Tuong with he length of 145 km, the width 500 m in Van Ly to 15,000 m in Ba Lat. The total mudflat area is 452,000 ha of which the upper mudflat (188,000 ha) is covered partly by mangroves. The system carries to the sea 144 m^3 of water and 114 million tons of alluvium which are divided between branches of the distributaries such as: Luoc River: 10-15 %; Tra Ly: 10-15 %; Cua Day (Nam Ha):30-40 %; Cua Ba Lat: 40-45 %. Sediments flowing through the Ba Lat mouth create the largest mudflat, with an upper area of 9,412 ha and a lower area of 5,513 ha (see Map 1).

Table 1.1. Elevation (m) and deposition rate in the coastal area (cm per year)

Elevation (m)	Deposition rate (cm per year)
≤ 0 m (Oceanographic map)	1.5 - 4
0 - 1.85	1 - 3
1.86 - 2.5	5 - 20
2.6 - 3.5	1 - 3
> 3.5	< 1

The horizontal extension of the coastal area is estimated to be 345 ha per year for the upper mudflat and 200 ha per year for the lower one. However erosion occurs, at the rate of 2.65 m per year for the upper mudflat and 3.09 m per year for the lower one in Van Ly for instance. Suspended particles have been seen 20 -25 km off the coast of the Day river, Ba Lat and Do Son. Salt intrusion into the river is estimated at 10-15 km, even to 15-20 km in the Van Uc mouth in winter. Salinity may be as low as 0.1 % - 0.4 % in the rainy season in the Day River, Ba Lat and Van Uc.

Sediment is mobilized by the mixing forces of tidal and river flows and waves. Clay sediment is predominantly deposited from suspension of muds which are rich in ions such as Fe^{3+} Al^{3+} , Mn^{2+} and argyles. The soil comprises 1-5 % of diameter >0.1 mm; 5-10 % of 0.1 - 0.01 mm; 15-30 % of 0.01 - 0.001 and 15-30 % of argyles. The Red River mouth has rapid deposition of sediment, without a green-gray layer on the surface of sediment. In the lower mudflat, it is mainly sands with a lot of shell. Soil structure is characteristic of sediments with 10-15 % of diameter <0.1 mm; 20-24 % of 0.1 - 0.01 mm; 1- 5 % of 0.01 - 0.001 mm; and 0-10 % of < 0.001 mm.

1.1.2. Coastal morphology: The coastal zones of the Red River Delta are gradually rising due to the deposition of sediments and alluvium. The mangrove also contributes to the process by trapping sediments through its root systems. Topographic features depend on tidal range of each river mouth and can be divided into the following landscapes:

a. *Upper mudflat covered partly by mangroves*: This is located from the mean tide level up to the upper limit of tidal water. The elevation is from 0-2.5 m compared to 0 m on the terrestrial map. Mudflats of which the lower edges are mainly covered by mangroves dominate the area. Besides mangroves, *Cyperus* can be found, reeds and other grasses in upper areas. The area is most productive in biological processes by being exposed to the sun during the low tide. About 50 % total area of mudflat or 250,000 ha are inundated during spring tide for 2 -3 hours. This area has a large potential for mangrove reforestation.

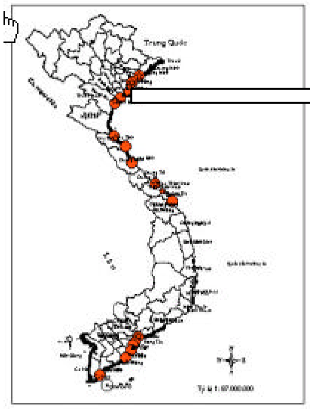
b. *Lower mudflat*: The elevation ranges from 0 m (oceanographic map) to the mean tide level. The area is frequently inundated during the neap tide. It is exposed from 2 to 6 hours and inundated 16 - 18 hours per day during the spring tide. Mangroves cannot developed. Based on the ground formation, this area can be divided into the following two categories:

Vietnam

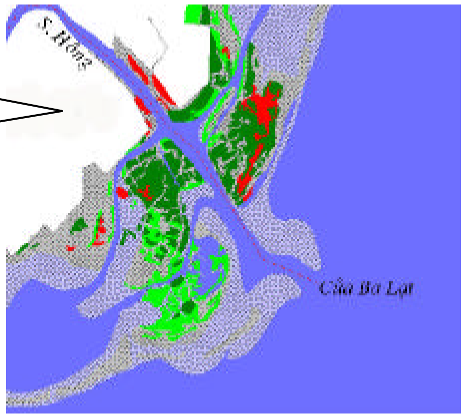
- *Lower mudflat with fine sand*: The area is located within the river mouths and affected by strong flow and wave action directly from the sea. It has high potential for supplying feeding grounds and shelters for shellfish culture including gastropod and bivalve mollusks such as cockles, clams and snails.
- *Lower mudflat with muddy clay*: The area is located in lower flat with low dynamic forces closing to mangrove swamps. It is usually developed along the coast or situated around small islands. There are a lot of benthic species providing a favorable habitat for shrimp, fish and crab culture.

c. *Small sand-islands in river mouth*: These are formed from sand carried in from rivers, then coastal flow and wave action creates small barriers located on both sides of the river mouths. The small sand islands emerge gradually depending on whether it is the dry or rainy season. The islands are usually elongated parallel with coast line and covered by mangrove pioneer species. The newly-formed islands are very favorable to fisheries and mangrove forestation.

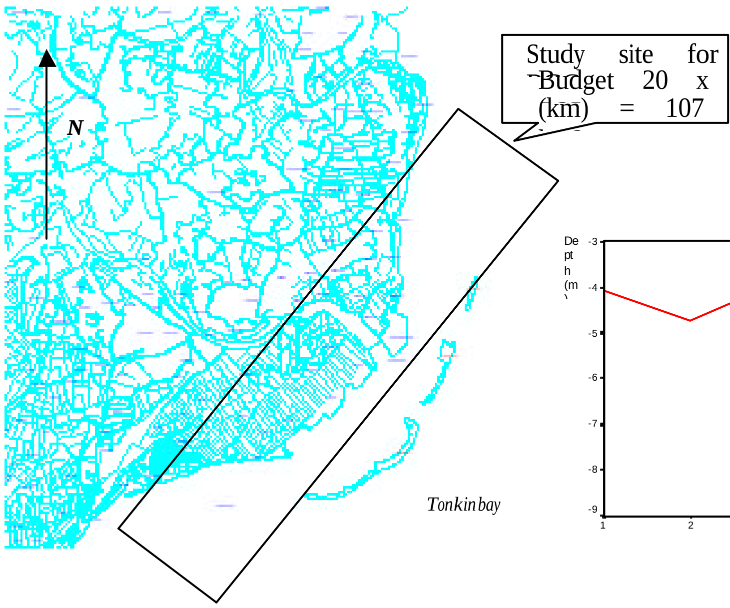
d. *Tidal canal systems*: They are usually water canals which also carry sediments. There are two types of tidal canals. The first one is called "erosion canals" elevated over 0 m on OM (Oceanographic Map) and the other is called "successive erosion canals" deeper than 8-9 m for transportation.



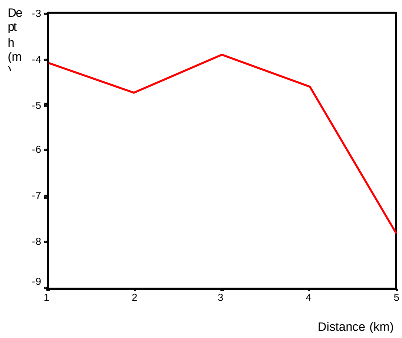
Hot spots in coastal zones of Vietnam



Satellite image of the Red River coasts and mangroves (green)



Map of the study site in the estuary within its creek system



The mean depth along the length of the estuary

Map 1. The Red River delta coastal system.

1.2. Climate features

The climate in the Red River Delta (RRD) is typical tropical monsoon climate, in which the cold winter is rather wet and humid at the end of the season and the summer is hot with plenty of rain (Figure 1.1). The most constant problems in RRD are natural catastrophes occurring each year associated with heavy rain and strong winds which cause damage in the coastal area in June, July and August.

The mean annual temperature is about 23-24 °C. The difference between winter and summer is about 12 °C. The extreme minimum is occasionally recorded at about 4-5 °C. Hoarfrost or rime is rare, but it causes a lot of damage to vegetable crops, especially in their young stages.

The coastal area is usually affected by typhoons and storms during July-October in which most of the danger is associated with strong winds with a velocity of 40-50 m/s accompanied heavy rain of 200-300 mm per hour. The rainfall can total 400-500 mm per hour during storms. On average, the storms constitute 25-30 % of total rainfall in summer.

Table 1.2. Climate data recorded in RRD hydro-meteorological station in Nam Dinh province.

Temperature (T °C)	**Records**	**Rainfall (mm)**	**Records**
Annual average T °C	23.5	Annual rainfall	1,671
Highest T °C in month	29 (Jul.)	Number of rainy days	134
Mean extreme high T °C in month	32.5 (Jun., Jul.)	Rainfall in highest month	309 (August)
Mean extreme low T °C in month	14.3 (Jan.)	Rainfall in lowest month	25 (Feb.)
Extreme highest T °C	40.1	No. of rainy days in highest month	15 (Feb.)
Extreme lowest T °C	5.8	No. of rainy days in lowest month	7 (Dec.)
Annual amplitude T °C	12 - 13	Diurnal maximal rainfall	350
Diurnal amplitude T °C	6.0	Annual minimal rainfall	978

The average rainfall is 1,600-1,800 mm per year with rainy days of 130-140 per year. The rainy season occurs during 6 months from May to October with 85 % of total annual rainfall.

The maximal rainfall occurs in August with 16-18 rainy days or 300-350 mm. It may vary over 500 mm during 10-20 % of the observed years. The annual average humidity is 82-85 %. The total solar radiation through a year is about 1,600 - 1,700 with 150 sunny hours in the summer months.

The period of frequent typhoons is from July to October of which the most occur in August. The average number of typhoons in the Red River Delta during 55 years (1911 - 1965) are 1 in May, 2 in June, 9 in July, 13 in August, 10 in September and 5 in October. The typhoons create a very strong wind along with heavy rain. The maximum wind velocity and rainfall are also recorded during the typhoons. In the coastal area, the wind velocity may reach 40-50 m/s, which is gradually reduced to 30-35 m/s for landward areas.

There are a lot of tropical storms in the Red River Delta. Around 90 - 100 storm days are recorded each year. They occur mainly in summer (from May to October) with 20 -25 storms each month on average. However at the beginning and the end of winter, there are also 4 -5 storm days each month.

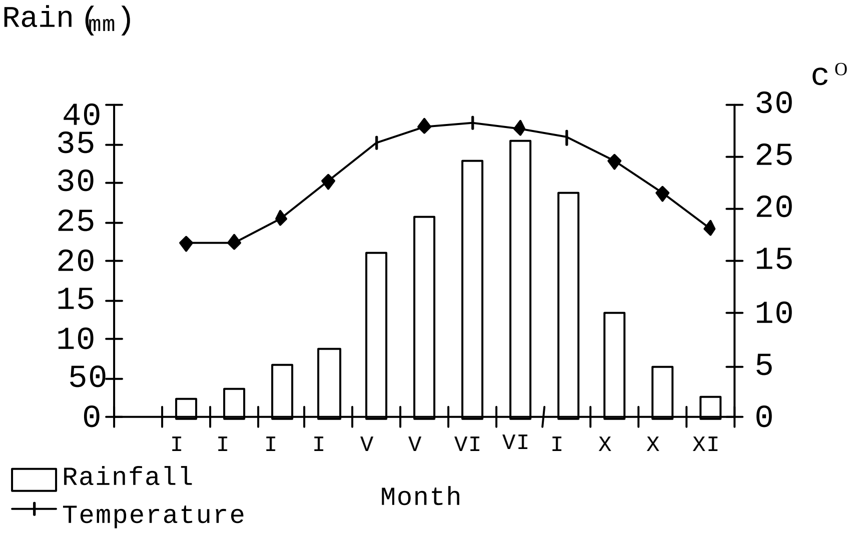


Figure 1.1: Climatic chart for the Red River Delta. Note: This chart is based on records of temperature in periods of 1904-1944; 1967-1970, rainfall in periods of 1904-1944; 1957-1970. The average values of rainfall and temperature were calculated within the long periods.

1.3. Catchments

The Red River is a second longest river in Vietnam after the Mekong. It originates in the Van Quy Highlands of South China and has many branches when coming into the country. The catchment area is about 117,700 km^2 with total annual water volume of 119.72 km^3. There are three main sub-river systems namely Da, Thao and Lo-Gam. The Thao is longest river in the system with length of about 1,126 km. In the northern plain, the Red River and Thai Binh River systems link together by many canals or sub-rivers. Water discharges from Red River into the sea through many river mouths. Hydrological features of the Red River system, including the downstream part in Vietnam, are presented in tables 1.3 and 1.4.

Table 1.3. Red River system and its hydrological features.

Sub-river systems	Rivers	Length (km)	Area of catchment (km^2)	Annual water volume (km^3)	Flow velocity (m^3/s)
Da	Da, Nam Na, Nam Muc, Nam Mu and Nam Bu	570	26,800	59.42	1,880.0
Thao	Thao, Bua and Thia	1,126	51,900	28.40	900.0
Lo - Gam	Lo, Gam, Chay, Pho Day, Mien, Nho Que and Nang	470	39,000	31.90	1,010.0
Total		**2,166**	**117,700**	**119.72**	**3,790**

The hydrological regime of the Red River has also two seasons. They are called “exhausted” or dry and “flooding” seasons. The flooding season lasts about 6 months from June to November in the upstream area; 5 months from June to October in the downstream area. In this season, the water-flow discharges about 80 to 85% of annual total. The run-off is very high with maximum value possibly up to 17,200 m^3/s in the Da River, 21,800 m^3/s in the Thao River and 14,000 m^3/s in the Lo River.

Table 1.4. Data of hydrological features collected from main stations by provinces in the catchment area.

Stations	River	Water level (cm)			Runoff (m^3/s)		
		January	July	year	January	July	year
Laichau	Da	7027	7695	7232	383	2750	1110
Hoabinh	Da	1421	1903	1588	544	4070	1690
Laokai	Hong	7494	7668	7564	231	956	526
Yenbai	Hong	2461	2690	2568	328	1310	768
Ghenhga	Lo	1704	2066	1843	242	1670	760
Thacba	Chay	2042	2222	2111	74.9	388	194
Sontay	Hong	592	1083	781	1270	7630	3560
Hanoi	Hong	320	793	504	1040	5590	2710

Suspended sediment concentration in river water is very high. In the flooding season, this value is up to 4.86 kg/m^3. Annual variation of water and sediment flows in some main rivers of the Red River system is presented in the figures 1.2 and 1.3.

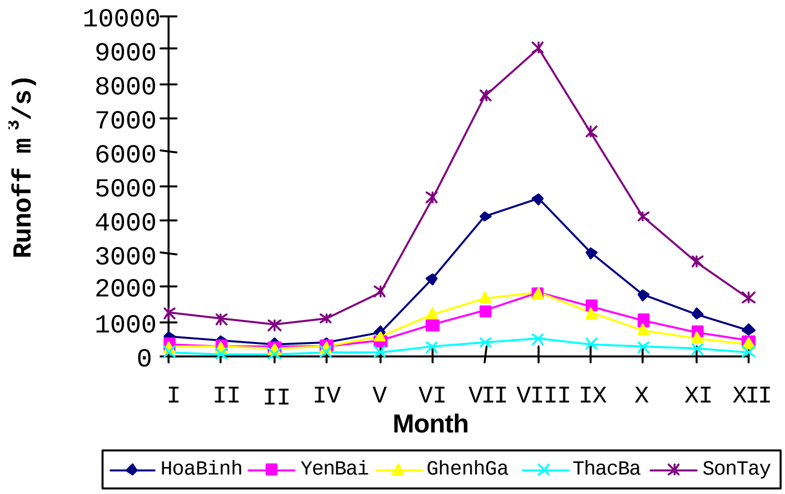


Figure 1.2. Annual variation of run-off in the Red River system.

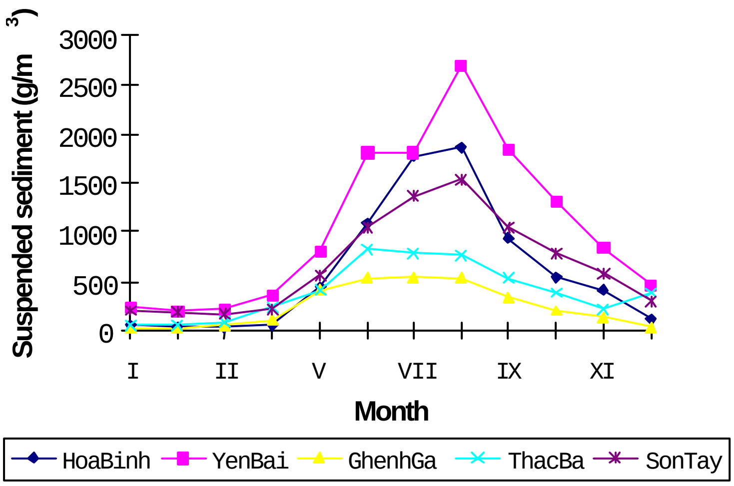


Figure 1.3. Annual variation of suspended sediment in the Red River system.

Vietnam

In the context of the SWOL core project, the research site chosen in Vietnam is an area of mangrove reserves in the coastal zone of Xuan thuy district, Nam dinh province. This is the mouth of the Balat, the biggest estuary in the North Vietnam.

1.4. Mangroves and sea grasses

The mangrove: There are 26 species of mangrove found in the coastal zones, covering over 30,000 hectares. In the past a luxurious cover of mangroves existed in the area. Due to under-valuation of this resource, a major part of the mangrove forest has been reclaimed and converted to agriculture, especially aquaculture ponds in recent years. Almost all the mangrove was cut down due to these activities. The rehabilitation of the mangrove was started in 1991 as a result of great efforts from national and international projects. One third of the area has been replanted, dominated by *Kandelia candel* and *Sonneratia caseolaris*. However, the mono-plantation of *Kandelia candel* is facing problems with respect to changing climate, gradual elevation of mudflats, diseases and other factors.

Some bio-ecological parameters of *Kandelia candel* presented in Table 1.5 show that the forest is still young and very important to the ecological processes of the system in terms of primary production and nutrient cycle.

Table 1.5. Growth rate, biomass and litter production of the mangrove forest

Growth rate	Age							
	1	2	3	4	5	6	7	8
Height (cm per year)	30.84	31.68	14.64	21.6	20.16	30.36	43.32	56.76
Diameter (cm per year)	0.12	0.12	0.84	1.08	1.2	0.36	1.32	0.6
Biomass (d.w kg per ha)	15	56	1,530	6,549	5,934	18,975	20,199	34,271
Litter production (d.w kg/ha/year)	650	664	879	1,534	1,950	1,993	2,636	4,601

Source: Tuan *et al.* (1999); Giang (1999)

The mangroves are mainly dwarf, fringed with small trees, but they have an economic importance as buffer defense protection of the sea dyke. The data presented in the Table 1.6 shows that the length of sea and river dyke system is equal to the coastline, so mangroves are considered to be of great importance in this context. It is estimated that function values of the mangrove are 20-30 % of avoided cost for annual maintenance and protection of the dyke system.

Table 1.6. Mangroves and dyke systems by provinces in coastal areas.

Province	Coastline (km)	Sea and river dyke system (km)			Mangroves (ha)		
		River dykes (km)	Sea dyke (km)	Total (km)	Planted mangroves (ha)	Natural mangroves (ha)	Total (ha)
Quang Ninh	377	66	64	130	600	12,694	13,294
Hai Phong	110	48	67	115	500	2,882	3,382
Thai Binh	50	135	135	270	3,700	2,500	6,200
Nam Dinh	65	15	76	91	5,236	1,764	7,000
Ninh Binh	17	6	24	30	400	100	500
Total	**619**	**270**	**366**	**636**	**10,436**	**19,840**	**30,376**

Seagrasses: Six species are reported in Quang Ninh, Hai Phong and Nam Dinh provinces. They are *Halophyla ovalis*, *Halophyla beccarii*, *Halophyla minor*, *Ruppia maritima*, *Zostera japonica* and *Zostera marina*. They play an important role in regulating disturbances and supplying nursery grounds for fish, shrimp and other marine products. In recent years, seagrass beds have been degraded due to increased turbidity from habitat disturbances through human activities.

1.5. Human activities

1.5.1. Population, income sources and consumption features

As presented in the Table 1.7, there are about 20 million people in over 80,000 km^2 in the region. The population density varies from 50 in the mountains to 2,000 people/km^2 in the cities. The average birth rate decreased from 2.8 % in 1990 to 1.8 % in 1998. The population distribution by age groups shows that the highest percentage of the population pyramid, 14-38% in the mountains and 11-12% in the delta area, belongs to ages of 0-4 and 5-9. The exploitation patterns of natural resources and the relationship between nature conservation and economic development in the future is dependant on this driving force.

Table 1.7. Areas and population distribution by provinces.

Provinces	Area (km^2)	Population	Density (persons per km^2)	No. of districts
RR Mountainous areas				
1. Ha Giang	7,831.1	505,643	65	9
2. Tuyen Quang	5,801.3	61,3595	106	5
3. L.ai Chau	17,139.7	481,496	28	10
4. Lao Cai	8,049.5	514,547	64	8
5. Yen Bai	6,801.5	616,702	91	7
6. Son La	14,210.0	753,512	51	9
7. Hoa Binh	4,611.8	698,496	151	9
Subtotal	**69,281.0**	**6,348,433**		
RR Delta areas				
9. Hai Hung (Hai Duong, Hung Yen)	2,551.6	2,611,788	1,024	10
10. Ha Tay (Ha Dong, Son Tay)	2,152.9	2,169,522	1,008	12
11. Hai Phong	1,503.5	1,542,343	1,026	8
12. Hanoi	920.5	2,106,051	2,288	5
Subtotal	**7,128.5**	**8,429,704**		
RR Coastal Areas				
13. Nam Ha (Nam Dinh, Ha Nam)	2,418.6	2,531,317	1,047	11
14. Thai Binh	1,523.5	1,738,157	1,141	7
15. Ninh Binh	1,386.8	818,462	590	5
Subtotal	**5,328.9**	**5,087,936**		
Total	**81,738.4**	**19,866,073**	**608.5**	**126**

Source: GSO, 1996.

Data in Table 1.8 indicates that the unemployment rate is 4.95-8.07 % in both regions. In fact, this rate depends on the availability of non-farm self-employment activities. Agricultural and forestry activities are the major sources of income.

Table 1.8. Employment status of active population (%) and sources of income (10^3 VND per year)

Employment status of active population (%)	**Mountainous and mid-land**	**Red River Delta**
Employed	95.05	91.93
Unemployed	4.95	8.07
Sources of income (Th.VND per year)		
Agricultural, and forestry activities	505.4	437.6
Non-farm self-employment	158.3	400.2
Wages	89.3	181.8
Pension, subsidies and scholarship	44.8	67.5
Other income	3.1	8.7
Total	**800.9**	**1095.8**

Source: State Planning Committee (SPC) and General Statistic Office (GSO), 1994;
Vietnam living standard survey 1992-1993.

Food expenditure for daily consumption is mainly for cereals from agricultural activities, as presented in Table 1.9. Lifestyle and consumption features of people are related to agricultural development. The traditional 'rice field' culture dominant in the region has considerable effect on the land-use and land-cover change in the area.

Table 1.9. *Per capita* food expenditure (10^3 VND per year) for consumption.

	Mountainous and mid-land	Red River Delta
Cereal	336.4	335.7
Meat, egg, fish...	156	186
Vegetable and fruits	90	95
Others	52	107

1.5.2. Land use

About 17 million people or 80 % of population is involved in agricultural activities, as presented in Table 1.10. This is driving land-use and land-cover change. Figure 1.4 shows the degradation of forests during five decades. The main cause is the reclamation of forest for agricultural activities, especially for rice fields.

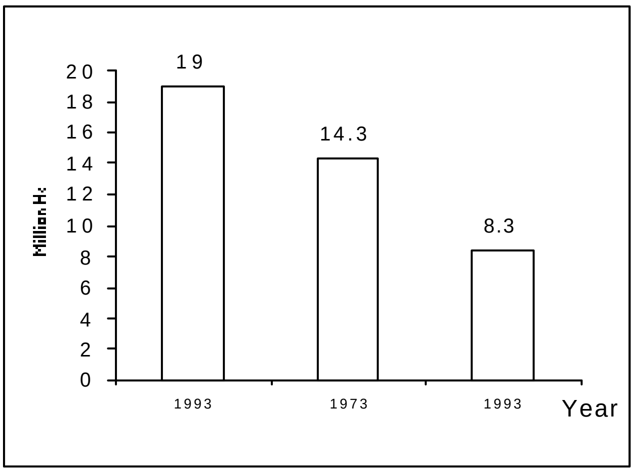


Figure 1.4. Forest degradation over five decades

Table 1.10. Land use of the Red River Region in 1995.

Data baseline of Red River area 1995	Total area (10^3 ha)	Agriculture land (10^3 ha)	Forest land (10^3 ha)	Agricultural population (10^3 person)
RR Mountainous (9 Provinces: Lai Chau, I.ao Cai, Yen Bai, Son La, Ha Glang, Tuyen Quang, Vinh Phu, Phu Tho and Hoa Binh)	6,928.2	1,438.7	1,421.8	6,632.6
RR Delta (7 provinces: Ha Noi, Hai Phong, Ha Tay (Ha Dong, Son Tay, Hal Hung (Hai Duong, Hung Yen)	716.9	387.3	35.5	6,206.5
RR Coastal provinces: Thai Binh, Nam Ha (Nam Dinh, Ha Nam), Ninh Binh	541.5	324.4	20	4,607.8
Total	**8,186.6**	**2,150.4**	**1,477.3**	**17,446.9**

In the land-use pattern, the annual crop accounts for 65.62 - 86.70 %. The forest is only 13.26 % in the mountainous area and 1.34 % in the Delta. As presented in Table 1.11, the annual harvest of perennial crops is equal to that of annual ones, but this activity has only developed in recent years.

Different categories of crop cultivation expenses presented in Table 1.12 show that the expenditure for chemical fertilisers is half that of all agricultural expenses. The trend is increasing annually, as shown in Figure 1.5. The use of chemical fertilisers is increasing both intensification and extension of agriculture. It is also contributing to the nutrient budgets in the coastal zone.

Table 1.11: Type of agricultural and forestry land (%) and annual value of harvest (10^3 VND /ha)

	Mountainous and mid-land	Red River Delta
Type of agricultural and forestry land (%)		
Annual	65.62	86.70
Parennial	7.63	5.50
Water surface	2.02	5.11
Forest	13.26	1.34
Other lands	11.47	1.34
Annual value of harvest (Th. VND /ha)		
Annual	9,176	10,649
Parennial	9,706	16,310
Water surface	2,582	3,683
Forest	11,358	10,700

Source: State Planning Committee (SPC) and General Statistics Office (GSO) 1994, Vietnam Living Standard surveys 1992-1993

Table 1.12: Crop cultivation expenses (%) in the region

Items	Mountainous and mid-land	Red River Delta
Seed	39.16	20.12
Chemical fertilizers	43.09	52.52
Bio. fertilizer	0.68	0.48
Insecticide	6.35	10.86
Transportation	0.22	0.36
Services	6.25	7.06
Equipment rental	2.57	7.04
Hiring labor	1.68	1.57

Source: State Planning Committee (SPC) and General Statistics Office (GSO) 1994, Vietnam Living Standard surveys 1992-1993

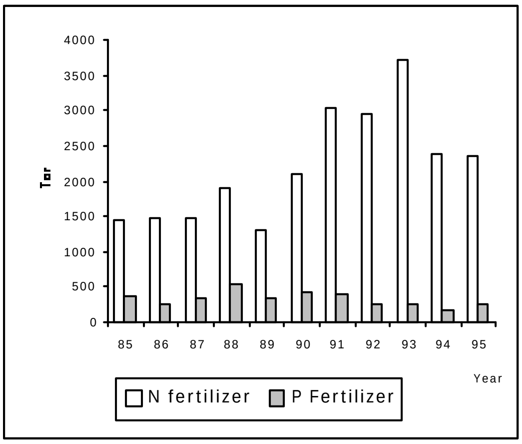


Figure 1.5. N and P fertilizers used during 1985 – 1995.

The Gross Domestic Product (GDP) has annually increased from 76 billion VND in 1991 to 110 billion in 1992, 136 billion in 1993, 174 billion in 1994 and 222 billion in 1995. It contributes up to 20-30 % of GDP value in the country. Figure 1.6 shows this trend. The economic triangle Ha Noi-Quang Ninh-Hai Phong, and industrial center of Viet Tri is the main economic contributor in the region. It is also driving residuals from the economic activities.

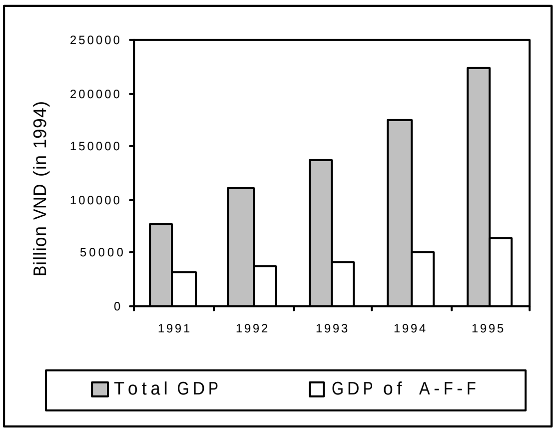


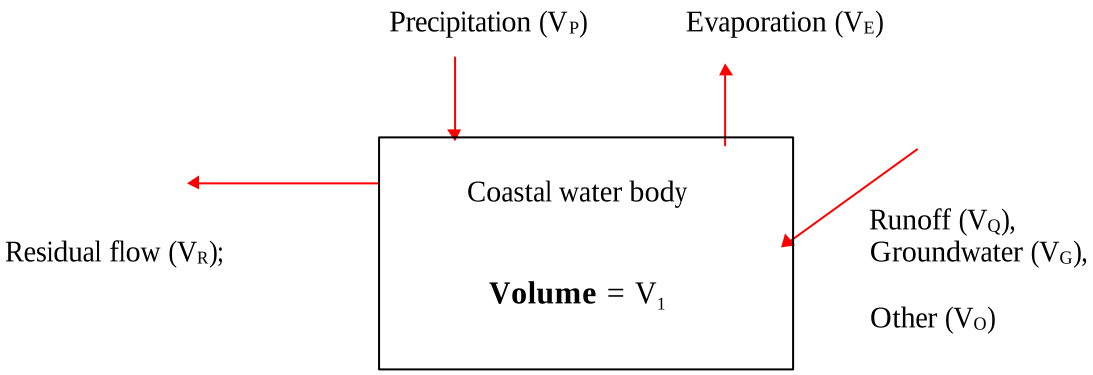
Figure 1.6. GDP growth during five years of Open-Policy. (Note: A-F-F=Agriculture, Forestry and Fishery).

2. THE BIOGEOCHEMICAL MODEL

2.1. Methodology: Methods for constructing the biogeochemical model are mainly from the LOICZ Biogeochemical Modelling Guidelines (Gordon et al. 1996)

2.1.1. Water and salt balances

The following is a simple model of the water exchange process in the estuary



The equation presented this process [5,6]:

$$\frac{dV(t)}{dt} = V_Q + V_p + V_o + V_G + V_{in} - V_E - V_{out} \qquad (1)$$

$$V_{in} - V_{out} = \frac{dV(t)}{dt} - (V_Q + V_P + V_O + V_G - V_E) \qquad (2)$$

In which

V_Q: Runoff (m^3/day) ; V_P: Rainfall (m^3/day)

V_O: Sewage (m^3/day) ; V_G : Ground water discharge (m^3/day)

V_E: Evaporation (m^3/day)

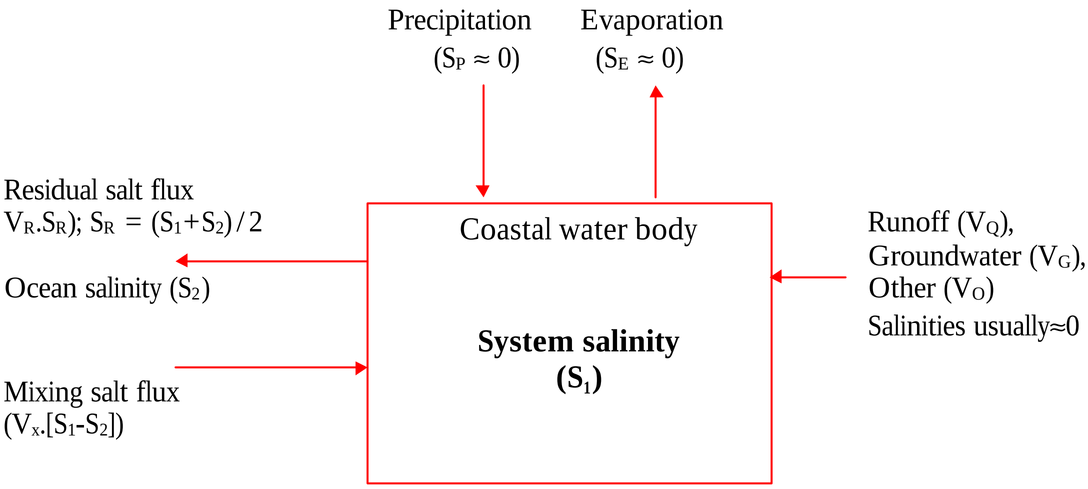
V_{in} and V_{out}: Input and output water to the system (m^3/day) and

$$V_R = V_{in} - V_{out} = \frac{dV(t)}{dt} - (V_Q + V_P + V_O + V_G - V_E) \qquad (3)$$

if $\frac{dV(t)}{dt} = 0$ we have :

$$\boxed{V_R = -(V_Q + V_P + V_O + V_G - V_E) = -V_{Q*}} \qquad (4)$$

In the condition of steady state, this exchange process has to be balanced by the salinity in the system. The figure below presents a simple model of this process



The basic equation of salt balance is as follows

$$\frac{d(V_1S_1)}{dt} = V_{Q^*}S_{Q^*} + V_{in}S_2 - V_{out}\, S_1 \qquad (5)$$

S_1 and S_2 are inside and outside salinities of the system. For most applications, all other salinities except S_1 and S_2 is very small and can be considered to be 0.

$$\frac{d(V_1S_1)}{dt} = V_{in}S_2 - V_{out}\, S_1 \qquad (6)$$

In this equation, the mixing change terms (V_{in} V_{out}) is unknown. By combining the above equations and expanding the term $d(V_1S_1)$, V_{in} and V_{out} it can be evaluated as follow:

$$V_{in} = \frac{1}{(S_2 - S_1)}[Vq^*.S_1 - V_1\frac{dS_1}{dt}] \qquad (7)$$

and

$$V_{out} = \frac{1}{(S_2 - S_1)}[Vq^*.S_1 - V_1\frac{dS_1}{dt}] - \frac{dV_1}{dt} + Vq^* \qquad (8)$$

If V_1 is constant, $\frac{d(V_1)}{dt} \approx 0$, $V_{in} = V_{out} - V_{Q^*}$

It is convenient to redefine V_{in} as the water exchange flow: V_x, and the salinity at the boundary is defined as S_R, we have

$$V_x = \frac{1}{(S_2 - S_1)}[-V_1\frac{dS_1}{dt} - VrSr] \qquad (9)$$

or

$$V_x = \frac{1}{(S_1 - S_2)}[V_1\frac{dS_1}{dt} + VrSr] \qquad (10)$$

S_r is the estimated average residual salinity of inside and outside of system

$$Sr = \frac{S_1 + S_2}{2}$$

If S_1 is also constant:

$$\frac{d(S_1)}{dt} = 0$$

$$V_x = \frac{1}{S_1 - S_2}\left[\frac{Vr(S_1 + S_2)}{2}\right] \qquad (11)$$

2.1.2. Conservative and non-conservative material balance

With conservative material Y (salinity: Y=S) the balance or budget equation is as follow

$$\frac{d(VY)}{dt} = \sum V_{in}.Y_{in} - \sum V_{out}.Y_{out}$$

or (12)

$$V\frac{dY}{dt} + Y\frac{dV}{dt} = \sum V_{in}.Y_{in} - \sum V_{out}.Y_{out}$$

With non-conservative materials Y (such as DIN, DIP..) the balance or budget equation as follow :

$$V\frac{dY}{dt} + Y\frac{dV}{dt} = \sum V_{in}.Y_{in} - \sum V_{out}.Y_{out} + \Delta Y$$

or (13)

$$\Delta Y = V\frac{dY}{dt} + Y\frac{dV}{dt} - \Sigma V_{in}Y_{in} + \sum V_{out}Y_{out}$$

DY can be considered as the material balance in the system. Its units are mass of material per time, generally presented as moles per day or mmol per m^2 per day. *DY* may be contributed to by physical and biotic chemical processes.

2.1.3. Stoichiometrically linking the non-conservative C, N and P budgets

Phosphorus - Carbon stoichiometry:

The ratio of C:P in the particulate material $(C:P)_{part}$, multiplied by the non-conservative flux of DIP becomes an estimate of organic matter (*p-r*) [6]

$$(p\text{-}r) = -\,D\,DIC_o = D\,DIP\,(C/P)_{part} \qquad (14)$$

- System with ΔDIP > 0 is interpreted to be production DIC via net respiration ($p\text{-}r<0$)
- System with ΔDIP <0 is interpreted to be consuming DIC via net organic production ($p\text{-}r>0$).
-

If the system is a calcifying system, then:

$$DDIC_t = D\,DIP\,(C/P)_{part} + D\,DIC_g + DTA/2 \qquad (15)$$

$$DDIC_g = D\,DIC_t - D\,DIP\,(C/P)_{part} - DTA/2 \qquad (16)$$

Nitrogen - phosphorus stoichiometry

Conversion from N_2 gas to organic nitrogen is termed "nitrogen fixation" while conversion from NO_3^- to N_2 is termed "denitrification". (*nfix - denit*) is the net effect of this transfer and often qualitatively significant to the nitrogen budget.

$$(nfix - denit) = DDIN - DDIP\,(N/P)_{part} \qquad (17)$$

$$DDIN_{obs} = DN_{(NO3)} + DN_{(NH4)} + DN_{(NO2)} \qquad (18)$$

$\Delta N_{(NH4)}$, $\Delta N_{(NO2)}$ tend to be small relative to $\Delta N_{(NO3)}$. The ratios N/P, C/P depend on the ecosystem:

- Redfield C: N: P molar ratio of 106:16:1 can be used for plankton.
- With various land plants the C:N:P ratio is 1000:30:1

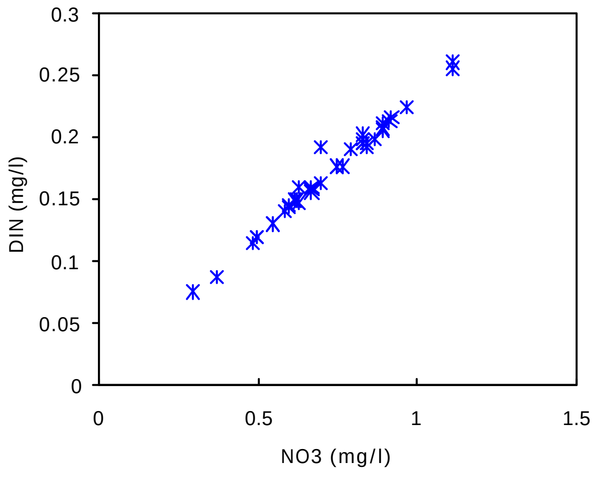


Figure 2.1. Relationship between DIN and NO3 in the flooding season

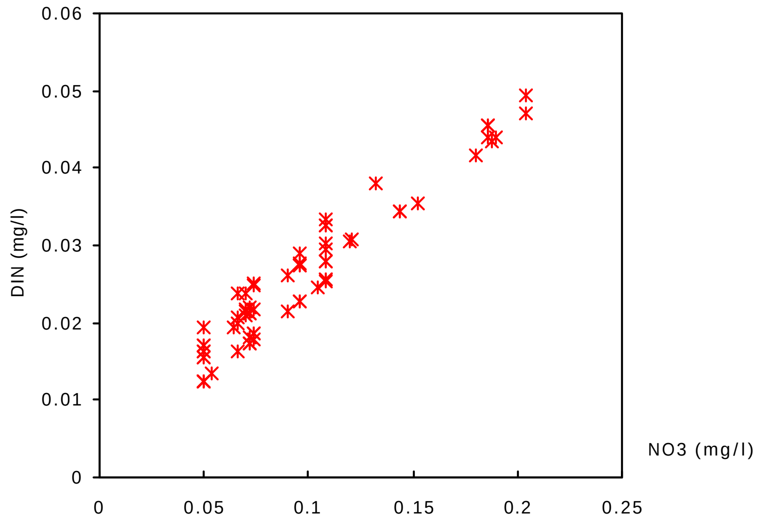


Figure 2.2. Relationship between DIN and NO3 in the dry season.

For the biogeochemical modelling, water data including salinity, alkalinity, pH, PO_4, NH_4, NO_3, CO_3, HCO_3, total P and total N have been collected and analyzed from a set of secondary data available from the National Hydro-meteorological Monitoring Station Network and recent surveys during 1996 - 1998 within the context of the SWOL project.

A close relationship among the chemical data have been found, such as: the correlation coefficient between NO_3 and DIN is 0.857; Total N and DIN : 0.864; , Total P and DIP : 0.890; NH_4 and DIN :0.895, as presented in the two figures above.

2.2. Results

2.2.1. Water and salt budget

The differentiation of data collected in two seasons from the Red River system with respect to the salt budget have been analyzed for March (dry season) and August (wet season).

The input data and components of water balance of the research site is presented in tables 2.1 and 2.2.

Table 2.1. Input data for water balance in the research site.

	Evaporation (mm)	Rainfall (mm)	Run-off (m^3/s)	S1 ($^o/_{oo}$)	S2 ($^o/_{oo}$)
March	35.8	34.5	318.5	11.36	26.7
August	99.7	335.2	3,164.0	6.34	19.0
Annual total	**973.8**	**1838.2**	**1246.0**	**9.20**	**24.4**

Based on equations from 1 to 11, it can be calculated daily values of freshwater volume of inflow to system from rainfall (P), Runoff (Q), Groundwater (G); going out system from Evaporation (E), outflow (Vr) and exchange flow (Vx). These calculated results were in round figures to (10^3 m^3 /day) and presented in the table below.

Table 2.2. Components of water balance in the research site ($10^3 m^3$/day).

	Rainfall	Evaporation	Runoff	Ground water	Vr	Vx
March	119	-124	27,518	74	-27,588	34,224
August	1,157	-344	273,370	74	-274,256	274,473
Annual total	**539**	**-285**	**107,654**	**74**	**-107,980**	**119,346**

From these results it is noted that:

- The hydrological regime of the two seasons yields a difference of evaporation in the estuary, especially at the beginning and end of the dry and wet seasons.

- The runoff of the system is high. For example, in the dry season the total is much smaller than that in flood season but the value of freshwater flows into the system by runoff is still ten times than rainfall. It affects the value of freshwater outflow (Vr). The exchange flow of system (Vx), therefore, is positive. The saline-water daily input from the sea by tidal flow is large. This has a considerable significance in salinity balance of the system.

2.2.2. DIP budgets

The dissolved inorganic phosphorus (DIP) is mainly taken from PO_4. Concentration of P in PO_4 of water is considered as DIP. Up to now, data has been scarce with respect to PO_4 in rain and ground water; therefore we have to assume that PO_4 in rainwater is 0 and PO_4 in ground water equals PO_4 in river water. The DIP concentration in water sources within the system are presented in Table 2.3.

Table 2.3. PO_4 concentration in water sources (g/m^3).

	River branches	Whole system	Sea
March	0.12	0.07	0.03
August	0.50	0.27	0.09
Annual total	**0.29**	**0.14**	**0.05**

Based on equations 13 and 14, the DIP budgets were calculated and Table 2.4 shows some of these calculated results. The model of DIP budget and flow is presented in Figures 2.3, 2.4 and 2.5.

Vietnam

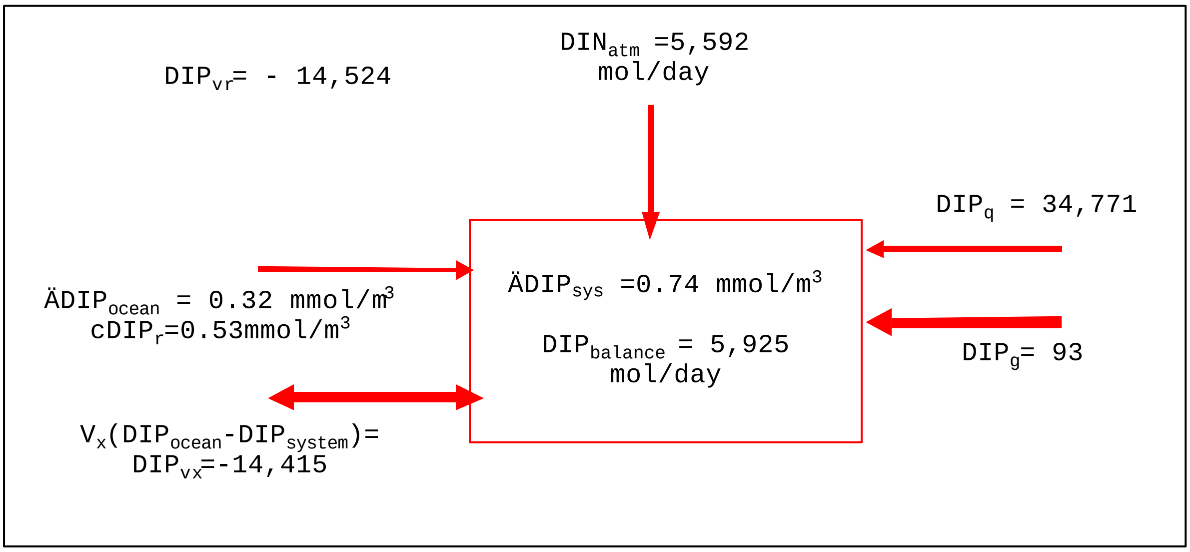


Figure 2.3. Daily DIP budgets in March (mol/day).

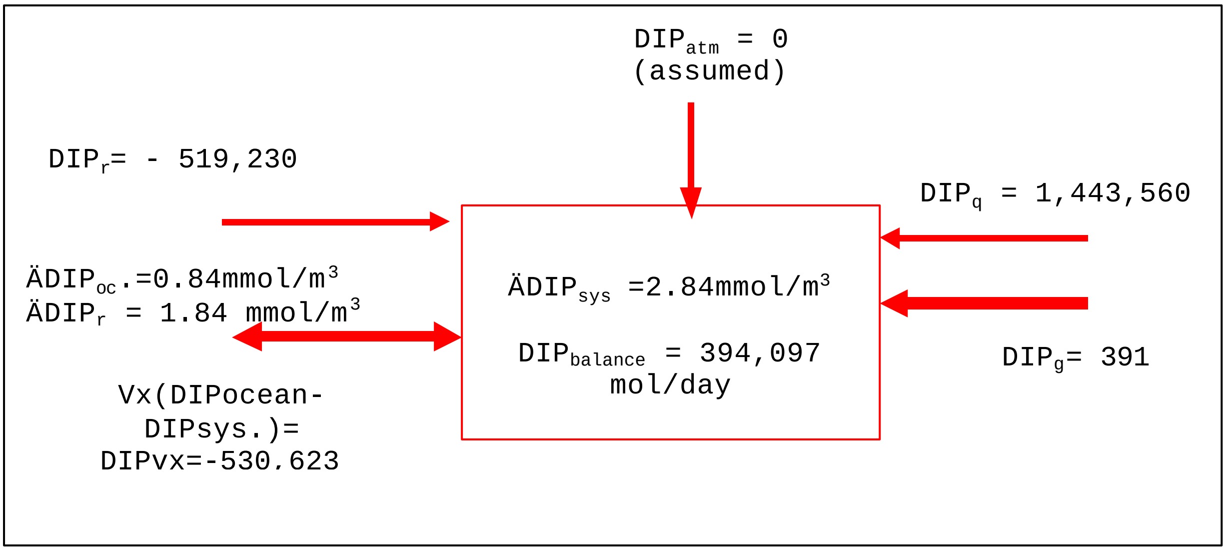


Figure 2.4. Daily DIP budgets in August (mol/day).

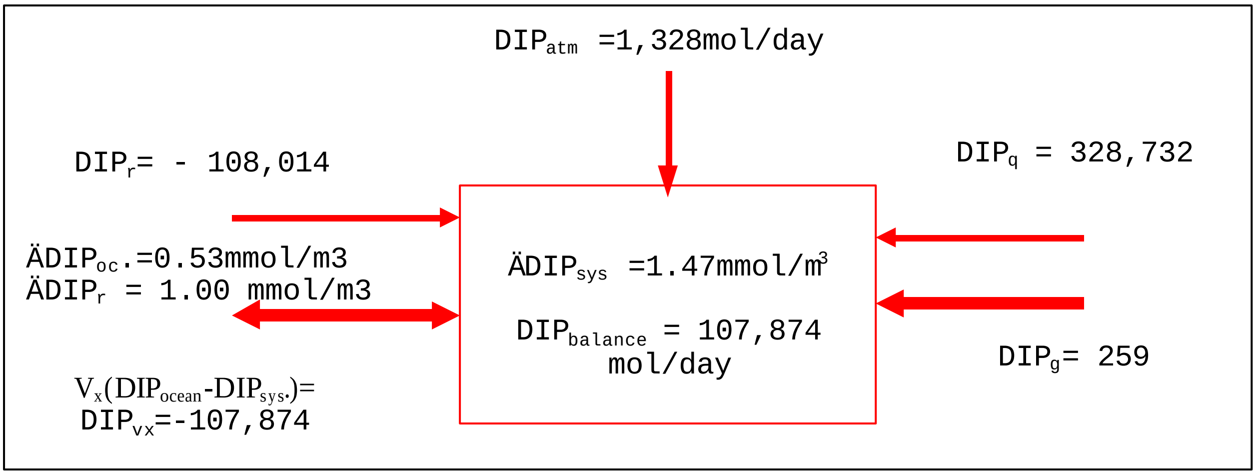


Figure 2.5. Annual DIP budgets (mol/day).

Table 2.4. Inorganic P flows and balances in mmol m^{-2} d^{-1} for the study system.

Month	DIP_g	DIP_r	DIP_{vr}	DIP_{vx}	Daily DIP input	Daily DIP balance
January	0.000	0.128	-0.081	-0.096	0.129	-0.049
February	0.000	0.203	-0.103	-0.104	0.203	-0.004
March	0.001	0.325	-0.136	-0.135	0.326	0.055
April	0.002	0.751	-0.243	-0.221	0.752	0.288
May	0.003	2.069	-0.598	-0.534	2.071	0.939
June	0.003	6.213	-2.096	-1.861	6.216	2.259
July	0.004	11.387	-3.903	-3.488	11.391	4.000
August	0.004	13.491	-4.853	-4.959	13.495	3.683
September	0.003	8.772	-2.958	-3.195	8.776	2.623
October	0.003	4.427	-1.317	-1.165	4.429	1.947
November	0.002	2.129	-0.626	-0.594	2.131	0.911
December	0.001	0.604	-0.251	-0.262	0.604	0.092
Average	**0.002**	**4.208**	**-1.430**	**-1.385**	**4.210**	**1.395**

From the results presented, it can be noted that:

- Nutrients in general and PO_4 in particular has a quick reduction during transport from the river to the sea. Its concentration in the flood season is greater than that in the dry season.

- Annual discharge of freshwater from the Red River system to the sea is rather large, driving DIP input to the system from river up to hundreds of thousand mol per day. DIP balance in the estuary is always positive with annual value being more than a hundred thousand mol/day, up to more than three hundred thousand mol/day in flood season.

2.2.3. DIN budget

The dissolved inorganic nitrogen (DIN) is largely nitrogen as NO_3 and NH_4. It is also an important nutrient in the water. Table 2.5 presents the concentration of NO_3 in water sources participating to the exchange process of DIN in the system. The NO_3 and NH_4 data has been collected and analyzed from three stations: PhuLien, HaiDuong and NinhBinh during two years 1996-1997 of the observation.

Table 2.5: NO_3 concentration in water sources (g/m^3)

	From rainfall	River branches	Whole system	Sea
March	0.48	0.41	0.14	0.09
August	0.34	0.79	0.12	0.08
Annual total	**0.44**	**0.55**	**0.13**	**0.09**

As with PO_4, the concentration of NO_3 is also reduced quickly from the river system to the sea. The concentration of NO_3 and DIN in the flood season is only higher than that in dry season in the case of river branches. The DIN exchange in the river estuary has been calculated by using equations 13 and 14. The result is presented in Table 2.6.

Table 2.6: Inorganic N flows and balance in mmol m^{-2} d^{-1} for the study system.

	DINg	DINp	DINr	DINvr	DINvx	Daily DIN input	Daily DIN Balance
January	0.004	0.009	2.027	-1.513	-0.490	2.040	-0.037
February	0.005	0.011	2.361	-1.249	-0.373	2.377	-0.755
March	0.007	0.012	2.531	-1.040	-0.293	2.551	-1.218
April	0.008	0.035	3.614	-1.192	-0.286	3.657	-2.179
May	0.010	0.065	7.503	-2.071	-0.384	7.577	-5.122
June	0.011	0.074	21.013	-5.033	-0.735	21.098	-15.329
July	0.012	0.080	36.836	-8.153	-1.130	36.928	-27.645
August	0.012	0.091	43.643	-9.728	-1.619	43.746	-32.400
September	0.011	0.084	29.670	-7.199	-1.438	29.765	-21.128
October	0.010	0.055	16.437	-4.545	-1.005	16.502	-10.952
November	0.008	0.023	9.090	-3.156	-0.943	9.120	-5.021
December	0.005	0.007	3.728	-1.967	-0.650	3.741	-1.125
Average	**0.009**	**0.045**	**14.871**	**-3.904**	**-0.779**	**14.925**	**-10.243**

The DIN mass from runoff water occupies a major part of DIN balance in the system. DIN from direct rainfall is also rather high. Annual value of DIN balance is up to 8 hundred thousand mol per day.

The mixing flow has a negative value in removing more than 32 thousand mol per day. In order to support this net export, there must be a positive value for DIN balance. Thus, calculated value presented in Table 2.6 for annual as well as monthly DIN balance is positive with values from hundred thousand to million mol/day. The model of DIN budget and flow is presented in Figures 2.6, 2.7 and 2.8.

2.2.4. Modelling

By using Stella 2, a linkage at the same time of three sub-models of water and salt budgets as well as DIP and DIN budgets of the complex system has been done and presented in Figure 2.9. These models are linked together in one combined model as a united form of all systems. All elements are incorporated into the system are linked. Any change of one quantity will influence the others and the final result. First is the basic model, the second and the third depend only on the first and are independent of each other but in the next step they are linked together to study the stoichiometric modelling.

Table 2.7. Monthly water budget input data for the Red River estuary (10^3 m^{-3} d^{-1}).

	Evaporation V_e	Ground water V_g	Precipitation V_p	River flow V_q	S system S_1 (0/00)	S ocean S_2 (0/00)	Residual flow V_r	Exchange flow V_x
January	204	74	66	38,405	11.69	28.3	-38,340	46,154
February	149	74	96	32,357	11.13	27.5	-32,378	38,186
March	124	74	119	27,518	11.36	26.7	-27,588	34,224
April	168	74	372	32,054	10.8	27.2	-32,332	37,457
May	321	74	766	56,851	9.65	27.4	-57,370	59,860
June	396	74	937	140,918	7.37	25.4	-141,533	128,654
July	433	74	1,090	230,731	6.34	22.1	-231,462	208,844
August	344	74	1,157	273,370	6.34	19	-274,256	274,473
September	331	74	970	198,979	7.17	19	-199,692	220,877
October	352	74	587	123,077	7.67	21.5	-123,386	130,122
November	328	74	214	83,462	9.83	22.8	-83,422	104,937
December	265	74	61	51,106	11.55	25.9	-50,976	66,518

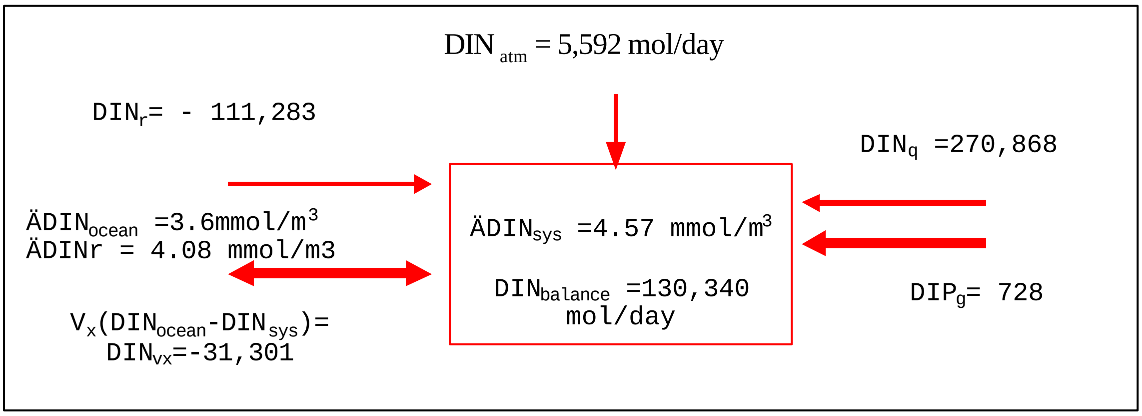


Figure 2.6. Daily DIN budgets in March (mol/day).

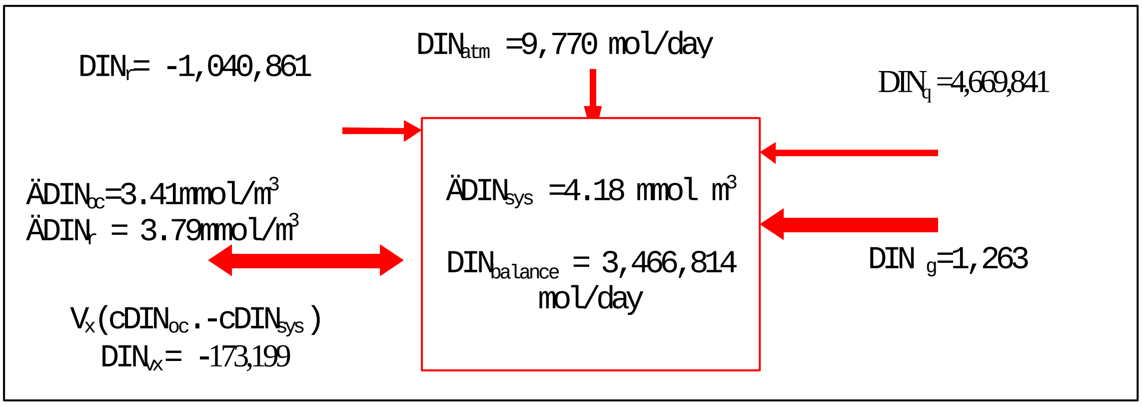


Figure 2.7. Daily DIN budgets in August (mol/day).

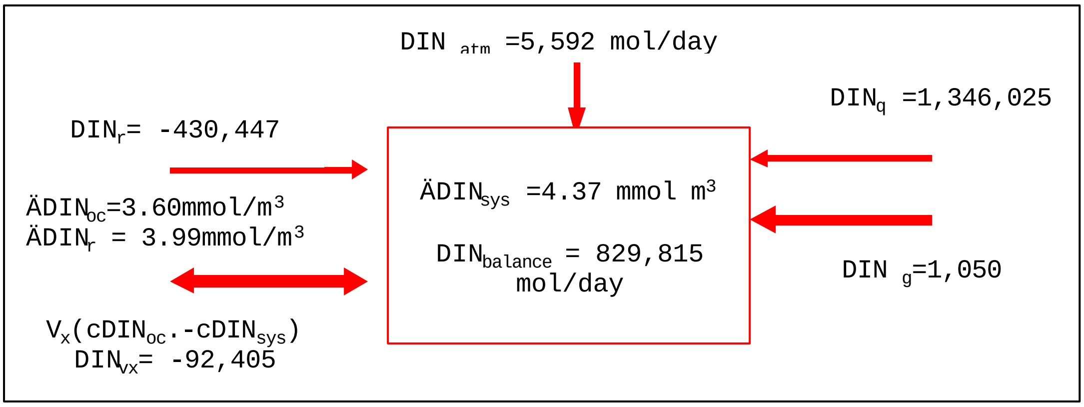


Figure 2.8. Annual DIN budgets (mol/day).

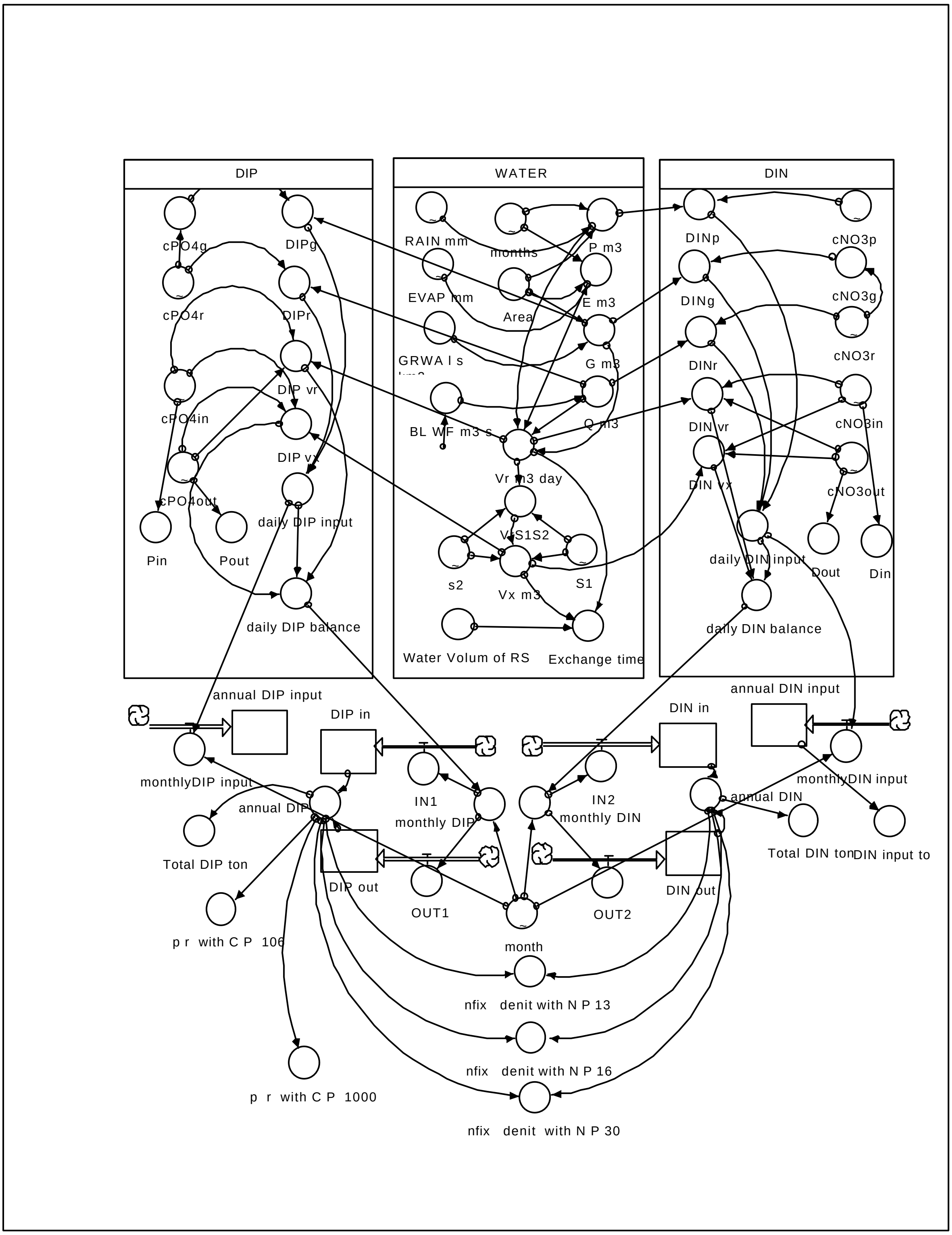


Figure 2.9. Modelling water and C, N and P budgets and flows in the system.

Assuming steady state and all above conditions are satisfied, Stella 2 gives us water and salt budget for all 12 months presented in Table 2.7. The annual total value of DIP and DIN input and balance in the system of the system is presented in Table 2.8.

Table 2.8. Annual DIP and DIN input and balance of the system.

	Annual balance(10^3mol)	Annual input (10^3mol)	Total (ton)
DIN	402,496	586,225	5,635
DIP	54,894	165,610	1,700

Stoichiometric calculations of aspects of net system metabolism

By using stoichiometric modelling, the value of $D(DIC)_{est}$ and $D(DIN)_{est}$ can be indirectly calculated from the ratio of C/P , N/P and *DDIP* of the system. Then, the values of (*p-r*) and (*nfix-denit*) of the system are also calculated following equations 14 and 18

In this report ratios of C:N:P and N/P were chosen as follow
- Redfield C:N:P ratio of plankton: 106 : 16 : 1
- In the state of more typical of various land plants C : N : P = 1000: 30 : 1
- With mangrove in the north of Vietnam N : P = 13 : 1

From the models developed by Stella 2, values of (*p-r*) and (*nfix-denit*) of the annual state of the system have been calculated. These results are presented in the Table 2.9.

Table 2.9: Annual state of system (10^3mol/day)

Months	*nfix - denit* with N/P=13	*nfix - denit* with N/P=16	*nfix - denit* with N/P=30	*p-r* with C/P =106	*p-r* with C/P =1000
Annual total	-852	-1,304	-3,409	-15,942	-150,395

From these results, the following remarks have been highlighted:

- In the three states, the calculated values of (*nfix-denit*) are negative. Denitrification exceeds nitrogen fixation throughout the year and the coastal system is therefore, an important sink of nitrogen.

- Regarding both states, the net ecosystem metabolism (NEM or [*p-r*]) is negative. That means that the system is net heterotrophic throughout the year.

2.3. Conclusion

This is the first time C, N and P budgets and fluxes of the coastal zone of the Red River system have been done by biogeochemical modelling. Data input, especially parameters of hydrological and chemical concentrations are still limited not only in quality but also quantity. Therefore, the results presented in this report are only preliminary ones. In order to have better results estimating water balance as well as the DIP and DIN budgets in the Red River estuary, it is necessary to continue doing surveys as well as research in this area. The Stella 2 is a sound application for biogeochemical modelling in this case study.

Table 2.10. Summary of data collected and analyzed in the biogeochemical modelling for the Red River system.

Water and salt budget			
Evaporation	Ve	10^3 $m^{-3}d^{-1}$	284.58
Ground water	Vg	10^3 $m^{-3}d^{-1}$	74
Precipitation	Vp	10^3 $m^{-3}d^{-1}$	536
River flow	Vq	10^3 $m^{-3}d^{-1}$	107,402
S system	S1	0/00	9
S ocean	S2	0/00	24
Residual flow	Vr	10^3 $m^{-3}d^{-1}$	-107,728
Exchange flow	Vx	10^3 $m^{-3}d^{-1}$	112,526
Inorganic N flows and balance			
DINg		mmol m-2 d-1	0.009
DINp		mmol m-2 d-1	0.045
DINr		mmol m-2 d-1	14.871
DINvr		mmol m-2 d-1	-3.904
DINvx		mmol m-2 d-1	-0.779
Daily DIN input		mmol m-2 d-1	14.925
Daily DIN balance		mmol m-2 d-1	-10.243
Inorganic P flows and balance			
DIPg		mmol m-2 d-1	0.002
DIPr		mmol m-2 d-1	4.208
DIPvr		mmol m-2 d-1	-1.43
DIPvx		mmol m-2 d-1	-1.385
Daily DIP input		mmol m-2 d-1	4.21
Daily DIP balance		mmol m-2 d-1	1.395

Stoichiometric calculation for the annual state of the system. Annual total (10^3 mol per day)

nfix - denit with N/P = 13	- 852
nfix - denit with N/P = 16	- 1,304
nfix - denit with N/P = 30	- 3,409
p-r with C/P = 106	- 15,942
p-r with C/P = 1000	- 150,395

3. THE REGIONAL INPUT - OUTPUT MODEL

3.1. The Region and Surveys

The Red River region covers 19 provinces, namely: Lai Chau, Lao Cai, Yen Bai, Son La, Ha Giang, Tuyen Quang, Vinh Phuc, Phu Tho, Hoa Binh, Son Tay, Ha Dong, Ha Noi, Hai Phong, Hai Duong, Hung Yen, Thai Binh, Nam Dinh, Nam Ha and Ninh Binh. The region has mountainous, mid-land, delta plain and coastal areas. This region was chosen because economic sectors in all provinces have impact on environmental changes in the coastal zone.

The eleven sectors recommended by the World Health Organization (WHO) plus household consumption are defined for Vietnam as: (1) agriculture, (2) fishery/aquaculture, (3) forestry and hunting, (4) mining and quarrying, (5) manufacturing 1 (heavy), (6) manufacturing 2 (light), (7) electricity and gas, (8) water supply, (9) transportation, (11) other services and (12) household consumption sector. All survey for regional I - O table is designed by following procedures:

- Preparation of questionnaires
- Identifying establishments: main products, by-products and others
- listing production units for sectors
- Sampling survey design/ conduct of pre-survey.
- Survey training: surveyors (economic, account...)
- Conduct of Field Survey Operations

3.2. Constructing the regional I-O table

3.2.1. Methodology and Data sources

The conventional I-O table of 11x11 sectors for the Red River region was initially constructed based on the GSO's national I-O tables for 1995 and 1996. Proper adjustments were then effected on this initial table based on data that were generated from the regional survey.

Available data obtained form the National Accounts Department of the General Statistical Office (GSO) and other government statistical sources provided the basic data. These were augmented by a ground-up field evaluation in the provinces covered to better meet the data requirements of the I-O model. Regional data on the household consumption sector were derived from a national project on "Vietnam Living Standards Survey, 1992 - 1993" by the State Planning Committee and the GSO.

The problem of how to maintain homogeneity of product grouping, one of the main attributes of I-O economics, also exists in constructing regional I-O tables. This problem occurs when a production unit engages in the production of not only its principal or characteristic product, but also secondary products. A secondary product if defined to be a good or service whose output is relatively smaller than the principal product of the unit's total gross output. Depending on the availability of information, the rule in I-O compilation is that the production structure of secondary products should be separated from its main or principal product. In other words, output of secondary production together with its corresponding cost or inputs should be transferred to the I-O sector where it is classified as the main product.

This problem of output and input transfers between sectors is best solved by conducting a highly-specialized supplemental survey to obtain more detailed information. When resources are insufficient to conduct this *ad hoc* survey, the alternative is to make use of mechanical methods of "purifying" the I-O table, following some restrictive technology assumptions. This mathematical method of adjusting the coefficients was adopted in this exercise.

As in national I-O tables, the first task in constructing regional I-O tables is to compile the basic tables, given the basic information generated from the regional I-O survey. These basic tables are the output or MAKE matrix of the industry x product format and the input or USE table of the product x industry format.

The second phase of the work is to "purify" the basic USE table. "Purifying" the USE table refers to the intersectoral transfer of inputs and outputs in order to produce a product x product I-O that is deemed best useful and meaningful for I-O analysis.

3.2.2. Constructing the MAKE Matrix

The MAKE matrix shows the distribution of the values of products produced by industries during the accounting period, based on the classification scheme of sectors identified in this study. Entries in this matrix are valued at producers' prices.

The MAKE matrix is an industry x product table where in the rows represents the industries while the columns represent the products. It is formulated by the following function:

$$V = (V_{kj})_{\text{industries x products}}$$

where V_{kj} represents industry sector k producing product j.

It can be observed that cell elements along the diagonal of the V matrix are the main products of each column sector and elements off diagonal account for the secondary products (if any).

3.2.3. Constructing the USE Matrix

The USE matrix is calculated from input or production structures of each sector surveyed. It is a product x industry table where in the rows represent the products and the columns denoting the industries. The following function is introduced:

$$X^1 = (X^1_{jk})$$

where X^1_{jk} is sector k using product j in the production process.

We then have the following model:

	k	
j	X^1 (Plot I)	Y^1 (Plot II)
	L^1 (Plot III)	

The model can be constructed from survey results. It includes the matrix of intermediate input or USE structures of industries, X^1, the matrix of value added, L^1 and the consumption matrix, Y^1.

The compilation of these matrices is articulated in sufficient detail in the Technical Appendix of this Paper.

3.2.4. Constructing the matrix of intermediate input coefficients

In its economic sense, the main objective of constructing I-O tables is to measure and analyze the relationship between sectors in the process of production and consumption. This relationship can be determined using the following equation:

$$q = (E - A)^{-1}. \; Y$$

where q: vector of gross output
Y: vector of final demand
E: unit matrix
A: matrix of intermediate input coefficients

As stated earlier, I-O analysis based on a product x product table gives more meaningful results. It is therefore essential to convert he basic product x industry USE matrix (X^1) into a "pure" product x product matrix of intermediate input transactions. In other words, matrix A in the formula should be computed from a USE table of product x product format.

The method used in "purifying" the basic USE matrix is the mathematical approach for the simple reason that resources for the conduct of an in-depth survey to gather required inputs data at the product level are quite limited.

The procedure for calculating the matrix of intermediate input coefficients, A, is shown as follows:

1. Given the MAKE matrix (V), the vector of industry outputs, g, can be derived from the following function:

$$g = Vi \qquad (1)$$

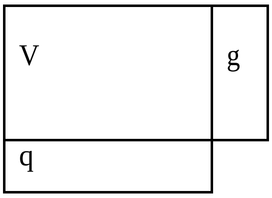
where: i: unit vector

By transposition, we have:

$$q = V'i \qquad (2)$$

where: q: gross outputs of products
v': transposed matrix of V
i: unit vector

It is described by the following model:



2. The coefficients of intermediate demand matrix (A^1) can be calculated from the equation:

$$X^1 = A^1.\hat{}g \qquad (3)$$

where: X^1: coefficient of intermediate demand matrix
^g: diagonal matrix in which element of vector g are shown in the diagonal and elements in the off-diagonal are all equal to zero.

3. The coefficients of the MAKE matrix (V) can be calculated from equation:

$$V' = C\hat{}g \qquad (4)$$

where: V': transpose of matrix V
C: coefficient matrix of V

$$C_{jk} = \frac{V_{kj}}{g_k}$$

where C_{jk}: elements of C matrix
V_{kj}: value of product j produced by industry k
g_k: gross output of industry k

4. Given the USE matrix and vector of final demand, Y, we have: $q = X^1 i + Y$.
Substituting X^1 in equation (3), we have:

$$q = A^1 g + Y \qquad (*)$$

where $g = \hat{}gi$.

5. We have Cg = C^gi. From equation (4), we have: Cg = V'i and Cg = q or g = C^1.q. Equation (*) therefore becomes q = $A^1.C^1$.q + Y, and

$$q = (E - A^1.C^{-1})^{-1}.C^1.Y \qquad (5)$$

6. The coefficient matrix of intermediate demand (A) is therefore equal to:

$$A = A^1.C^{-1} \qquad (6)$$

where:
A^1 is coefficient matrix of product (row) x industry (column) dimension level;
C^{-1} is inverse of coefficient matrix of industry (row) x product (column) dimension level.

The level of matrix A is "purified" into a product x product matrix of coefficients through the *commodity technology* assumption which assumes that products have the same input structures wherever they are produced. This approach is deemed to be more economically plausible than the *industry technology* assumption which states that a secondary product produced by an industry possess the same input structure as its main product.

Using equation (6), however, produces some negative numbers that are economically insensible. To eliminate these negative coefficients in matrix A, the following procedures are adopted:

i. If negative numbers are observed to be very minimal, these coefficients are then considered to be zero, and rebalance the A matrix using the RAS method

ii. If negative coefficients in A are relatively large, make adjustments by reviewing basic data used in constructing the MAKE and USE matrices, and recalculate the A matrix using equation (6). Apply the RAS method when negative numbers are found to be small.

A comprehensive discussion of the RAS method of adjusting the coefficient table is shown in the Technical Notes of this paper.

3.2.5. "Purifying" the matrix of value added, L^1 (plot III in I-O model)

Plot III (value added matrix) is "purified" following the same method used in "purifying" Plot I (matrix of intermediate input coefficients), as follows:

$$L = L^1.C^{-1}$$

where:

L: matrix of value added of product x product dimension level;
L^1: matrix of value added with its columns representing industries or sectors and its rows denoting the primary factors of production consisting of compensation of employees, production tax, consumption of fixed capital and operating surplus; and
C^{-1}: inverse of the MAKE matrix of coefficients.

3.2.6. Product x Product I-O Tables for the Red River Region

Table 3.1 shows the matrix of direct input coefficients computed from the final transactions table for the Red River Region for 1996. Table 3.2 is the matrix of inverse coefficients, i.e. $(E-A)^{-1}$ in the Leontief equation, $X = (E-A)^{-1}Y$.

Each cell element in Table 3.2 accounts for the total (direct plus indirect) output requirement of a certain product (sector) per unit of its final demand. It can be observed that coefficients along the diagonal are more than unity. This means that production by a particular product (sector) has to be increased by more than one unit to meet the input requirements of other production sectors so as to satisfy one unit of ultimate demand by the final consumption sectors.

Table 3.1: Conventional 11x11 sectors input - output table for 19 provinces in the Red River region in 1996 *(at producer's price in million VND)*

Sectors	1	2	3	4	5	6	7	8	9	10	11	First Demand	Consumption Expenditure	in which Consumption of household	Accumulation	Export - Import	GO	Y
1. Agriculture	3,277,066	37,367	90,329	651	1,045,215	53,662	-	-	48,292	6,811	1,031,591	5,590,984	12,244,273	12,244,273	(34,003)	9,688,619	27,489,874	21,898,890
2. Fishery	-	72,858	-	-	748,557	12,780	-	-	-	-	78,620	912,815	799,315	799,315	-	(501,469)	1,210,662	297,847
3. Forestry and hunting	1,885	1,175	55,223	2,978	44,364	348,913	1,947	-	31,455	269	73,410	561,619	464,664	464,664	7,077	730,478	1,763,838	1,202,219
4. Mining and quarrying	1,795	7,304	27,933	18,773	32,213	58,409	113,993	-	22,322	-	27,822	310,563	-	-	53,489	564,391	928,443	617,880
5. Manufacturing I (Heavy)	2,550,576	85,768	36,933	11,096	3,502,665	653,602	554	-	19,147	425,237	936,952	8,222,530	6,935,162	6,935,162	283,261	902,872	16,343,825	8,121,295
6. Manufacturing II (Light)	465,418	180,262	11,823	251,056	451,756	2,967,563	433,569	47,166	8,325,388	985,945	1,819,533	15,939,481	4,762,013	4,762,013	3,672,355	(12,044,297)	12,329,552	(3,609,929)
7. Electricity, gas	257,330	3,141	74,597	36,854	100,356	185,798	162,218	7,536	43,638	16,818	570,509	1,458,796	417,483	417,483	-	607,812	2,484,090	1,025,295
8. Waterworks and supply	5,270	1,649	802	1,001	13,014	6,163	3,561	4,001	2,783	1,886	38,560	78,690	162,927	162,927	-	66,722	308,340	229,650
9. Construction	3,687	4,666	43,748	12,026	24,557	248,510	18,200	4,650	-	786	439,656	800,485	-	-	12,414,711	-	13,215,196	12,414,711
10. Transportation	1,139,354	27,817	27,530	34,802	450,951	322,096	40,938	11,335	215,657	11,986	283,122	2,565,587	1,055,934	1,055,934	124,080	(822,241)	2,923,359	357,772
11. Other services	2,096,987	68,253	119,947	100,125	614,197	814,099	94,436	19,184	408,467	187,342	2,116,784	6,639,821	26,272,122	12,292,178	261,296	(12,176,453)	20,996,785	14,356,964
Intermediate consumption	9,799,368	490,261	488,866	469,361	7,027,845	5,671,594	869,415	93,872	9,117,148	1,637,081	7,416,559	43,081,370	53,113,892	39,133,948	16,782,266	(12,983,564)	99,993,964	
Value added	17,690,506	720,401	1,274,972	459,082	9,315,980	6,657,958	1,614,675	214,468	4,098,048	1,286,278	13,580,226	56,912,594			16,782,297			
GI (gross input)	27,489,874	1,210,662	1,763,838	928,443	16,343,825	12,329,552	2,484,090	308,340	13,215,196	2,923,359	20,996,785	99,993,964						

Table 3.2: Leontief inverse matrix (at producer's price)

Sectors	1	2	3	4	5	6	7	8	9	10	11
1. Agriculture	1.154508592	0.055033522	0.070322916	0.018996763	0.103017506	0.024784458	0.009329293	0.010137223	0.02295647	0.030873933	0.072413382
2. Fishery	0.008341901	1.071283715	0.00305047	0.004557034	0.064331464	0.007571633	0.002299605	0.002364836	0.00540805	0.012591541	0.00924674
3. Forestry and hunting	0.003353709	0.009565576	1.035387017	0.017484557	0.007095184	0.041624876	0.010427265	0.008375	0.029341795	0.015946514	0.009892914
4. Mining and quarrying	0.001900345	0.009052831	0.019937585	1.026245452	0.004461253	0.009297702	0.052474942	0.003323679	0.008042862	0.004416151	0.004694769
5. Manufacturing I (Heavy)	0.159817673	0.13444428	0.052570839	0.069432729	1.311156863	0.114040904	0.033674006	0.034377486	0.08140055	0.236678591	0.092190369
6. Manufacturing II (Light)	0.080685998	0.262465481	0.080908477	0.450303344	0.103110126	1.39408466	0.306271902	0.267584995	0.894591513	0.501398159	0.184102124
7. Electricity, gas	0.017942423	0.012777218	0.053262615	0.057726802	0.014682339	0.0296672	1.080466241	0.034930872	0.024108961	0.020986943	0.038510102
8. Waterworks and supply	0.000690338	0.001982331	0.000887543	0.001866611	0.001429708	0.001144261	0.001992152	1.01359241	0.001048432	0.001421517	0.002409494
9. Construction	0.004759333	0.012263295	0.030178802	0.026949702	0.00637045	0.032206202	0.016812507	0.023333993	1.021602652	0.014069501	0.028444725
10. Transportation	0.056886698	0.039979587	0.026318457	0.057297006	0.046570739	0.044616999	0.030865094	0.04841874	0.046286523	1.028162618	0.02760015
11. Other services	0.116575379	0.102485166	0.100217238	0.169847844	0.080471119	0.119596179	0.080510927	0.098988151	0.114070672	0.126600203	1.142263395

3.3. Estimating residuals generated from production and consumption

From *LOICZ Meeting Reports* No. 28 and 32, the economic-environmental coefficient is calculated by the following formula:

$$D^* = D\,(I - A)^{-1}\,Y$$

Where: D^* = economic-environmental coefficients for generated residuals when increasing an unit of final demand from each sector:

$D = (d_{ij})_{mxn}$

where: D = Residual matrix

d_{ij} = quantity of residual type of i generated from sector j

m = type of residuals

n = number of sectors

The economic-environmental coefficient tables is presented in Table 3.3.

Table 3.3: Economic-environmental coefficients of residuals per unit of final demand for each sector (ton per million VND)

	1	2	3	4	5	6	7	8	9	10	11
BOD5	0.005427799	0.000663945	0.001845498	0.000719778	0.001139388	0.001198656	0.000416328	0.000876835	0.000912678	0.001178779	0.00170388
TSS	6.830030347	0.538894503	1.772544679	2.667895666	0.88279324	0.747439526	0.437900473	0.293664937	0.603329137	0.539517701	1.55272651
Nitrogen	0.001430745	0.00013562	0.000222435	0.000145343	0.00017368	0.000242689	9.08591E-05	0.000111522	0.000183108	0.000169156	0.00043372
Phosphorous	0.00086879	7.89479E-05	9.03975E-05	0.000321952	0.00012926	0.000130762	5.23455E-05	5.32742E-05	9.45641E-05	8.35325E-05	0.0002072

3.4. Forecasting the relationship between economic growth and residual generation

Prediction of natural processes and socio-economic aspects is a vital task in developing integrated modelling in the context of IGBP in general and SWOL in particular. The three scenarios of economic development for the Red River region have been designed from secondary documents (MOSTE 1994; GSO 1997). They illustrate economic growth in the last decade and predict for the next one. Economic development is obviously dependent on the institution and the social forces driving the development. The growth rate for each sector in Table 3.4 has been computed from the three scenarios.

Table 3.4: Forecasting the growth rate (in percentage) of each sector to the scenarios of socio-economic development

	Scenario 1	Scenario 2	Scenario 3
Growth rate of GDP (%)	*5.03*	*6.08*	*7.4*
1. Agriculture	3.50	4.23	3.80
2. Fishery	1.50	1.81	1.20
3. Forestry and hunting	0.00	0.00	0.00
4. Mining and quarrying	1.80	2.18	1.00
5. Manufacturing I (Heavy)	8.70	10.52	8.00
6. Manufacturing II (Light)	7.50	9.07	9.00
7. Electricity, gas	3.50	4.23	4.00
8. Waterworks and supply	3.50	4.23	3.50
9. Construction	4.00	4.83	8.00
10. Transportation	8.00	9.67	8.00
11. Other services	7.50	9.07	8.50

Economic development usually drives residual generation. It is also not exceptional for the region. However it is dependent on technical innovations of clean industry or reforestation efforts of national plans. The data presented in Table 3.5 shows percentages of increased residuals along with economic growth of the three scenarios, assuming that the status would be as at present.

Table 3.5: Forecasting the increased residuals (in percentage) to the scenarios of socio-economic development

	Scenario 1	Scenario 2	Scenario 3
Growth rate of GDP (%)	*5.03*	*6.08*	*7.4*
BOD5	4.39	4.85	6.83
TSS	3.78	4.04	6.45
Nitrogen	4.45	4.96	6.81
Phosphorous	4.18	4.51	6.73

3.5. Testing the extension of the I-O model in analysis of feedback

As presented, a basic I-O model of Leontief matrix showing the vector of production X in relation with the vector of final demand Y is following:

$$X = (I - A)^{-1}. \ Y \qquad (1)$$

where: A: input-output matrix; I: identity matrix

The extension of the I-O matrix to environmental variables is as following:

$$\begin{bmatrix} I - A & \phi \\ - V^* & I \end{bmatrix} \begin{bmatrix} X \\ V \end{bmatrix} = \begin{bmatrix} Y \\ \phi \end{bmatrix} \qquad (2)$$

where: V^*: matrix of residuals generated directly from production
V: vector of overall impacts of residuals
ϕ: the null matrix

The equation (2) is only related to residuals generated directly from production. A question is posing that whether the residual effects to production as a feedback, and V is a vector of two-ways impacts of residuals. We suggest the following equation to resolute the problem:

$$\begin{array}{c} \\ n \\ m \end{array} \begin{array}{c|c} n & m \\ I - A & \phi_1 \\ \hline -V^* & I \end{array} \quad \begin{array}{c} \\ X \\ \hline V \end{array} \quad \begin{array}{c} \\ Y \\ \hline \phi_2 \end{array} \qquad (3)$$

Where: ϕ_1 is the feedback matrix in which residuals effect to production.
The matrix ϕ_1 is following:

$$\phi_1 = \left[\phi_{1ij} = \frac{U_{ij}}{V_j} \right]_{n \times m}$$

where: n: number of sectors in the I-O table
m: number types of residuals
U_{ij}: expenditure of sector i (i = 1, n) for abating the residual j
V_j: total residual j
ϕ_2: vector of the residual coming from other sources: rainfall, atmosphere and outside the border in the case of RRD.

from (3) we have:

$$(I - A).\ X - \phi_1.\ V = Y \qquad (4)$$

$$- V^*.\ X + V = \phi_2 \qquad (5)$$

$$\boxed{V = \phi_2 + V^*.\ X}$$

from (5) we have: (6)

ϕ_2: residual generation from other sources
$V^*.X$: residual generation from production
V: total residuals

from (4) we have: $X = AX + Y + \phi_1.\ V$
and $Y = X - AX - \phi_1.\ V$

then we have: $\boxed{V = X - AX - U}$ (7)

where U is vector of total cost of production sectors for abating the residuals

then we have $\boxed{\Sigma\ Y = GDP - \Sigma\ U = Real\ GDP}$ (8)

from (3) we have

$$\begin{array}{c} X \\ V \end{array} \quad \begin{array}{cc} I - A & -\phi_1 \\ -V^* & I \end{array}^{-1} \quad \begin{array}{c} Y \\ \phi_2 \end{array} \qquad (9)$$

This is a basic relation in the extension of I-O table.

Supposing B =

$$\begin{matrix} I - A & -\phi_1 \\ -V^* & I \end{matrix}$$

B is a matrix of total economically cost efficient production and residuals for a unit of final demand and residual from nature.

The total cost is not only an amount by columns of the Leontief matrix, but also a residual coefficient of these sectors. Otherwise the total cost also must include expenditure for combating the residuals from nature, an increase of one unit.

Supposing that increment of final demand of any sectors affecting Δij: Production value of sector i effected by residual j. We have a change: $\Sigma Y = GDP - \Sigma\Delta$, so Real GDP = GDP $\pm$ net $\Sigma\Delta$.

Table 3.6 and 3.7 present the computed results and the cost of pollution abatement would be 5,084 MVND and real GDP of 56,907,509 MVND in comparison with GDP of 56,912,594 MVND.

Table 3.6: Input - Output table with consideration of environmental impacts of the residuals

Sectors		1	2	3	4	5	6	7
1. Agriculture		0.88079	-0.03086	-0.05121	-0.00070	-0.06395	-0.00435	0.00000
2. Fishery		0.00000	0.93982	0.00000	0.00000	-0.04580	-0.00104	0.00000
3. Forestry and hunting		-0.00007	-0.00097	0.96869	-0.00321	-0.00271	-0.02830	-0.00078
4. Mining and quarrying		-0.00007	-0.00603	-0.01584	0.97978	-0.00197	-0.00474	-0.04589
5. Manufacturing I (Heavy)		-0.09278	-0.07084	-0.02094	-0.01195	0.78569	-0.05301	-0.00022
6. Manufacturing II (Light)	**(I-A)**	-0.01693	-0.14890	-0.00670	-0.27041	-0.02764	0.75931	-0.17454
7. Electricity, gas		-0.00936	-0.00259	-0.04229	-0.03969	-0.00614	-0.01507	0.93470
8. Waterworks and supply		-0.00019	-0.00136	-0.00045	-0.00108	-0.00080	-0.00050	-0.00143
9. Construction		-0.00013	-0.00385	-0.02480	-0.01295	-0.00150	-0.02016	-0.00733
10. Transportation		-0.04145	-0.02298	-0.01561	-0.03748	-0.02759	-0.02612	-0.01648
11. Other services		-0.07628	-0.05638	-0.06800	-0.10784	-0.03758	-0.06603	-0.03802
BOD5		-0.00447	-0.00006	-0.00129	-0.00010	-0.00038	-0.00060	-0.00005
TSS	**V***	-5.77592	-0.00022	-1.15391	-2.17763	-0.12433	-0.29213	-0.08207
Nitrogen		-0.00120	0.00000	-0.00009	-0.00001	-0.00001	-0.00012	-0.00001
Phosphorus		-0.00073	0.00000	-0.00001	-0.00025	-0.00003	-0.00007	0.00000

				FEED BACK			
8	**9**	**10**	**11**	**BOD5**	**TSS**	Nitrogen	Phosphorus
0.00000	-0.00365	-0.00233	-0.04913	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	-0.00374	-0.00424	-0.00181	-0.01360	-0.25797
0.00000	-0.00238	-0.00009	-0.00350	0.00000	0.00000	0.00000	0.00000
0.00000	-0.00169	0.00000	-0.00133	0.00000	0.00000	0.00000	0.00000
0.00000	-0.00145	-0.14546	-0.04462	0.00000	0.00000	0.00000	0.00000
-0.15297	-0.62999	-0.33726	-0.08666	0.00000	0.00000	0.00000	0.00000
-0.02444	-0.00330	-0.00575	-0.02717	0.00000	0.00000	0.00000	0.00000
0.98703	-0.00021	-0.00065	-0.00184	0.00000	0.00000	0.00000	0.00000
-0.01508	1.00000	-0.00027	-0.02094	0.00000	0.00000	0.00000	0.00000
-0.03676	-0.01632	0.99590	-0.01348	0.00000	0.00000	0.00000	0.00000
-0.06222	-0.03091	-0.06408	0.89919	0.00000	0.00000	0.00000	0.00000
-0.00051	-0.00006	-0.00048	-0.00105	1.00000	0.00000	0.00000	0.00000
-0.03928	-0.03918	-0.03835	-0.91236	0.00000	1.00000	0.00000	0.00000
-0.00003	-0.00001	-0.00003	-0.00028	0.00000	0.00000	1.00000	0.00000
-0.00001	0.00000	0.00000	-0.00012	0.00000	0.00000	0.00000	1.00000

Table 3.7: Overall coefficient of residual generation with consideration of its feedback.

Sectors	1	2	3	4	5	6	7
1. Agriculture	1.15520	0.05509	0.07050	0.01927	0.10311	0.02486	0.00937
2. Fishery	0.02188	1.07236	0.00653	0.00983	0.06609	0.00907	0.00317
3. Forestry and hunting	0.00347	0.00958	1.03542	0.01753	0.00711	0.04164	0.01044
4. Mining and quarrying	0.00201	0.00906	0.01997	1.02629	0.00448	0.00931	0.05248
5. Manufacturing I (Heavy)	0.16152	0.13458	0.05301	0.07009	1.31138	0.11423	0.03378
6. Manufacturing II (Light)	0.08400	0.26273	0.08176	0.45159	0.10354	1.39445	0.30648
7. Electricity, gas	0.01810	0.01279	0.05330	0.05779	0.01470	0.02969	1.08048
8. Waterworks and supply	0.00072	0.00198	0.00089	0.00188	0.00143	0.00115	0.00199
9. Construction	0.00491	0.01228	0.03022	0.02701	0.00639	0.03222	0.01682
10. Transportation	0.05739	0.04002	0.02645	0.05749	0.04664	0.04467	0.03090
11. Other services	0.11787	0.10259	0.10055	0.17035	0.08064	0.11974	0.08059
BOD5	0.00544	0.00066	0.00185	0.00072	0.00114	0.00120	0.00042
TSS	6.83684	0.53945	1.77430	2.67055	0.88368	0.74819	0.43834
Nitrogen	0.00143	0.00014	0.00022	0.00015	0.00017	0.00024	0.00009
Phosphorus	0.00087	0.00008	0.00009	0.00032	0.00013	0.00013	0.00005

Sectors	8	9	10	11	FEED BACK BOD5	TSS	Nitrogen	Phosphorus
1. Agriculture	0.01017	0.02302	0.03093	0.07257	0.00023	0.00010	0.00075	0.01421
2. Fishery	0.00295	0.00661	0.01367	0.01233	0.00455	0.00194	0.01458	0.27663
3. Forestry and hunting	0.00838	0.02935	0.01596	0.00992	0.00004	0.00002	0.00013	0.00247
4. Mining and quarrying	0.00333	0.00805	0.00443	0.00472	0.00004	0.00002	0.00012	0.00234
5. Manufacturing I (Heavy)	0.03445	0.08155	0.23681	0.09258	0.00057	0.00024	0.00183	0.03472
6. Manufacturing II (Light)	0.26773	0.89489	0.50166	0.18486	0.00111	0.00048	0.00357	0.06778
7. Electricity, gas	0.03494	0.02412	0.02100	0.03855	0.00005	0.00002	0.00017	0.00330
8. Waterworks and supply	1.01359	0.00105	0.00142	0.00242	0.00001	0.00000	0.00003	0.00051
9. Construction	0.02334	1.02162	0.01408	0.02848	0.00005	0.00002	0.00017	0.00317
10. Transportation	0.04844	0.04633	1.02820	0.02772	0.00017	0.00007	0.00054	0.01032
11. Other services	0.09904	0.11419	0.12670	1.14256	0.00044	0.00019	0.00139	0.02646
BOD5	0.00088	0.00091	0.00118	0.00171	1.00000	0.00000	0.00001	0.00017
TSS	0.29396	0.60393	0.54006	1.55428	0.00229	1.00098	0.00734	0.13916
Nitrogen	0.00011	0.00018	0.00017	0.00043	0.00000	0.00000	1.00000	0.00004
Phosphorus	0.00005	0.00009	0.00008	0.00021	0.00000	0.00000	0.00000	1.00002

Appendix: Technical Notes

1. Relationship Between Regional and National I-O Tables

There are two types of regional I-O tables, namely: (1) intra-regional or single-region and (2) inter-regional I-O tables. An intra-regional I-O table is similar to the format of national I-O tables except that exports and imports in the final demand matrix now refer to transactions not only with foreign countries but also with the other regions of the country. It may be constructed of the competitive-imports or non-competitive-imports type of I-O transactions, depending on the availability of data.

Intersectoral transactions is a competitive-imports type of I-O table, with no distinction between locally-produced and imported goods and services. An I-O table of the non-competitive-imports type requires the separation of locally-produced from imported products. An inter-regional I-O table describes the national economy's transactions of goods and services, both intra-regionally and inter-regionally. For a better appreciation of its main features, a highly-simplified inter-regional I-O model of a two-region economy is illustrated below.

Two-region Inter-regional I-O Table

To / From	Intermediate Demand		Final Demand		To Foreign Countries	Gross Output
	Region Z	Region W	Region Z	Region W		
Region Z	A_1	A_2	F_1	F_4	F_7	X_i
Region W	A_3	A_4	F_2	F_5	F_8	X_j
Foreign Countries	A_5	A_6	F_3	F_6		
Value Added	V_i	V_j				
Gross Input	X_i	X_j				

The model is a national I-O table that is being disaggregated into two intra-regional sub-tables. Reading along the rows, it shows the disposition of outputs of economic activities to meet intermediate and final demands by economic activities and final consumers is the region itself as well as demands by other regions and foreign countries. This is, for Region Z,

$$\sum (A_1 + A_2 + F_1 + F_4 + F_7) = X_i$$

where,

A_1: Matrix of intermediate demand by sectors in Region Z for products produced by the region Z itself;

A_2: Matrix of intermediate demand by sectors in region W for products produced by region Z;

F_1: Matrix of final demand by region Z for products produced by region Z itself;

F_4: Matrix of final demand by region W for products produced by region Z itself (or exports to region W of products produced by region Z); and

F_7: Matrix of products produced by region Z exported to foreign countries.

By reading down the columns, it shows input structures of economic activities in each region as well as its final consumption patterns. Intersectorial transactions are further broken down into origin or source, whether locally-produced, from other regions or from foreign countries. So, for region Z,

$$\sum (A_1 + A_3 + A_5 + V_i) = X_i$$

where,

A_1: Matrix of intermediate demand by sectors in region Z for products produced by the region Z itself;

A_3: Matrix of intermediate demand by sectors in region Z for products produced by region W (or imports by region Z of products produced by region W)

A_5: Matrix of intermediate demand by sectors in region Z for products coming from foreign countries (or imports by region Z of products coming from foreign countries)

V_i: Value added of region Z ($\sum_i V_i$ = GDP of region Z).

The same interpretation could be made of the row and column elements of region W. It should be emphasized that the sum of the respective elements in the inter-regional table should equal to corresponding elements in the national table. For example, the sum of vectors $X_i + X_j$ is equal to vector of the nation's gross output (= gross input). The sum of vectors $V_i + V_j$ is equal to the nation's GDP.

Let,

B_1 is coefficient matrix of A_1
B_2 is coefficient matrix of A_2
B_3 is coefficient matrix of A_3
B_4 is coefficient matrix of A_4

Then,

$$B = \begin{matrix} B_1 & B_2 \\ B_3 & B_4 \end{matrix}$$

Given gross output, $X = (X_i, X_j)$ and final demand, $Y = (Y_i, Y_j)$, we have the following Leontief equations:

$X = (I - B)^{-1}Y$ for the nation
$X_i = (E - B_1)^{-1}Y_i$ for Region Z; and
$X_j = (E - B_4)^{-1}Y_j$ for Region W

where Y_i = vector of final demand for products produced in Region Z (F_1, F_4, F_7);
Y_j = vector of final demand for products produced in Region W (F_2, F_5, F_8); and
$(E - B_1)^{-1}$ and $(E - B_4)^{-1}$ are Leontief matrices of the regions.

2. Method for calculation of regional gross output, consumption and accumulation

As mentioned in section 2.4.3. of this paper, the I-O table consists of three plots representing the input and output structures of production activities of the country's economy. Plots I and III present the input structures. Plots I and II shows the output structures. Total of plot II (total final demand) must be equal to total of plot III (total value added).

2.1. Vector of gross output of the region

This vector can be calculated by using the following information:

i. Annual reports compiled by provincial statistical offices in the region;
ii. Data from industrial surveys conducted by industrial statistics section of provincial statistical offices in the region; and
iii. Data from business surveys.

2.2. Consumption Matrix

In this matrix, the rows represent the sectors identified in the I-O table and the columns denote the final demands of state or government and households.

For state consumption, its value is equal to the gross output of state management and is recorded in the intersection of the row for the state sector and the final demand column for state consumption.

The vector of household consumption is calculated using data obtained from multi-purpose household survey conducted by the GSO for some 100 kinds of goods and services consumption by households.

All gross outputs from activities by non-profit institutions, lotto operations, household income from employment and imputed rents from ownership of dwellings are treated as household consumption. Data are from statistics reports of provincial/city statistics offices. Excluded as household final consumption are usage of fertilizers, insecticides, agricultural medicines and products of construction. These products are considered either as intermediate inputs or as accumulation.

2.3. Accumulation Matrix

This matrix is of the form $T = (t_{ij})_{nx2}$

where i: 1,n (number of sectors survey in the model)
j: 1,2
t_{i1}: accumulation of fixed assets
t_{i2}: change in inventory stocks

Accumulation of fixed assets (t_{i1}) occurs within sectors that produce material products. These include machinery and other durable equipment and construction. Also included are the value of animal breeding stocks, orchards, vineyards and other perennial tree plantations.

Change in inventories (t_{i2}) refers to the difference between beginning and ending periods of non-completed products or stocks (for material products only). Data are obtained from provincial/city statistical reports of the GSO.

3. Calculation of regional exports and imports

In regional I-O table compilation, it is necessary to determine the value of outflows (exports) of products produced by a particular region to other regions and to foreign countries, further disaggregated into its intermediate and final use. Similarly, inflows (imports) to that particular region of products produced by other regions and foreign countries should be determined and further broken down into intermediate consumption and final demand sector consumption. These data requirements could be obtained only through in-depth ground-up surveys since existing statistical records on these types of information are very limited.

For the purpose of this study, exports and imports are calculated residually. Exports net of imports is estimated as the difference between gross output and the sum of intermediate demand, final consumption demand by households and state, and accumulation of fixed assets and inventory stocks.

4. Aggregation of Sectors

Aggregation of sectors depends on the objectives and purposes of constructing I-O tables. As stated earlier, this regional study involves eleven (11) sectors which were aggregated in conformity with the sector classification of the national I-O table.

5. The RAS Method of Updating I-O Tables

The compilation of I-O is a very taxing exercise. Its mathematics is relatively simple, but the assembly, balancing and reconciliation of the basic data that are usually gathered from various sources require enormous time, effort and money. It is for this reason that, in Vietnam, benchmark I-O tables are constructed only once every five years. However, the increasing demand for I-O tables as effective tools for micro-economic analysis and forecasting underscores the need for up-to-date I-O data.

To satisfy this practical issue, some non-survey methods such as the well-known RAS method are usually resorted to by most countries in updating I-O tables.

5.1. Objective of the RAS Method

The primary objective of the RAS method is to produce an I-O table for any current year t, given base-year (t_0) I-O data and available, though limited, information for current year t. For example, in Vietnam, the national I-O table was constructed in 1989 based on survey data. In order to meet the demands by economic planners and policy makers for up-to-date I-O data, the 1989 benchmark I-O table has to be updated annually.

Specifically, the 1989 matrix of intermediate input coefficients (A_0), which is a vital source of data in the micro-economic analysis of structural changes in the production process, has to be adjusted periodically.

At present, an I-O table for 1995 has been generated using the RAS method supplemented by a limited number of 1995 data obtained from surveys and other available sources.

5.2. Requirements and Assumptions of the RAS Method

Based on survey data, a benchmark I-O table is constructed initially with industries in the columns and products in the rows, i.e. it is of product-by-industry format. Then it is “purified” or converted into a product-by-product table for effective analytical purposes. This includes the matrix of intermediate input coefficients which is the main matrix that needs to be updated using the RAS method.

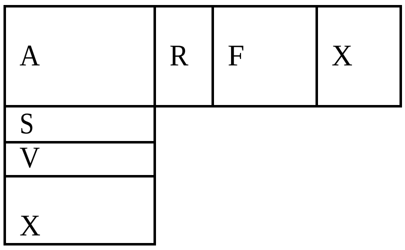
When using the simple RAS method, the following information for current year t has to be generated:

a. Vector of gross output, X, obtained from GSO estimates;
b. Matrix of final demand, Y, generated based on national accounts estimates;
c. Vector of value added, V, generated based on national accounts estimates.

The generation of levels for matrix Y is based on the assumption that there were no changes in the structural patterns of final demands between the base-year period, t_0, and the current (update) year, t. Similarly, it is also assumed that there existed no changes in the structure of sectoral value added ratios between t_0 and t in order to calculate vector V for current year t.

5.3. Main Steps in Using the RAS Method

As stated earlier, the objective of using the RAS method is to update base-year input coefficients, A(o), to chosen update year coefficients, $A_1(t)$, given predetermined levels of total intermediate demands and total intermediate inputs relating to current year t. The following general model describes the main steps to be followed in using the RAS method of adjustment:



where: A(o): Coefficient matrix of intermediate inputs of base-year I-O table
A(t): Coefficient matrix of intermediate inputs of update year t
R(t): Vector of intermediate demand of update year t
F(t): Vector of total final demand of update year t
S(t): Vector of total intermediate inputs of year t
V(t): Vector of value added of year t
X(t): vector of gross output of year t.

From the above analytical model, the following relations can be established:

a. Total intermediate demand + total final demand = total gross output

$$R + F = X$$

b. Total intermediate input + total value added = total input

$$S + V = X$$

In practice, there are three main steps to be followed when using the simple RAS mehod, given matrix A(o):

Step 1. Construct the matrices of final demand, F(t), and value added, V(t), for update year t, based on available information.
Step 2. Compute for vectors of intermediate demand, R(t) and intermediate inputs S(t) , given gross output levels, X(t), and matrices F(t) and V(t); and
Step 3. Apply the interation method of adjusting A(o), given row and column contraints, R(t) and S(t), respectively

The iteration method is a proportional adjustment of elements of A(o) successively along the rows and columns until convergence is reached, i.e. the iterated row and column sums are equal to known row and column totals as determined in Step 2.

5.4. Implementing Procedures of the RAS Method
Step 1. Balancing along the rows

Let X'(t) be a matrix with vector of output, X(t), as elements on the diagonal:

$$A_1(t) = A(o) \times X'(t)$$

and $R_1(t)$ be a matrix with elements on the diagonal:

$$R_1 ij = \frac{R_i}{\sum_{j=1}^{n} a_1 ij}$$

where $a_{1\,ij}$ are elements of matrix $A_1(t)$.

Then we have:

$$A_2(t) = R_1(t) \times A_1(t) = R_1(t) \times A(o) \times X'(t)$$

Matrix $A_2(t)$ has a total along the rows equal to vector R(t) (vector of intermediate demand).

Step 2. Balancing down the columns

Let $S_1(t)$ is a matrix with elements on the diagonals:

$$S_1 ij = \frac{S_j}{\sum_{i=1}^{n} a_2 ij}$$

where $a_{2\,ij}$ are elements of matrix $A_2(t)$.

Then we have

$$A'_2(t) = A_2(t) \times S_1 = R(t) \times A(o) \times X(t) \times S_1(t)$$

The new matrix, $A'_2(t)$, has column totals equal to S (vector of intermediate input). However, adjusting along the columns results in new row totals (intermediate demand). The matrix is then iterated successively along the rows and columns until both row and column totals are equal. We then have the following equation:

$$A(t) = R_n(t) \times R_1(t) \times A(o) \times X_1(t) \times S_1(t) \times \ldots \times S_n(t)$$

The *n* number of iterations depends on ratio differentials between intermediate input and demand ratios relative to base-year, t(o). The RAS method cannot be applied if ratio differentials are relatively large.

5.5. Lessons learned from using the RAS method in Vietnam
Based on the I-O table constructed in 1989, the RAS method is used for adjusting and updating an I-O table of 25 sectors by sectors for 1994 and 1995. It has supplied the required analyses and predictions of the macro-economy of the country while reducing the time and budget costs.

The I-O table constructed in 1994 is relevant to the year issuing a fixed price table. So it is important initially for calculating GDP at the price of the original year (1994) from the I-O table.

In using the RAS method for adjusting and updating the I-O table for 1994-5, some issues have arisen:

- The economy of the country is under transition, so all factors can not be kept stable as supposed by the RAS method. Additional data from surveys in 1992 and 1994 for adjusting and updating plots of I and II are referenced in using the RAS method. So the result obtained is relevant to the economy in practices.
- Affected by changes of goods and commodities imported from foreign countries, the results of using the RAS method is still limited, as the economy is unstable.

For constructing the I-O table of 1996, more information should be gathered for adjusting and updating, in relation to practical issues, especially production investment from outside, technology innovation and equipment improvement, etc.

4. THE INTEGRATED ECONOMIC-ENVIRONMENTAL MODELLING

As required, all residuals of C, N and P should be modelled in the integration. However, due to shortage of relevant data available, we are testing only nitrogen in the integrated economic-environmental modelling.

4.1. Estimation of modelling components

For constructing an integrated model for natural processes and socio-economic activities in the Red River region, three main parts should beincluded:

- The residuals generated from production and household consumption inside Vietnam territory. These have been introduced by the I-O model.
- Residuals generated from the nature including direct rainfall and forest runoff in the watersheds.
- Residuals in runoff and flows coming from outside the country, contributing a significant source.

4.1.1. Nitrogen source from direct rainfall

This is calculated from data of rainfall and air quality collected in the meteorological and environmental network in the river basin. If the river basin is divided into n parts, each part with area S_i (km2), rainfall is considered as identical with annual value R_i (mm) and N concentration in rainwater c_i (mg/l). The N value in rainwater is usually calculated directly from NO_2, NO_3, and NH_4. The total N may be calculated indirectly from NO_3 recorded by following formula:

$$c(N) = 0.235361 * c(NO3) + 0.16576 \qquad (1)$$

The relation between total N and NO_3 in freshwater from surveys was presented in Figure 4.1. From this result, the simple formula for calculating annual total N (ton/year) driving to the river basin is as follow:

$$TN_{atm} = 1/1000.\sum S_i R_i c_i(N) \qquad (2)$$

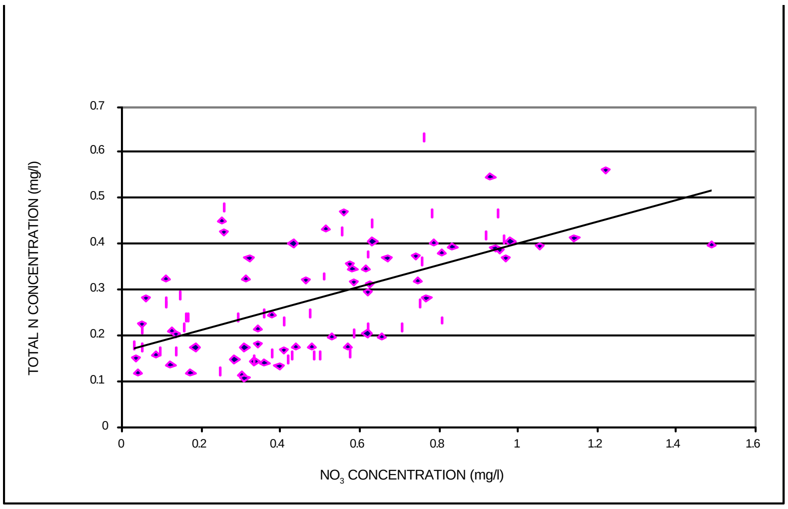


Figure 4.1. Correlation of total nitrogen and NO_3 concentration in fresh water.

Table 4.1. Nitrogen deposits from rainfall by provinces in the catchment area.

Provinces	Area (km^2)	Average rainfall (mm)	Nitrogen (ton)
Ha Giang	7,831	2,692	4,322
Tuyen Quang	5,801	1,573	1,871
Lai Chau	17,140	2,259	7,937
Lao Cai	8,050	1,469	2,424
Yen Bai	6,802	2,048	3,437
Son La	14,210	1,667	4,856
Hoa Binh	4,612	1,374	1,564
Vinh Phu	4,836	1,416	1,478
Hai Hung	2,552	1,606	1,210
Ha Tay	2,153	1,829	978
Hai Phong	1,504	1,829	629
Ha Noi	921	1,240	285
Nam Ha	2,419	1,305	788
Thai Binh	1,524	1,237	431
Ninh Binh	1,387	1,467	567
Total	81,738		32,777

Source: Data of rainfall and chemicals in rain water collected in 1995-1996 from Meteorological and Environmental Monitoring Networks (Lien 1996)

4.1.2. Nitrogen source from forest runoff

Natural nitrogen source generated from forest runoff can be estimated by following formula, although it also depends on forest structure and function.

$$N_{forest} = \sum SF_j \cdot c_j(N) \qquad (3)$$

in which SF_j is area of forest belonging to category j (km^2)
c_j is weight of N (kg) generated from 1 km^2 per year of that forest category.

Due to shortage of data measured directly for each category of forest, the total nitrogen generated from a forest of about 143-357 kg/km^2/year in US and 840 kg/km^2/year in Swiss pre-Alps has been tested (Dekker 1987; Arceivala 1986). A primary estimation of nitrogen regenerated from forest in the Red River basin has been calculated by assuming that the whole forest area is identical in nitrogen generation and an average value is about 250 kg total nitrogen per km^2 per year (cN).

The forest area is covering 14,973 km^2 in the Red River basin. Based on formulae (1) and (3), the nitrogen generated from forests totals about 3,743 tons per year.

4.1.3. Nitrogen sources from outside the national border

There are four main river-branches in Red River system. They are Gam, Lo, Thao and Da River. Four these river-branches originate in China. The area upstream belonging to China occupies more than half of the river basin. Therefore, the contribution of water and chemicals from outside the border is a significant volume. Based on the data from the National Hydrological Monitoring Network and other sources, preliminary estimation of water flow and NO_3 or total N concentration in water of Gam, Lo, Thao and Da river at national border areas have been done. Total N inputted from outside to the down stream of the Red River in 1996 is about 21,649 tons, in which :

Gam river :	365 ton	Lo river : 965 ton
Thao river:	6,525 ton	Da river: 13,794 ton

4.1.4. Nitrogen generation from economic activities

This source is taken from the I-O model. The formula for calculating of total N generated by economic sectors as follows:

$$X_{pro} = B ✪ Y_{FD} \quad (4)$$

Where:
X_{FD} = {xp_j }; xp_j is vector of annual total nitrogen generated by production sector i (ton).
B = {b_i} (i=1... 11) is vector of "economic environmental co-efficient of nitrogen residual per unit of final demand for each sector" (ton/million VND), was presented in part 2.
✪ is Scalar multiplication
Y_{FD}= {yp_j }, yp_j is vector of annual total final demand of sector i (million VND).

The total residual generation by economic and household consumption has been estimated (Table 4.2).

Table 4.2: Estimation of residual generation from economic activities based on the final demand and economic-environmental coefficient.

	Final demand (MVND)	Nitrogen (ton)	Total suspended solid (ton)	Phosphorus (ton)	Biological oxygen demand (ton)
Agriculture	21,898,890	31,332	149,570,083	19,026	118,863
Fishery	297,847	40	160,508	24	198
Forestry and hunting	1,202,219	267	2,130,987	109	2,219
Minning and quarying	617,880	90	1,648,439	199	445
Manufacturing I	8,121,295	1,411	7,169,424	1,050	9,253
Manufacturing II	-3,609,929	(876)	(2,698,204)	(472)	(4,327)
Electricity,gas	1,025,295	93	448,977	54	427
Waterworks and supply	229,650	26	67,440	12	201
Construction	12,414,711	2,273	7,490,157	1,174	11,331
Transportation	357,772	61	193,024	30	422
Other services	14,356,964	6,227	22,292,439	2,975	24,463
Total		**40,943**	**188,473,275**	**25,123**	**163,493**

The percentage of nitrogen generation from nature and economic activities is presented in the table 4.3. However, regarding the ambient concentration, many branches and canals in the downstream link the Red River system and Thai Binh river system with each other. It is estimated that there are about 24% of water volume of Red river system contributing to Thai Binh river system. The annual percentage of water volume flowing through seven river mouths as follow: Kinh thay 7%, Van Uc 11.5%, Thai Binh 16%, Tra Ly 9%, Balat 38%, Luc 10.5% and Ninh co 8%.

Table 4.3. Percentage of nitrogen generated from different sources.

Sources	**Nitrogen**	
	(ton)	(%)
Economic activities	40,943	43.97
Out-side border	21,649	23.25
Forest run-off	3,743	4.02
Direct rainfall	26,777	28.76
Total	**93,112**	**100**

The rate of nitrogen loss in transport process is evident, but it is not possible to identify for the whole river basin. The loss is a complicated process depending on many factors. The total DIN inputted to Balat estuary from fresh water runoff of Red River was 8,181 ton. It is estimated about 11,612 ton of nitrogen or 25.8 % of total nitrogen was generated in the basin flowed to the Balat river mouth. Supposing that the N flow is identical for all river system as well as at river mouths, the loss function is simple i and total nitrogen inputted at the river mouth j (NRMj) (j=1,7) is:

$$NRM_j = A_j \,.\, Res.\, Co \,.\, TN\,/100 \qquad (5)$$

where:

A_j is the percentage of annual water volume of all Red River basin flowed into river mouth j;

Res.Co is residual co-efficient of nitrogen - the difference between total nitrogen generated and loss in the basin.

The maximum nitrogen generated from natural and economic sources of the year 1996 in the Red River basin is estimated about 99,111 tons. An ambient measurement of nitrogen during field trip surveys and data collected from monitoring stations in 1996 is presented in Table 4.4.

Table 4.4. Ambient distribution of nitrogen (ton) input to the Red and Thai Binh river mouths.

River mouth	**Total Nitrogen flow (ton)**	
	Maximum	1996
Kinh thay	6,938	1,567
Van uc	11,397	2,476
Thai binh	15,858	3,445
Tra ly	8,920	1,938
Ba lat	37,662	8,181
Luc	10,407	2,261
Ninh co	7,929	1,722
Total	**99,111**	**21,590**

* Maximum amount is calculated assuming no losses during transportation

** Amount in 1996 is an ambient measurement during field trip surveys and data collected from monitoring stations during this year.

4.2. Integrated modelling

4.2.1. Integrated model for nitrogen

By using the Stella 2, the nitrogen generated from economic activities in the catchment linking to biogeochemical processes in Ba Lat estuary has been modeled. However, there are some modifications in consideration of variables. In this case, the variable in "cumulated operator" such as sectors and areas have been used as time variables. Because of the difference in variables, the process must be separated into parts, which aren't connected together. But the result of the block will be linked in terms of input data. There are five blocks in the model, described in Figure 4.2..

- Block of nitrogen generated from direct rainfall
- Block of nitrogen generated from forest runoff
- Block of nitrogen inputted from outside the national border
- Block of nitrogen generated from production and household consumption
- Block of nitrogen accumulated from all generated sources and its delivery to river mouths.

Based on the modelling, the estimation on nitrogen and phosphorus as well as DIN or DIP exchange in the estuaries of the Red River can be done at the same time. However, because of some problems in lack of data, the estimates are still limited. It is necessary to extend the study in the next phase of the Project.

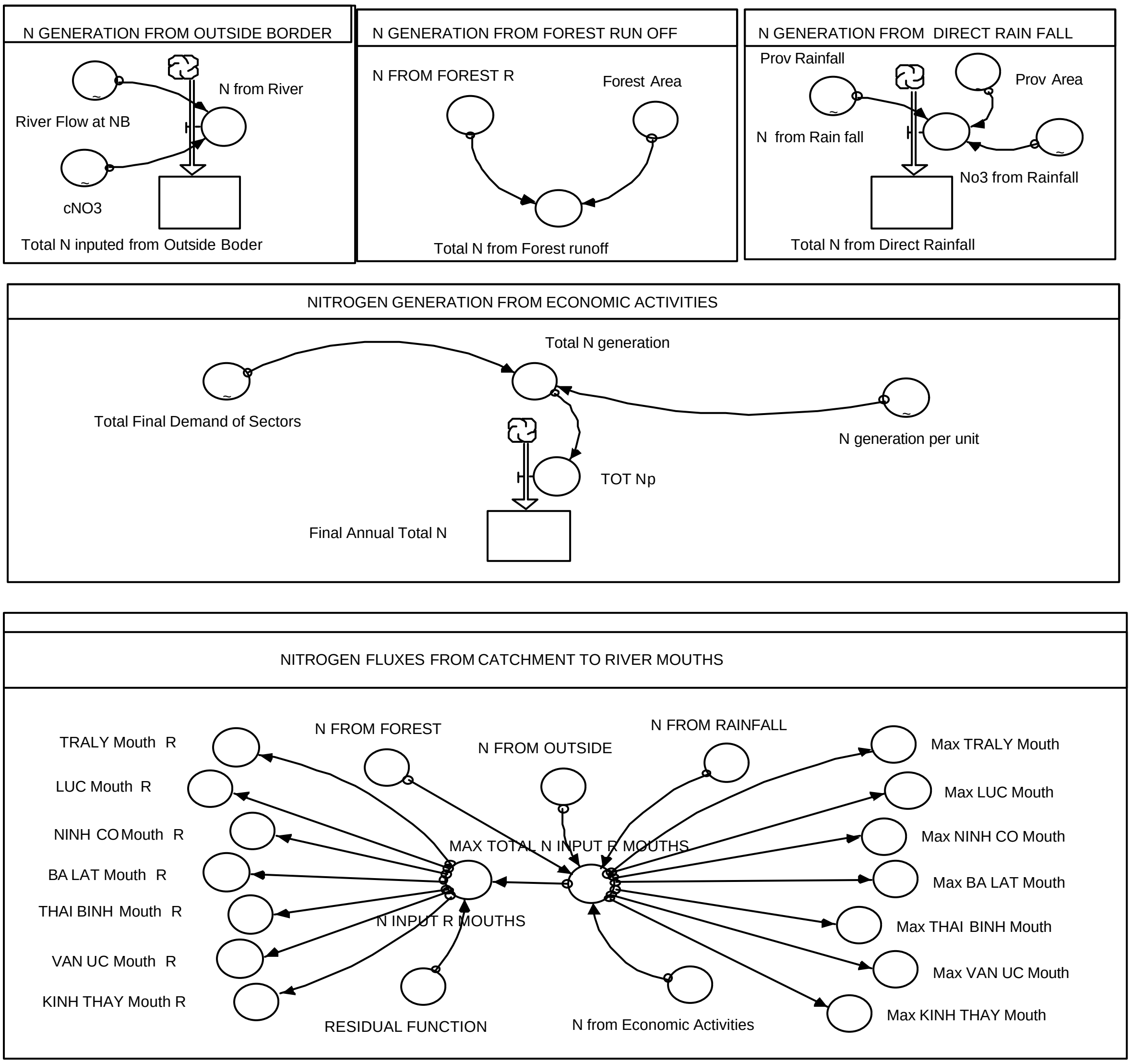


Figure 4.2. Integrated modelling for the nitrogen generation

4.2.2: Scenario development for the integrated modelling

Based the scenarios developed in previous parts, the increased nitrogen has been estimated. It is stated that in the period of 10-20 years, the economy in the region is still dependent to the agriculture development including foodstuff and industrial tree plantation. The agriculture sector is remaining over 75 percent of total generated nitrogen residual. However the attention should be paid to the consumption derived from population growth which is included in the final demand as described in the I-O model.

The forecasting will be extended for the rest of residuals, such as phosphorous, carbon, total suspended sediment and biological oxygen demand.

Table 4.5. Forecasting the increased nitrogen generation (ton) from the scenarios of socio-economic development in the region

Sectors	Scenario 1 (Increased GDP 5.03%)	Scenario 2 (Increased GDP 6.08%)	Scenario 3 (Increased GDP 7.4%)
Agriculture	32,725.99	32,885.78	33,465.42
Fishery	42.19	42.40	43.14
Forestry and hunting	279.32	280.68	285.63
Mining and quarrying	93.80	94.26	95.92
Manufacturing I	1,473.27	1,480.47	1,506.56
Manufacturing II	(915.08)	(919.54)	(935.75)
Electricity, gas	97.30	97.78	99.50
Waterworks and supply	26.75	26.88	27.36
Construction	2,374.39	2,385.99	2,428.04
Transportation	63.21	63.52	64.64
Other services	6,504.00	6,535.76	6,650.95
Total	**42,765.15**	**42,973.96**	**43,731.41**

4.3. Testing Dose-Response model

In order to estimate the impact of residuals resulting from economic activities through the biogeochemical processes, a model of dose-response for selected species has been tested by suitability index.

The dose-response index is calculated for selected species, based on the following assumption

SI = minimum $\{I_1, I_2, I_3 ... I_n\}$

Where SI is Suitability Index; I_n is index as derived from evaluation species requirements a long with ambient concentration of C, N and P.

A dose-response of nitrogen and phosphorus has been tested for *Kandelia candel,* a dominant species extensively planted in the area. The results show that adding nitrogen to the soil is getting a positive result in terms of growth rate and successful establishment rate of seedlings, but no response for phosphorus addition.

The uncertainty of the result requires intensive research in the area. An addition, the dose-response model should be tested for biological producers, in particularly mangroves and phytoplankton.

4.4. Proposed indicators for sustainable management

The research is meeting the SARCS and LOICZ objectives, and also contributing to the national priorities in rehabilitation and sustainable management of the coastal ecosystems.

Based on the national program on monitoring research, a set of indicators for coastal ecosystems health is developed, and proposed indicators for mangrove ecosystem health in the Red River Delta are designed by using the Stella 2 in clarifying the relationship and necessity of the work.

Five blocks in the model indicate different areas in networking of the indicators. These include energetic and nutrient dynamics, hydrology, geomorphology, natural habitats and biological communities. So, C, N and P budgets are only one indicator for ecosystem health. The understanding of changes of the residuals should be elucidated through its relationship with other factors, such as sediment, topography, habitat disturbance and sea level rise.

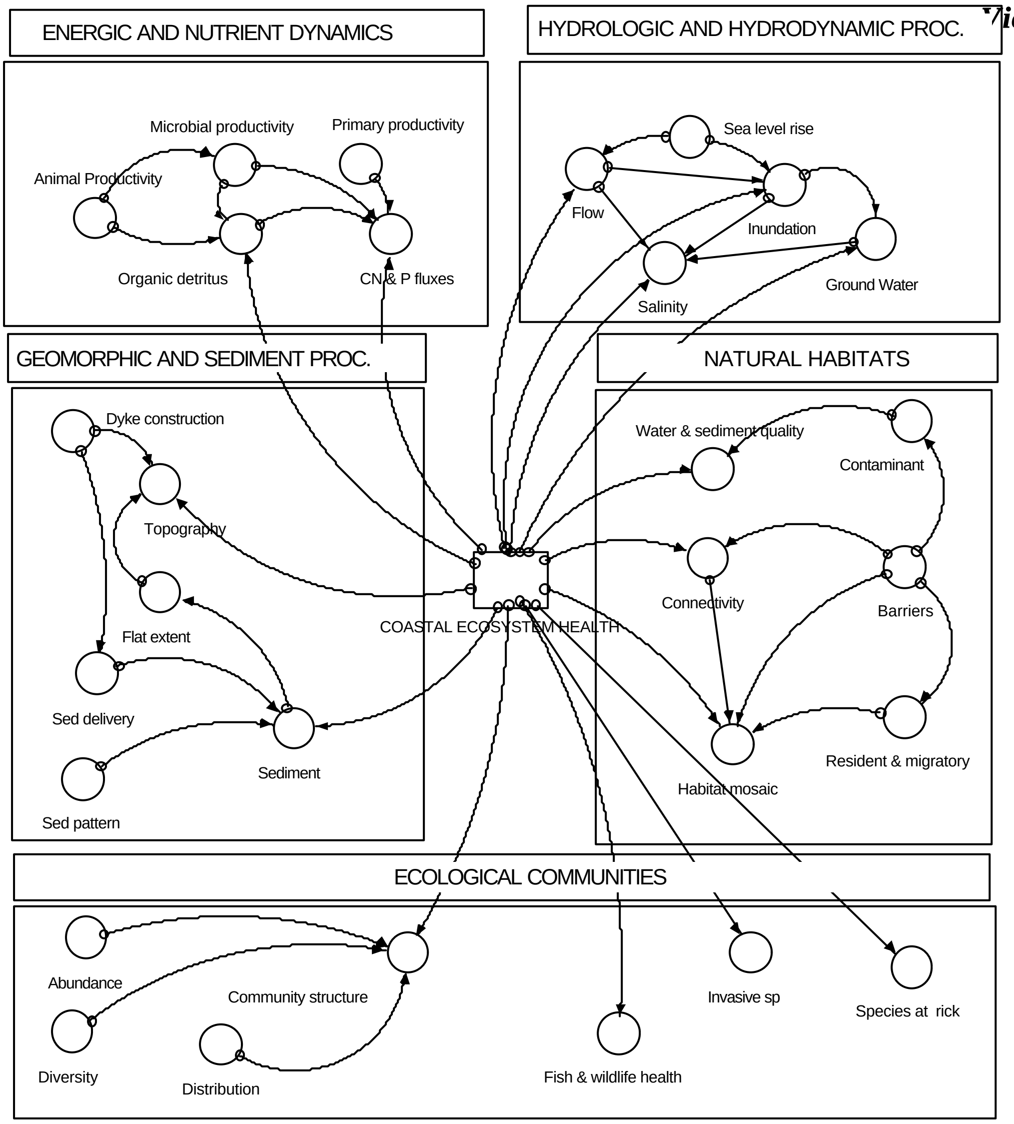


Figure 4.3. Proposed indicators for coastal ecosystem health in the Red River Delta

5. CONCLUSION AND SUGGESTIONS

The budgeting of C, N and P in the Red River system depends on size, hydrological and hydrographical regime and biogeochemical function. Within the context of system analysis at three states (N/P=13; N/P=16 and N/P=30), the calculated values of (*nfix-denit*) are negative. That means that denitrification exceeds N fixation throughout the year and it is, therefore, an important sink of nitrogen. Regarding both states, the net ecosystem metabolism (NEM or [*p-r*]) is negative, so it is a net heterotropic system thoughout the year.

Human impacts in terms of economic activities and household consumption contribute significant residuals into the coastal zone with 43.97% contribution to the total 93,112 tons of nitrogen in 1996. The relationship of the growth rate of Gross Domestic Product (GDP) and residual generation is evident. Land-use and land cover change and other activities are driving changes in C, N, P and sediment fluxes in terms of the time and space patterns. The elucidation of the change to ecosystem health in the coastal zone and feedbacks to the economic activities need more appropriate approaches.

Results from the research are providing a sound scientific basic for the sustainable management of the coastal zone in the Red River Delta and as a demonstration site to the strategy of conserving and enhancing the coastal environment.

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