UNIVERSITAS INDONESIA

DISTRIBUTION OF NUTRIENTS IN FLOODPLAIN BASED ON SPATIAL AND TEMPORAL VARIATION (Case Study: Azame-no-Se Floodplain, Saga Prefecture, Japan)

FINAL REPORT

THANTI OCTAVIANTI
0706163893

FACULTY OF ENGINEERING
ENVIRONMENTAL ENGINEERING STUDY PROGRAM
DEPOK
JANUARY 2012

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Proposed as one of the requirements to obtain a Bachelor's degree

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JANUARY 2012

STATEMENT OF AUTHENTICITY

I declare that this final report is the result of my own research,

and all of the references either quoted or cited here

have been mentioned properly.

Name	**: Thanti Octavianti**
Student ID	**: 0706163893**
Signature	:
Date	: January 20, 2012

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Skripsi ini adalah hasil karya saya sendiri,

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telah saya nyatakan dengan benar.

Nama	**: Thanti Octavianti**
NPM	**: 0706163893**
Tanda Tangan	: [signature]
Tanggal	: 20 Januari, 2012

STATEMENT OF LEGITIMATION

This final report submitted by

Name	: Thanti Octavianti
Student Number	: 0706163893
Study Program	: Teknik Lingkungan
Thesis Title	: Distribution of Nutrients in Floodplain Based on Spatial and Temporal Variation (Case Study: Azame-no-Se Floodplain, Saga Prefecture, Japan)

Has been successfully defended before the Council of Examiners and was accepted as part of the requirements necessary to obtain a Bachelor of Engineering degree in Environmental Engineering Program, Faculty of Engineering, Universitas Indonesia.

BOARD OF EXAMINERS

Adviser I	: Dr. Cindy R. Priadi, S.T., M.Sc.	(............................)
Adviser II	: Ir. Irma Gusniani, M.Sc.	(............................)
Examiner I	: Dr. Ir. Setyo S. Moersidik, DEA	(............................)
Examiner II	: Ir. Firdaus Ali, M.Sc., Ph.D.	(............................)

Defined in : Depok
Date : January 20, 2012

HALAMAN PENGESAHAN

Skripsi ini diajukan oleh
Nama : Thanti Octavianti
NPM : 0706163893
Program Studi : Teknik Lingkungan
Judul Skripsi : Persebaran Nutrisi di Dataran Banjir (*Floodplain*) Berdasarkan Variasi Spasial dan Temporal (Studi Kasus: Dataran Banjir Azame-no-Se, Prefektur Saga, Jepang)

Telah berhasil dipertahankan di hadapan Dewan Penguji dan diterima sebagai bagian persyaratan yang diperlukan untuk memperoleh gelar Sarjana Teknik pada Program Studi Teknik Lingkungan, Fakultas Teknik, Universitas Indonesia.

DEWAN PENGUJI

Pembimbing I : Dr. Cindy R. Priadi, S.T., M.Sc. (............................)

Pembimbing II : Ir. Irma Gusniani, M.Sc. (............................)

Penguji I : Dr. Ir. Setyo S. Moersidik, DEA (............................)

Penguji II : Ir. Firdaus Ali, M.Sc., Ph.D. (............................)

Ditetapkan di : Depok
Tanggal : 20 Januari 2012

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Depok, January 20, 2012

Thanti Octavianti

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Program Studi : Teknik Lingkungan
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ABSTRACT

Name : Thanti Octavianti
Study Program : Environmental Engineering
Title : Distribution of Nutrients in Floodplain Based on Spatial and Temporal Variation (Case Study: Azame-no-Se Floodplain, Saga Prefecture, Japan)

Flood event carrying nutrients from main stream to floodplain is indispensable for organisms living in the floodplain. The escalation of nutrient concentrations is a function of hydrological connectivity of river-floodplain dynamic system. Thus, the aims of this study are to investigate the distribution of nutrients based on spatial and temporal variation during flood event and to identify the possible sources of nutrients contributing to the flood event.

Four sampling sites and five sampling points in various elevations for each site were established around Azame-no-Se floodplain. Moreover, surface water was sampled one day before and two days after inundation to investigate the temporal variation.

The spatial variation demonstrates that site in close proximity to input channel connecting floodplain and main stream (Matsuura River) contains the highest nutrients, with particulate matter in considerable part. In addition, particulate matter tends to accumulate in the lower elevation. Temporal variation indicates that the highest nutrient concentrations occur during inundation time, in which flood event carried in significant portion of dissolved matter. The excees of nutrient content showed by these variations is a signal of eutrophication in the floodplain. Possible sources of nutrient during flood event are the agricultural runoff from adjacent land use and local source of the agitation of bottom sediments of floodplain.

Keywords:
Floodplain, Azame-no-Se, Matsuura River, Flood event, Eutrophication

ABSTRAK

Nama : Thanti Octavianti
Program Studi : Teknik Lingkungan
Judul :Persebaran Nutrisi di Dataran Banjir (*Floodplain*) Berdasarkan Variasi Spasial dan Temporal (Studi Kasus: Dataran Banjir Azame-no-Se, Prefektur Saga, Jepang)

Banjir yang membawa nutrisi dari sungai utama ke dataran banjir (*floodplain*) adalah kejadian penting bagi organisme yang hidup di *floodplain*. Eskalasi nutrisi merupakan fungsi dari konektivitas hidrologi yang terjadi antara sistem dinamis sungai-*floodplain*. Oleh karena itu, tujuan studi ini adalah untuk menginvestigasi persebaran nutrisi berdasarkan variasi spasial dan temporal selama banjir di *floodplain* dan mengidentifikasi sumber nutrisi yang mungkin berkontribusi pada kejadian banjir.

Empat lokasi *sampling* dan lima titik *sampling* pada tiap lokasi ditetapkan di dataran banjir Azame-no-Se. Selain itu, *sampling* juga dilakukan untuk air permukaan satu hari sebelum dan dua hari setelah banjir untuk menginvestigasi variasi temporal.

Variasi spasial menunjukan bahwa lokasi *sampling* yang berada dekat dengan saluran penghubung *floodplain* dan sungai utama (Sungai Matsuura) mengandung nutrisi tertinggi, dengan dominasi materi partikulat. Selain itu, materi partikulat ini cendrung berada di elevasi rendah pada semua lokasi. Sedangkan, variasi temporal mengindikasikan bahwa konsentrasi nutrisi tertinggi terjadi selama banjir, dimana banjir membawa materi terlarut dalam jumlah yang signifikan. Tingginya kandungan nutrisi merupakan sinyal eutrofikasi yang terjadi di *floodplain.* Sumber nutrisi yang mungkin berkontribusi pada banjir di *floodplain* adalah limpasan dari areal pertanian dan sumber lokal berupa agitasi sedimen *floodplain*.

Kata kunci:
Floodplain, Azame-no-Se, Sungai Matsuura, Banjir, Eutrofikasi

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CHAPTER 1
INTRODUCTION

1.1 Background

Japan is an archipelago with a total area of 377,800 km^2. About 74% of the area is mountainous, with a mountain range running through each of the main islands. These islands extend over 2,000 km in total length but spread only about 300 km in width. Japan lies in the northeast tip of the Asian Monsoon Zone that encompasses India, China, Korea, and the Southeast Asian countries. The country’s four distinct seasons feature three periods of heavy precipitation: heavy winter snowfalls blanket the Japan Sea side, *tsuyu* (the rainy season) brings continuous heavy rains to most of the archipelago during the second annual wet period in June and July, and typhoons that originate in the southern Pacific. These three wet periods shove the nation's average annual precipitation which is almost double of the world (MLIT, n.d.).

Due to Japan’s extreme topographical and meteorological conditions, the nation’s river exhibit distinctive natural characteristics. The rivers are prone to flooding because they flow rapidly, due to the steepness of slopes along their basins and the relative shortness. Besides, they carry their sediment to the flatlands where they deposit it to form moderately sized alluvial plains (MLIT, n.d.). The mountainous setting contributes in creating these characteristics.

The vulnerable position of flood and typhoon disaster coupled with the fact that Japan’s population density is primarily concentrated in lowland urban areas have cost Japan big loss. Between 1945 to 1960, typhoon and flood caused 20,000 people dead in Japan. Therefore, regulations regarding river and flood control become an important issue to protect citizens and boost economic sector (Nakamura, n.d.).

In the last decades, most riverbanks in Japan have been constructed into concrete. It aims to make rainwater flow faster downstream avoiding risk of flood (Yoshimura et al., 2005). However, this flood protection caused habitat loss for certain species, resulting in the extinction of biodiversity in most of Japanese rivers and wetlands, where in fact, wetlands are one of the most productive habitats on earth, and they support many kinds of life (Keddy, 2010). In the beginning of 1990s, Japanese government implemented restoration to rivers and wetlands to restore flora and fauna that have been lost due to the alteration of riverbanks.

Wetland can be found in various ecosystems, for instance floodplain. Floodplains are ecosystems whose vegetation dynamics and primary productivity are strongly influenced by flood events (Beltman, Willems, & Gusewell, 2007). Junk, Bayley, & Sparks (1989) termed floodplain area as the aquatic/ terrestrial transition zone (ATTZ) because it alternates between aquatic and terrestrial environments.

In river-floodplain systems, the hydrological regime is the key factor that promotes ecological functioning and determines biodiversity patterns (Agostinho, Bonecker, & Gomes, 2009), and this regime is maintained mainly by the flood pulse (Junk, Bayley, & Sparks, 1989). Floods cause a sudden dramatic change in all environmental parameters such as water flow, thermic and oxygen conditions, light penetration, nutrient gradients, etc (Godlewska et al., 2003).

Inundation supplies floodplain in significant amount of nutrients from river system. As the result, escalation of nutrient gradient occurs during flood event. The high nutrient status of stream indeed will induce eutrophication in floodplain. Based on the potency of eutrophication due to the connectivity of river-floodplain dynamic system, the objectives of this study are to investigate the nutrient distribution in floodplain during flood event based on spatial and temporal variation and to identify the possible sources of nutrients.

1.2 Research Question

The following are the research questions of this study.

- How is the distribution of nutrients based on spatial and temporal variation during flood event in floodplain?
- What are the possible sources of nutrients contributing to the nutrient input during flood event in a river-floodplain system?

1.3 Aims of the Study

The following are the aims of this study.

- To investigate the distribution of nutrients based on spatial and temporal variation during flood event in floodplain.
- To identify the possible sources of nutrients contributing to the nutrient input during flood event in a river-floodplain system.

1.4 Scope of the Study

- Study is conducted in Azame-no-Se floodplain located in Saga Prefecture, Japan. This floodplain is an artificial restored floodplain whose input water originates from Matsuura River.
- Observed parameters are total nitrogen (TN), dissolved total nitrogen (DTN), total phosphorus (TP), and dissolved total phosphorus (DTP).
- During inundation only one direction of nutrient transfer, from river to floodplain, is observed.
- Sample is flood water collected from twenty sampling points varied by site locations and elevations. Due to the limitation of sampling methodology, the possible number of sampling is one series for one flood event.
- The magnitude of flood event cannot be determined, hence samples may be collected from discrepant flood events.

1.5 Benefits of the Study

This study can be beneficial to several parties as follows.

a. To writer

Writer becomes acknowledged of floodplain existence and factors affecting it. Moreover, this study is proposed as one of the requirements to obtain a bachelor title of environmental engineering in Universitas Indonesia.

b. To associated stakeholders

This study is an integrative study regarding the nutrient cycle in the floodplain conducted by current doctoral student in Kyushu University. Moreover, as it will present nutrient distribution pattern in flood event, it can be useful to understand biodiversity distribution in floodplain by investigating the vegetation growth pattern and certain fauna habitat. The potency of eutrophication and the associated implication in providing qualified raw water for drinking water and other purposes will also be an input to certain stakeholders.

c. To community

This study can give certain information to communities about the importance of nutrient concentration carried by flood event to floodplain and the contribution from watershed activities to the escalation of nutrient gradients in floodplain.

CHAPTER 2

LITERATURE REVIEW

2.1 Floodplain Overview: Definition and Function

River floodplains are ecosystems whose vegetation dynamics and primary productivity are strongly influenced by flood events (Beltman, Willems, & Gusewell, 2007). While, Junk, Bayley, & Sparks (1989) defined floodplains as areas that are periodically inundated by the lateral overflow of rivers or lakes, and/ or by direct precipitation or groundwater; the resulting physicochemical environment causes the biota to respond by morphological, anatomical, physiological, phonological, and/ or ethological adaptations, and produce characteristic community structures. The "active floodplain" of a river is defined by North American hydrologists as the area flooded by a 100-year flood (Bhowmik & Stall, 1979).

Junk, Bayley, & Sparks (1989) termed the floodplain area as the Aquatic/ Terrestrial Transition Zone (ATTZ) because it alternates between aquatic and terrestrial environments. On a global scale, it occupies a substantial area (more than 2×10^6 km^2 or 1.3% of the earth's land surface) and show strong alteration and degradation with increasing human population density (Tockner & Stanford, 2002).

Floodplain consists of several types of ecosystem, including wetland. In Figure 2.1, wetland ecosystem is represented by backswamp. Wetland is an ecosystem that arises when inundation by water produces soils dominated by anaerobic processes, which, in turn, forces the biota, particularly rooted plants, to adapt to flooding (Keddy, 2010).

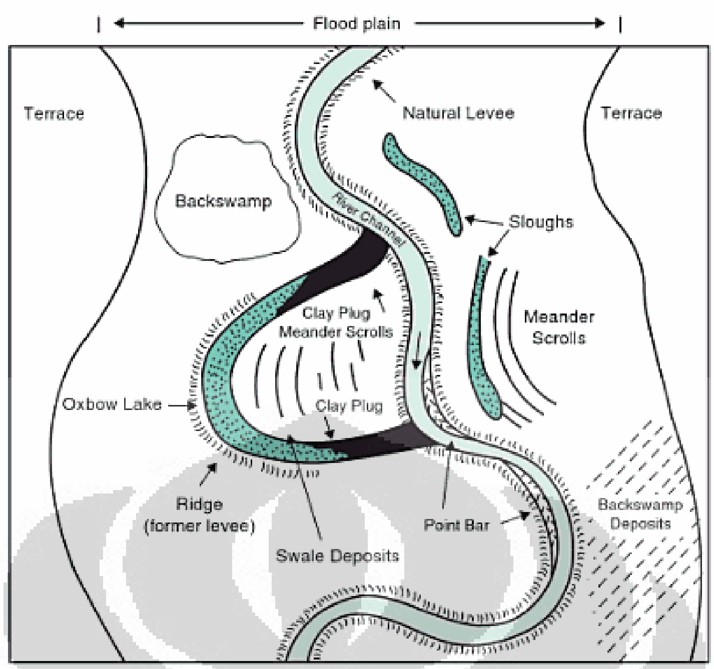


Figure 2.1. Typical floodplain shape

(Mitsch & Gosselink, 1986)

Although the concepts of shallow water or saturated conditions, unique wetland soils, and vegetation adapted to wet conditions are fairly straightforward, combining these factors to obtain a precise definition of wetland is difficult. Figure 2.2 depicts wetland definition from its unique components.

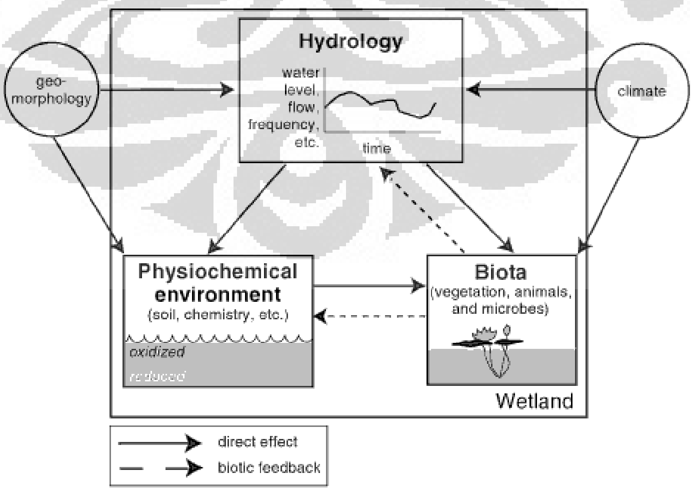


Figure 2.2. The-three-components basis of a wetland definition: Hydrology, physiochemical environment, and biota

(Mitsch & Gosselink, 2007)

Floodplain are recycled as eroding banks provide the coarse sediment and large woody debris for building new bars (Dykaar, Bruce, & Wigington, 2000). River transportation is an essential process in the formation of a floodplain caused by deposition during flooding over a long period of time. At this stage, the river will carry a large load. The load is carried primarily by solution and suspension. When the water level of the river reaches the level of its banks, this is known as "full-bank discharge". At this time, river deposition will be the main process. The depth of the flooded water will be shallow, leading to friction with the ground surface. This will reduce the speed and energy of the flow.

Figure 2.3 shows the illustration of the formation of floodplain. As the floodwater loses energy, the capacity and competence of the flood-water is reduced, leading to deposition. The bed-load, the heaviest part of the load, will be dropped first and nearest to the channel. Ridges of deposition will form beside the river. These are known as levees. The suspended load is carried further and deposited over a wider area. This deposited material is known as alluvium and consists primarily of sand and silt. Over millenia, thick alluvial soils may build up. This is known as aggradation and these soils tend to be very fertile (Junk, Bayley, & Sparks, 1997).

Floodplains have many valuable functions and services. Following are several floodplains' functions to support ecosystem:

- Floodplains enhance water quality in streams and watersheds by trapping sediment and by accumulating and transforming a variety of nutrients and other chemical substances. There is great potential to use the estuary wetland as a final filter for nutrient enriched river water, and reduce the possibility of coastal water eutrophication (Li et al., 2003).
- Floodplains have high production. The rate of organic production in wetlands is one of the highest in the world, matched nearly by tropical forest. Since the water level changes, wetlands maintain the widest range of oxidation-reduction reactions of any ecosystem on the landscape (Keddy, 2010).

- Floodplains play an important role in regulating the climate through carbon storage, the production of methane, and their historical role in producing coal (Keddy, 2010).
- Floodplains not only support large numbers of individual species, but they support many different kinds of species. Some 100,000 animal species alone require freshwater habitats (Lévêque, Balian, & Martens, 2005).
- Floodplains help prevent flood damage by storing storm runoff and slowly releasing water to streams and groundwater, thereby decreasing the severity of peak floods (Padersen, Andersen, Nielse, & Linneman, 2007).

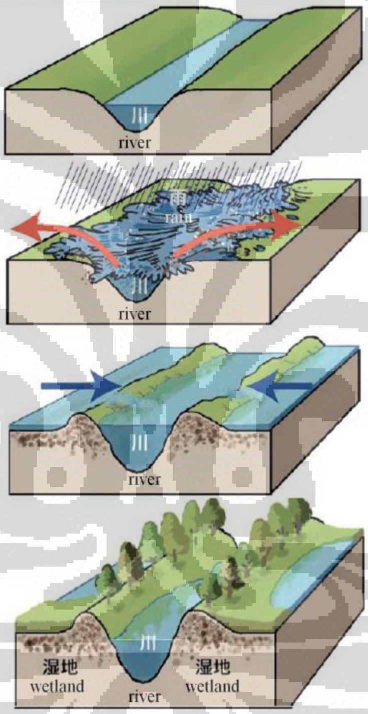


Figure 2.3. Illustration of floodplain formation

(Takeo Office of River, 2006)

2.1.1 Nutrients and Fertility

Biogeochemical cycling of nutrients in wetlands, as shown in Figure 2.4, is governed by physical, chemical, and biological processes in the soil and water column. The aerobic and anaerobic interface generally found in saturated soils of wetlands creates unique conditions that allow both aerobic and anaerobic processes to operate simultaneously.

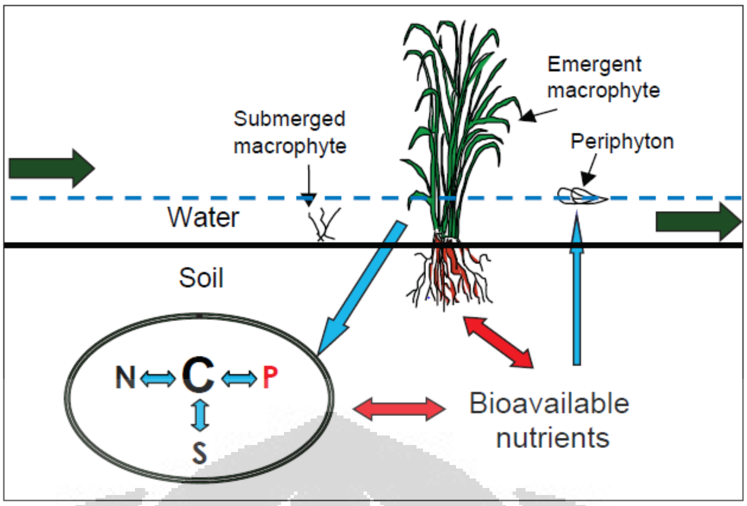


Figure 2.4. Schematic showing basic nutrient cycles
in soil water column of a wetland
(Andrews et al., 2008)

Compared to terrestrial ecosystems, most wetlands show an accumulation of organic matter, and therefore wetlands function as global sinks for carbon. Rates of photosynthesis in wetlands are typically higher than in other ecosystems, and rates of decomposition are typically lower due to anaerobic conditions, hence organic matter tends to accumulate (Andrews et al., 2008).

a. Nitrogen

Nitrogen enters wetlands in organic and inorganic forms, with the relative proportion of each depending on the input source. Organic forms are present in dissolved and particulate fractions, while inorganic N (NH_4-N, NO_3-N and NO_2-N) is present in dissolved fractions or bound to suspended sediments (NH_4-N). Particulate fractions are removed through settling and burial, while the removal of dissolved forms is regulated by various biogeochemical reactions functioning in the soil and water column (Andrews et al., 2008). Relative rates of these processes are affected by physico-chemical and biological characteristics of plants, algae, and microorganisms. Exchange of dissolved nitrogen species between soil and water column support several nitrogen reactions (Perakis, 2002).

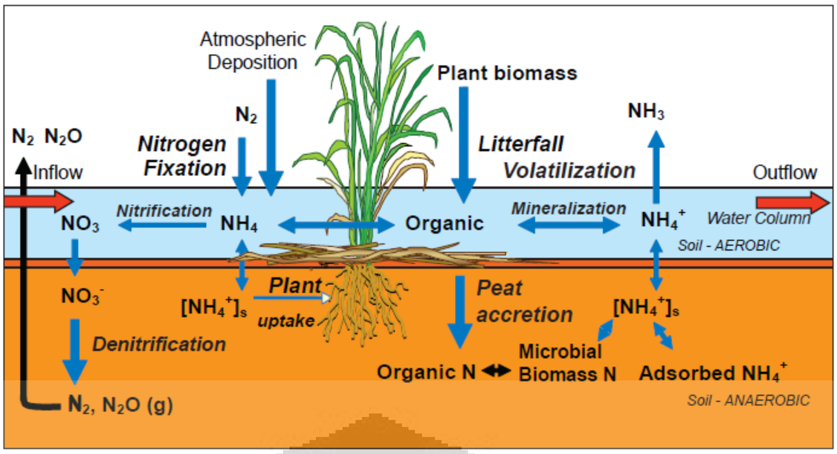


Figure 2.5. Schematic of nitrogen cycle in wetlands

(Andrews et al., 2008)

b. Phosphorus

Phosphorus retention by wetlands is regulated by physical (sedimentation and entrainment), chemical (precipitation and flocculation), and biological mechanisms (uptake and release by vegetation, periphyton, and microorganisms) (Andrews et al., 2008). Phosphorus in the influent water is found in soluble and particulate fractions, with both fractions containing a certain proportion of inorganic and organic forms. Phosphorus forms that enter a wetland are grouped into: (i) dissolved inorganic P (DIP); (ii) dissolved organic P (DOP); (iii) particulate inorganic P (PIP); and (iv) particulate organic P (POP) (Richardson, 1985).

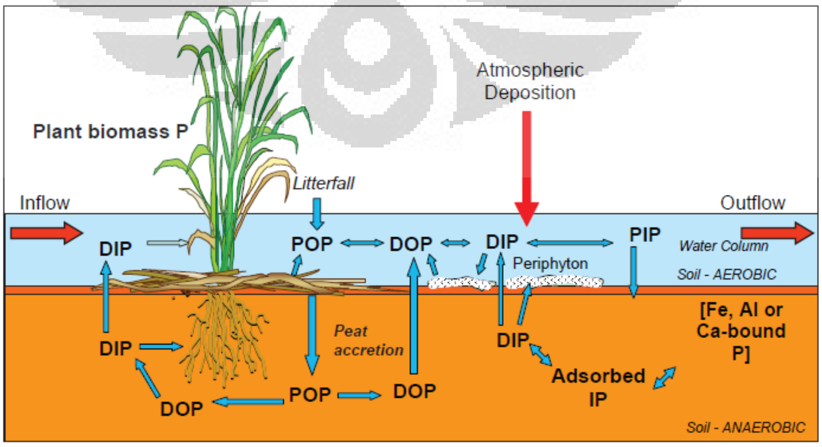


Figure 2.6. Schematic of the phosphorus cycle in wetlands

(Andrews et al., 2008)

Although nitrogen and phosphorus are the key elements to consider, they are of course, not the only elements that can limit plant and animal growth. For plants, other resources include potassium and magnesium, as well as carbon dioxide (Persic, Horvatic, Has-Schon, & Bogut, 2009). In flooded sites, resources like soil oxygen can limit growth; in others (but rarely wetlands), scarcity of water has similar effects. Factors such as high salinity or low temperatures can also reduce growth rates, and therefore are also considered to affect fertility. Any environmental factor that constraints plant productivity is generally termed as stress (Keddy, 2010).

2.1.2 Floodplain as an Ecosystem

Inundation affects the vegetation through temporarily high water levels and waterlogged soils as well as through the deposition of river sediments (Beltman, Willems, & Gusewell, 2007). Fluctuations in water level are essential for maintain the diversity and abundance of wildlife species in wetlands. Both plants and fish are highly affected by flood pulse. Plant species richness in lakes is greatest when water level fluctuations are intermediate in magnitude, low-water periods are important for species that persist as seeds buried in the sediment. High-water periods drown woody vegetation and allow marsh and wet meadow expansion. Figure 2.7 shows vegetation types caused by flood events.

Water level fluctuations affect wildlife by creating and maintaining different wetland habitat types. In addition, nearly all species of animals are sensitive to both the depth of water and the timing of floods. Most wetland organisms can tolerate flooding, and many benefit form or depend upon it. From their perspective, flooding is necessary, and their life cycles are timed to exploit the flood peak (Keddy, 2010).

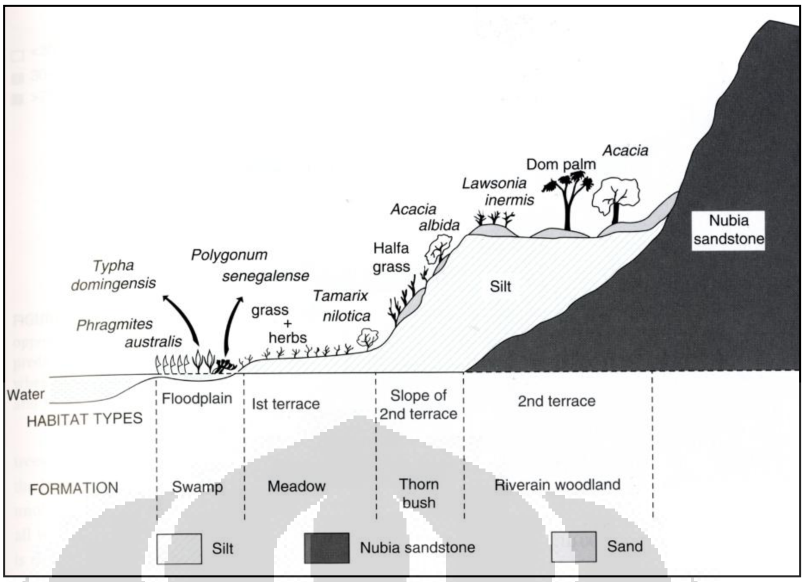


Figure 2.7. Flooding along with sediment erosion and deposition, produces the characteristic vegetation types of the Lower Nile floodplain (Springuel, 1990)

Organisms have specific adaptations that allow them to tolerate the wet/ dry conditions that are a part of a flood-pulsed environment (Junk, Bayley, & Sparks, 1997). Not only does each species have different water requirements and tolerances, these differ for each life stage - seed, seedling, and adult (Middleton, 2002).

2.2 Impact of Hydrological Process on Nutrients in Floodplain

The principal kinds of wetlands can be related to two sets of environmental factors: water regime and nutrient supply. The term “water regime” refers to hydrological factors including depth and duration of flooding, while “nutrient supply” refers to chemical factors including available nitrogen, phosphorus, and calcium (Gruberts et al., 2007).

The amplitude and frequency of water level fluctuations are probably the most important factors affecting the composition and function of wetlands. Differences in the annual hydrograph, floodplain topography (including anthropogenic modifications), and sediment and nutrient loads of the river channel may influence whether a particular floodplain acts as a sink or source for organic matter (Keddy, 2010).

2.2.1 Hydrological Regime

In river floodplain systems, the hydrological regime is the key factor that promotes ecological functioning and determines biodiversity patterns (Agostinho, Bonecker, & Gomes, 2009), and this regime is maintained mainly by the flood pulse.

The flood pulse concept was first developed to describe seasonal changes in water levels on Amazonian floodplains and their relationships to functional dynamics and the maintenance of species diversity (Junk, Baley, & Sparks, 1989). The interconnection of the river channel and floodplain is critical because functions such as production, decomposition, and consumption are driven by the flood pulse (Richardson, 1985) and water fluctuation drives succession (Middleton, 2002).

A spectrum of geomorphological and hydrological conditions produces flood pulses, which ranges from unpredictable and from short to long duration. As the size of floodplain increases, usually along with increasing river discharge, the frequency of flood decreases, and their duration and predictability increase (Junk, Bayley, & Sparks, 1989).

Based on water level dynamics and water retention times, Tockner et al. (1999) identified three phases of river-floodplain connectivity: disconnection (phase I), seepage inflow (phase II), and upstream surface connection (phase III).

Generally, the floodplain shifts from a closed and mainly biologically controlled ecosystem during phase I to an increasingly open and more hydrologically controlled system during phases II and III. Phase I, with internal processes dominating, is designated the “biotic interaction phase”. Phase II, with massive nutrient inputs to the floodplain yet relatively high residence times, and therefore, high algal biomass, is classified as the “primary production phase”. Finally, since transport of particulate matter is mainly restricted to short flood pulses above bankfull level, phase III has been defined as the “transport phase”. These phases are depicted in Figure 2.8.

The matter transported from the whole catchment areas together with large amounts of dissolved and mineral nutrient compounds (mainly nitrates and phosphates) are stored in a lower part of the river or in a dam reservoir, which are zones of intensive sedimentation and deposition (Godlewska et al., 2003).

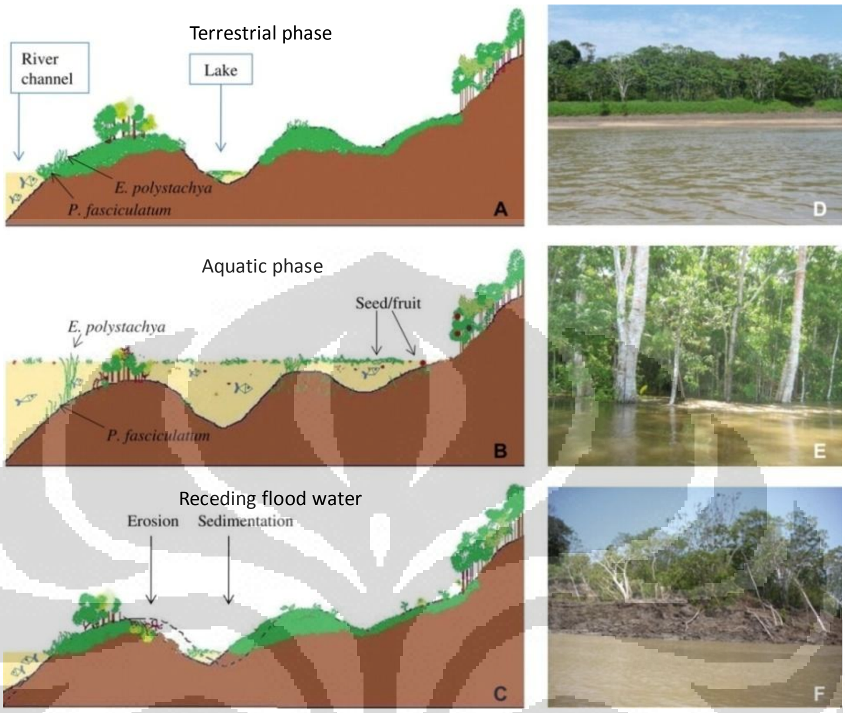


Figure 2.8. Hydrological connectivity in the Várzea floodplain

A and D: terrestrial phase, when the lakes show little or no connection with the main river channel; B and E: aquatic phase, when the river overflows and the water invades the adjacent floodplain carrying large amounts of sediment, macrophytes, seedlings, seeds and fish; C: water retreat, when sedimentation and; F: erosion of river banks are evident

(Ferreira et al., 2010)

Flood pulse may cause mechanical damage to the existing vegetation sward but may also promote the establishment of plants from seeds or vegetative parts, and they are a major source of nutrients for the floodplain vegetation (Beltman, Willems, & Gusewell, 2007).

2.2.2 Nutrient Transport to Floodplain in Sub-tropical Water Basin

Process of nutrient transportation to floodplain is complex. The source of nutrients can be classified as point source and nonpoint source. Point source discharges of nutrients to floodplains may come from municipal or industrial discharges, including stormwater runoff from municipalities or industries, or in some cases from large animal feeding operations. In general, point source discharges that are not stormwater related are fairly constant with respect to loadings (Andrews et al., 2008).

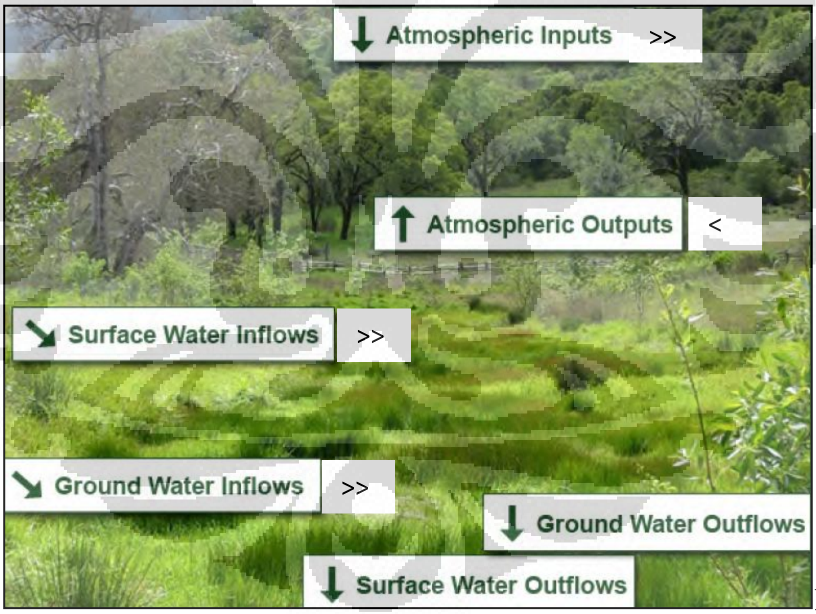
Nonpoint sources of nutrients are commonly discontinuous and can be linked to seasonal agricultural activity or other irregularly occurring events such as silviculture, non-regulated construction, and storm events. Nonpoint nutrient pollution from urban and suburban areas is most often associated with climatological events (rain, snow, and snowmelt), when pollutants are most likely to be transported to aquatic resources. (Dykaar, Bruce, & Wigington, 2000).

Urban and agricultural runoff is generally thought to be the largest source of nonpoint source pollution; however, growing evidence suggests that atmospheric deposition may have a significant influence on nutrient enrichment, particularly from nitrogen (Jaworski, Howarth, & Hetling, 1997). Gases released through fossil fuel combustion and agricultural practices are two major sources of atmospheric N that may be deposited in waterbodies (Carpenter et al., 1998). Nitrogen and nitrogen compounds formed in the atmosphere return to the earth as acid rain or snow, gas, or dry particles.

Wetland nutrient inputs mirror wetland hydrologic inputs (e.g., precipitation, surface water, and ground water), with additional loading associated with atmospheric dry deposition and nitrogen transformation (Baldwin & Mitchell, 2000). Total atmospheric deposition (wet and dry) may be the dominant input for precipitation-dominated wetlands, while surface- or ground-water inputs may dominate other wetland systems. The total annual nutrient load (mg-nutrients/yr) into a wetland is the sum of the dissolved and particulate loads. Surface-water nutrient inputs are associated with flows from influent streams, as well as diffuse sources from overland flow through the littoral zone. Ground-water inputs can also be concentrated at points (e.g., springs), or diffuse (such as seeps).

Because wetlands generally tend to be low-velocity, depositional environments, they often sequester sediments and their associated nutrients. These sediment inputs generally accumulate at or near the point of entry into the wetland, forming deltas or levees near tributaries, or along the shoreline for littoral inputs. Particulate input from ground-water sources can usually be neglected, while particulate inputs from atmospheric sources may be important if local or regional sources are present (Andrews et al., 2008)..

Wetland nutrient outputs mirror hydrologic outputs (e.g., surface- and ground-water), and loads are estimated as the product of the flow and the concentration of nutrients in the flow. While evaporation losses from wetlands may be significant, there are no nutrient losses associated with this loss. Instead, loss of nutrients to the atmosphere may occur as a result of ammonia volatilization, as well as N_2O losses from incomplete denitrification. Because sediment outputs from wetlands may be minor, nutrient exports by this mechanism may not be important. Nutrient accumulation in wetlands occurs when nutrient inputs exceed outputs. Net nutrient loads can be estimated as the difference between these inputs and outputs (Walling et al., 2003).



F

Figure 2.9. Schematic of nutrient transfer among potential system sources and sinks (Andrews et al., 2008)

There are many studies regarding nutrient transportation to floodplain. In most sub-tropical water basin, big flood events usually occur during summer and winter time, and both have different characteristic of flood. Therefore, studies regarding the nutrient transportation are commonly conducted in annual term (e.g. Agostinho, Bonecker, & Gomes, 2009; Beltman, Willems, & Gusewell, 2007; Pedersen, Andersen, Nielse, & Linneman, 2007).

Since nutrients are transported in the form of sediments, most studies examined nutrient concentrations of bottom sediments floodplain. For instance, Pedersen, Andersen, Nielse, & Linneman (2007) used artificial grass mats to measure nutrient deposition rate during flood events. They were placed at different distances from the river in the Skjern River floodplain, Denmark before the floodplain inundated by winter floods. Depositions occurred representing the net deposition from winter floods. Since there are several water sources entering floodplain (e.g. groundwater, runoff from local drainage canals etc.), the transportation of nutrients is largely determined by the size of the nutrient sources in the entire catchment.

Tockner et al. (1999) collected water samples for calculating input-output fluxes of the floodplain, and samples were taken during the rising and falling limbs of the flood hydrograph. Based on continuous water level recording, three phases of hydrology connectivity were able to be identified: (I) disconnection; (II) seepage inflow and downstream surface connection; and (III) upstream and downstream surface connection as defined in previous part.

Other types of studies described the correlation between nutrients carried by flood event to the growing of certain species, mostly phytoplankton (e.g. Persic, Horvatic, Has-Schon, & Bogut, 2009; Godlweska et al., 2003; Agostinho, Bonecker, & Gomes, 2009; and Lehman, Sommer, & Rivard, 2008). The flood pulse is important for floodplain productivity because it is facilitated the growth of chlorophyll a affecting phytoplankton life cycle.

Study of nutrients transportation was also conducted in Japanese wetland. Nakamura et al. (2002) conducted study in Kushiro Mire, the largest mire in Japan, that presently faces some changes associated with stream channelization. They clarified the process of sedimentation in the Kuchoro Stream, part of Kushiro River watershed. A shortening of the channel length, due to channelization of the meandering stream, steepened the slope and enhanced the stream power to transport sediment during flood events.

2.2.3 Human Intervention Affecting Flood Pulse

The world is now covered with reservoirs created by Homo sapiens. As a result, natural water fluctuations are being disrupted around the globe. Alteration of hydrology is believed to be one of the three major causes of damage to aquatic animals; in the United States of America alone, there are now more than 75,000 large dams (higher than 8 m) and 2.5 million small ones (Ritcher et al., 1997). The giant Three Gorges Dam has recently been built on the Yangtze River in China; it will flood more that 10,000 km^2 (Wu et al., 2004) while changes in sediment transport will affect areas far downstream along the coast to Shanghai. Many more dams are being proposed for other large rivers (Keddy, 2010).

To reengineering at a landscape level in wetland restoration, simpler and widely used approaches such as damming create static water levels and so are not adequate restoration approaches (Middleton, 2002). After levees were constructed along major rivers such as the Mississippi, floodplains were converted to other uses, such as agriculture (Allen, 1997). Impoundment is often used in restoration as a means of increasing water levels in a dried wetland, but because of the lack of a flood pulse, regeneration - from seed dispersal to the seedling recruitment stage - is problematic (Middleton, 20002). Figure 2.10 shows what happens when humans reduce flood peaks and augment low-water periods.

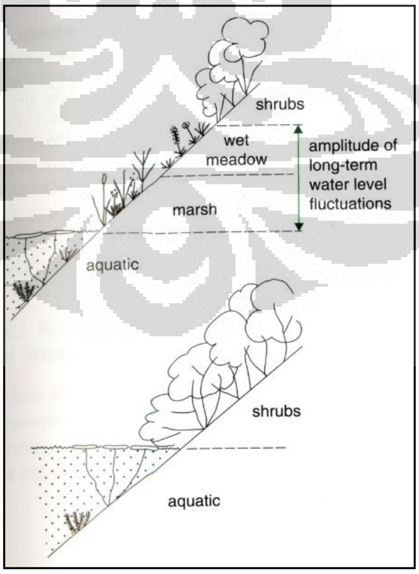


Figure 2.10. Stabilizing water levels compresses wetlands from four zones (top) to two zones (bottom)

(Keddy, 2010)

In Europe and in the densely populated areas in Asia, for instance, Lair et al. (2009) found that floodplain–river systems –depending on the rivers' discharge patterns– can represent long-term sinks for sediment-associated contaminants, but can episodically become significant sources for pollution of downstream areas during flood events.

Increased flood duration and frequency results in an increase of salinity, levels of total N and P, heavy metals and organic micropollutants in the water and sediments, resulting in eutrophication, decrease in biological diversity, blooms of Cyanophyta, shift from the macrophyta- dominated community towards a phytoplankton- dominated one and so on (Gruberts et al., 2007).

However, the exact type and source of eutrophication in floodplains is often rather unclear since it may originate from agricultural land use as well as from nutrient input by polluted river water. N and P, both significantly decreased with increasing distance to the river, indicating higher nutrient supply close to the river (Klaus, Sintermann, Kleinebecker, & Holzel, 2011).

It is widely known that wetlands are nutrient sinks which trap nitrogen and phosphorus, reducing the eutrophication of downstream aquatic ecosystems. However, Richardson (1985) conducted comparative studies of phosphorus retention capacity among twenty sites and found that high initial rates of phosphorus removal will be followed by large exports of phosphorus within a few years.

In general, higher nutrient levels lead to higher amounts of biomass. Higher amounts of nutrients, combined with higher biomass, almost without exception cause the composition of wetlands to change, and plant diversity to decrease (Keddy, 2010). It is important to understand the pattern: that increased nutrient levels reduce plant diversity, particularly affecting uncommon types of species. High fertility levels led to much higher levels of biomass irrespective of the habitat types. Simultaneously, high fertility levels led to reduced numbers of plant species. In other words, biomass is directly correlated with fertility, species richness is inversely correlated with fertility (Beltman, Willems, & Gusewell, 2007). Figure 2.11 illustrates this pattern.

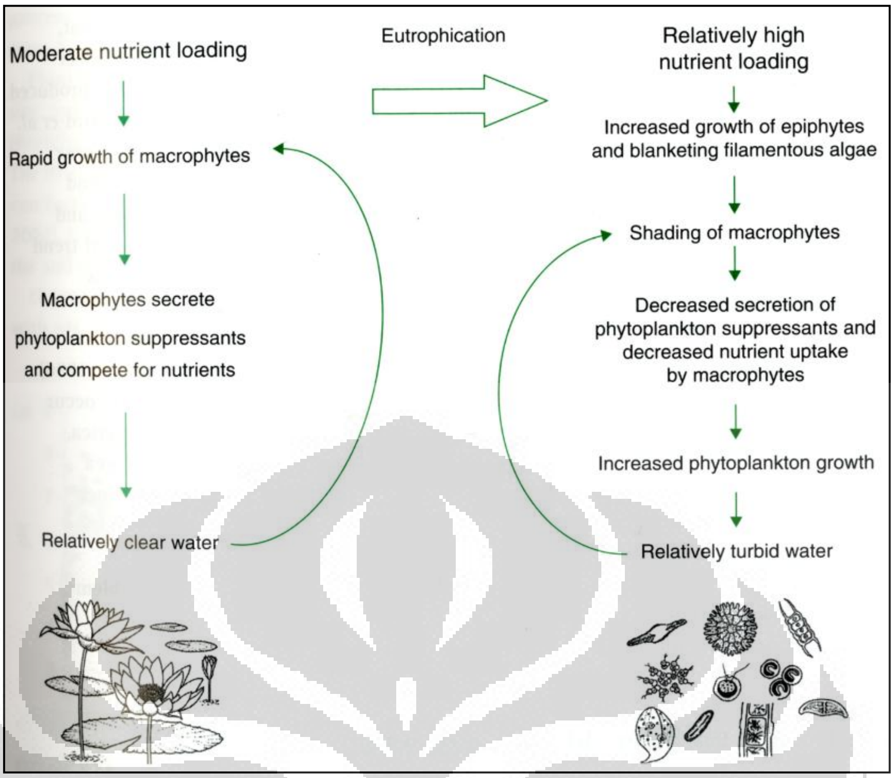


Figure 2.11. Eutrophication may increase phytoplankton populations and thereby reduce the abudance of aquatic macrophytes
(Phillips et al., 1978)

2.2.4 Nutrients Transport to Floodplain in Azame-no-Se

According to Nakai (n.d.), rivers in Japan are classified into three categories: class A river, class B river, and locally designated rivers. Class A Rivers are rivers which belong to such water systems especially important from the view of land conservation and/ or national economy, designated by the Minister of Land, Infrastructure and Transport (MLIT). Class B Rivers are rivers which belong to such water systems which have important relation to public interests and other than Class A Rivers, designated by the prefectural governors concerned. Locally Designated Rivers are rivers which are designated by the head of cities, towns or villages, other than any of Class A Rivers and Class B Rivers. Matsuura River is considered as class A river and under responsibility of Ministry of Land, Transport and Tourism (MLIT), representing by Takeo Office of River in Takeo city.

There are two rivers flow through Saga Prefecture in the west part of Kyushu Island, which are Matsuura River and Rokkaku River (Figure 2.12). Rokkaku River Basin flows into the Ariake Sea inland, another is Matsuura River basin, mainstream of Azame-no-Se floodplain. The Matsuura River basin is located in northwest of Saga Prefecture comprised of three cities, Karatsu, Imari, and Takeo. It flows from Mt. Seirai, Takeo City. The river flows to the north while meeting some tributaries. It meets Kyuragi River at about 13 km upstream from the estuary, and meets the Tokusue River at about 6 km upstream from the estuary. It flows through the urban center of Karatsu City, then flows into the Sea of Genkai. The basin is characterized with society, economy and culture of northwest part of Saga prefecture.

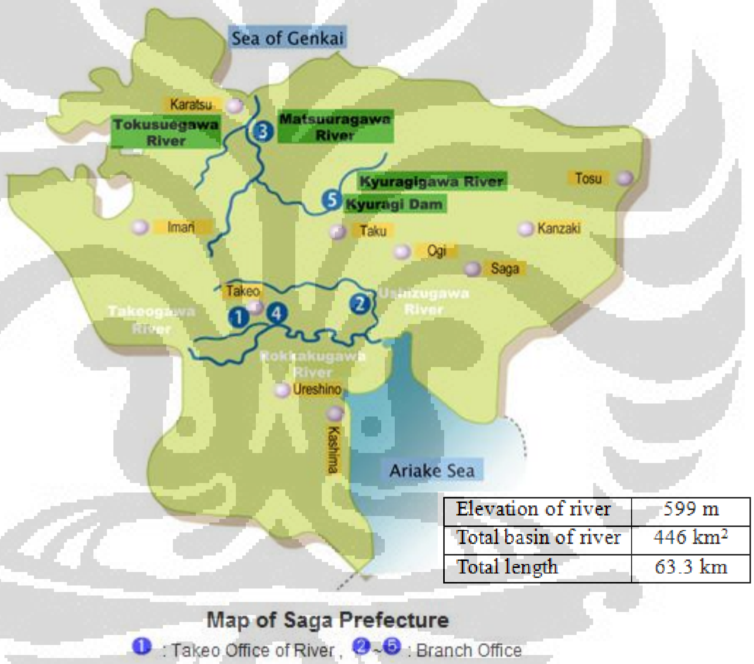


Figure 2.12. Saga Prefecture

(Takeo Office of River, n.d.)

Standard applied to asses water quality status of Matsuura River is established by NOWPAP POMRAC (Northwest Pacific Action Plan, Pollution Monitoring Regional Activity Centre) under UNEP (United Nation Environmental Program) as shown in the Table 2.1. The discrepancy of the class is based on each designated uses.

Table 2.1. Surface water quality standard of Japanese rivers

Class	Item	Standard value (annual mean)							
	Water use	**pH**	**BOD** (mg/L)	**SS** (mg/L)	**DO** (mg/L)	**Total Coli** (MPN/ 100 mL)	**Total N** (mg/L)	**Total P** (mg/L)	**Total Zn** (mg/L)
AA	Water supply class 1, conservation of natural environment	6.5-8.5	< 1	< 25/1	> 7.5	50	< 0.1	< 0.005	< 0.03
A	Water supply class 2, fishery class 1, bathing	6.5-8.5	< 2	< 25/5	> 7.5	1000 MPN/ 100 mL	< 0.2	< 0.01	< 0.03
B	Water supply class 3, fishery class 2	6.5-8.5	< 3	< 25/15	> 5	5000 MPN/ 100 mL	< 0.4	< 0.03	< 0.03
C	Fishery class 3, industrial water class 1	6.5-8.5	< 5	< 50	> 5	-	< 0.6	< 0.05	< 0.03
D	Industrial water class 2, agricultural water	6.5-8.5	< 8 m	< 100	> 2	-	< 1	< 0.1	
E	Industrial water class 3 and conservation of environment	6.5-8.5	< 10		> 2	-	< 1	< 0.1	

Source: NOWPAP POMRAC, 2009

Water resources has been a critical issue for Saga Prefecture from a long time ago. Due to large-scale agricultural irrigation and industrial production, groundwater had been excessively employed to benefit the economy development and life improvement in Chikugo-Saga plain since the middle of last century, which led to many environmental problems such as a notable land subsidence and flooding intrusion. In order to mitigate the impacts of environmental hazards, some water supply projects have been performed to substitute surface water for groundwater in the recent 30 years, such as from Chikugo River and Kase River in the south part of Saga Prefecture (Cai, Esaki, Mitani, & Ikemi, 2009).

Matsuura River is also an important water resources which helps overcome the serious land subsidence occuring in this prefecture. Kyuragi Dam built in 1987 in Kyuragi River, upper tributaries of Matsuura River, is utilized for many purposes (Figure 2.13), such as flood control and others designated uses. Designed flood discharge at the dam is 660 m^3/s, while for water use, it allocates the usage for several acitivities, such as power generation water (3 million m^3), drinking water (1.37 million m^3), and industrial water (0.43 million m^3) (Takeo Office of River, 2008).

Figure 2.13. Kyuragi Dam

(Takeo Office of River, 2008)

Azame-no-Se is an artificially restored floodplain that is located in Matsuura River watershed, Saga Prefecture, Japan. Aiming in "rehabilitation of a floodplain wetland" and "restoration for a close relationship of humans with wildlife," the Ministry of Land Infrastructure and Transport of Japan began the restoration project at 2003. The restored area is located at mid-order stream of the Matsuura River, with total area of 6 ha approximately 1,000-m (3,280-ft) long and 400-m (1,310-ft) wide (Hayashi, Shimatani, & Kawaguchi, 2008).

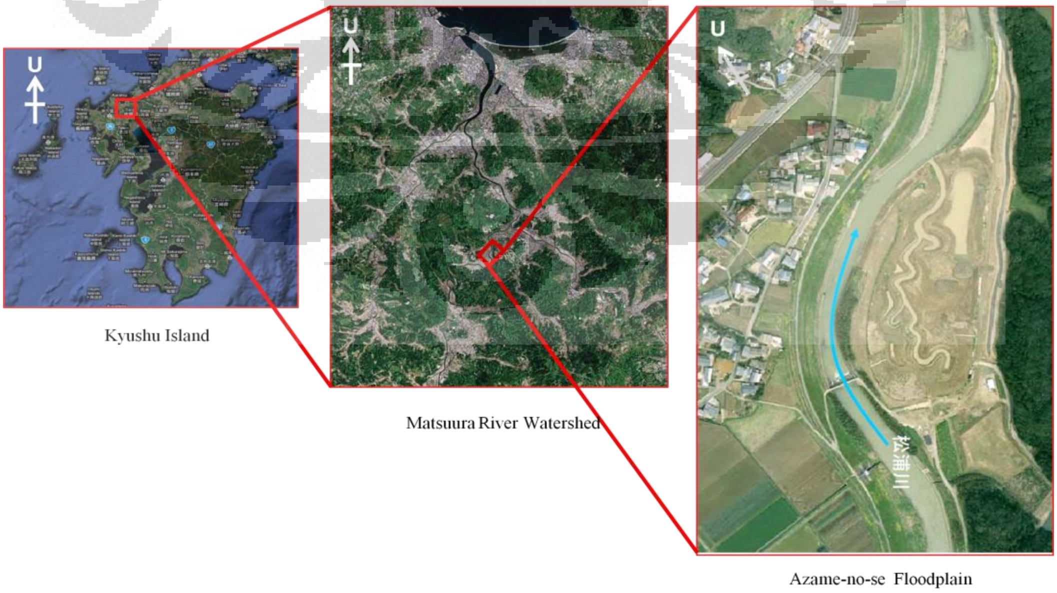
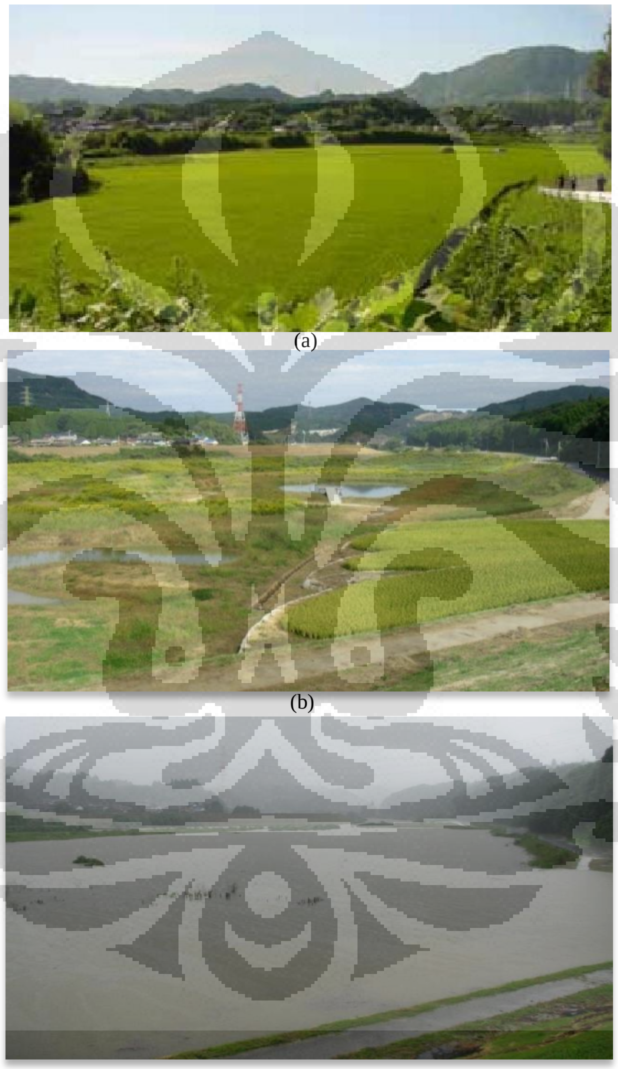


Figure 2.14. Location of Azame-no-Se

(*Google Maps,* 2011)

Azame-no-Se area is an ancient rice paddy field (Figure 2.15). The natural paddy field allowed fish to evacuate in this area during high discharge of the main river. As water recedes, fishes had a place to spawn in the floodplain area. Due to the increasing of urbanization and river regulation, fishes no longer have a safe place to spawn. The construction of levees and riverbed excavation became a great barrier between floodplain and main stream (Figure 2.16).



(a) (b) (c)

Figure 2.15. Azame-no-Se transformation

(a) before restoration (2001); (b) after restoration (2004)- normal time;

(c) after restoration (2004)- inundation time

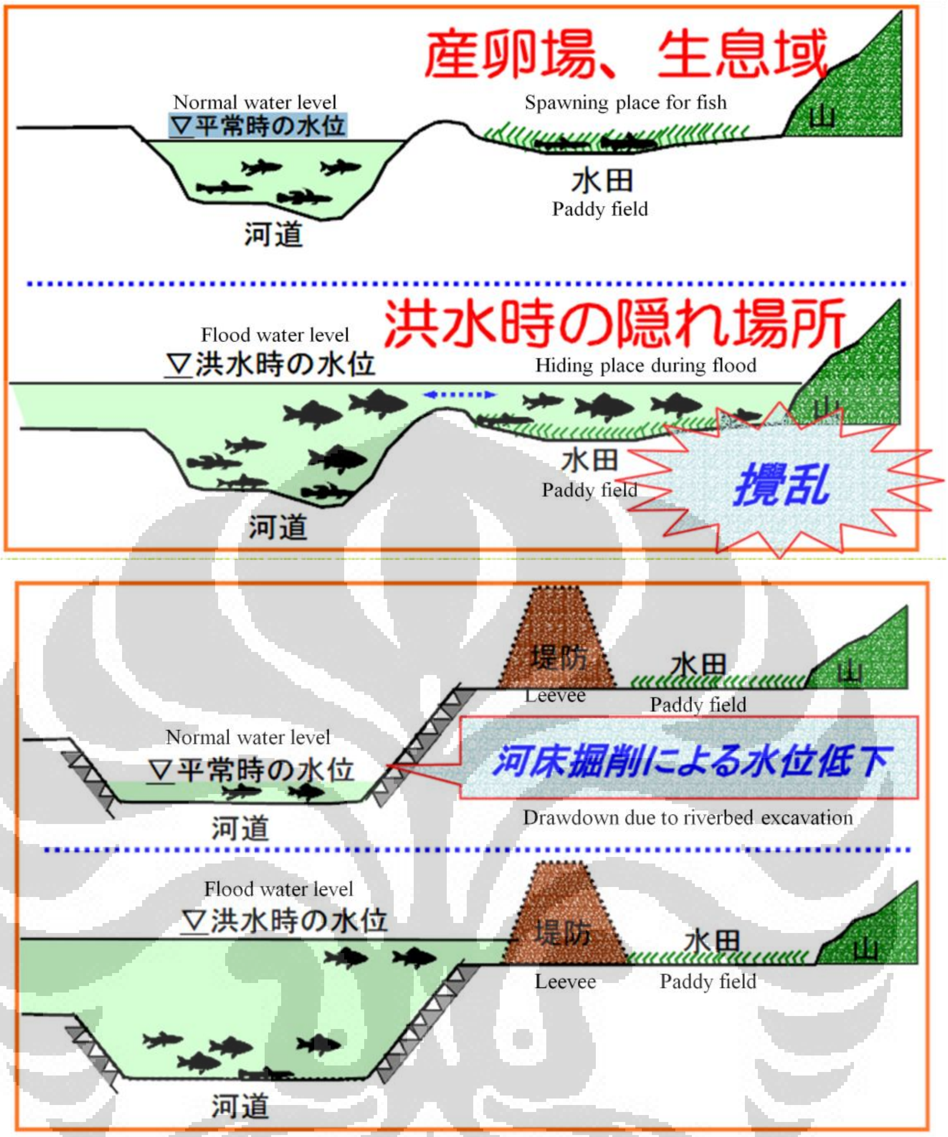


Figure 2.16. The loss of fish spawning site due to construction of levee

(Takeo Office of River, 2006)

In the restoration project, Azame-no-Se area was excavated about 5 m to reconnect the area to Matsuura River. The site consists of some ponds, creeks, and a terraced rice paddy (Figure 2.17). It is currently hydrologically connected to the Matsuura River only by the creek and only at flooding time.

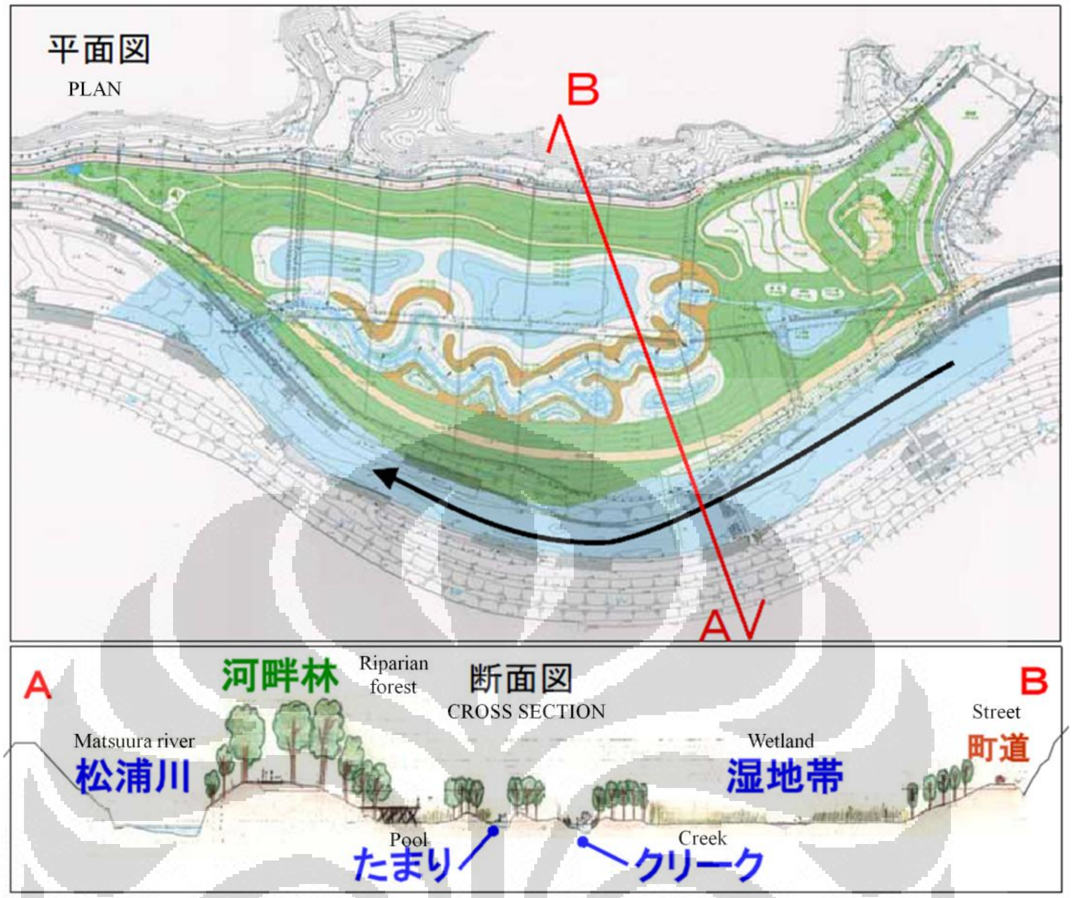


Figure 2.17. Plan and cross section of Azame-no-Se

(Takeo Office of River, 2006)

The characteristic of flood event that is commonly inundated the floodplain and the characteristic of restored floodplain with certain morphology are important to be recognized.

a. Flood event characteristic

Each flood event has its own uniqueness, distinguish it from others. The amplitude of a flood event is a variable that depends mainly on discharge of river water due to rainfall event. In Azame-no-Se, the 5-m water high flood usually inundates this floodplain. Although stakeholders of floodplain are fully aware by the common magnitude of flood event, there is possibility of the occurence of flood event in an extremely different magnitude. The effect of water quantity on floodplain ecosystem, i.e. limnology, biota, and fishery, will be varied depends on its magnitude. (Agostinho, Bonecker, & Gomes, 2009).

If large flood event takes place in floodplain, main stream and site located in close proximity to input channel will have higher nutrient content rather than floodplain site. On the contrary, floodplain site will probably higher in its nutrient content, if shallow flood event occurs. The shallow flood event will agitate the bottom sediments of floodplain, resulting in much more nutrients contained in the water column as bottom sediments are rich of nutrients because of the accumulation of organic matter.

Nutrient carried into floodplain also varies to the season of flood event. Therefore, season is becoming a critical factor to be analyzed regarding the flood event characteristic. Flood event in Azame-no-Se usually occur in the beginning of summer season. The nutrient status will be different if inundation occurs in other seasons, like autumn or winter. In autumn, decomposition rate is quite high due to the decay of many vegetations; whereas, winter has low decomposition and photosynthetic rate. These distinct behaviors will present dissimilar pattern of nutrient concentrations.

Another factor of hydroperiod is duration or retention time of flood event in a floodplain. Most flood event in Asia have less retention time than the ones occur in Europe. Azame-no-Se has a very short retention time of inundation, it will last about several days. And, it will affect the vegetation pattern found in the floodplain as they do not undergo advance adaptation triggered by habitat alteration.

b. Floodplain characteristic

The local factors characterizing floodplain, such as lake morphology, internal loading of nutrients from sediments, throphic interactions as well as local source of dissolved organic matter, give impact to hydrology on aquatic communities (Gruberts et al., 2007). Floodplain is highly influenced by the adjacent areas, including the exact location in the mainstream since the alteration of water quality along the river will contribute to the flood event. Azame-no-Se is located in the middle stream of Matsuura River. The adjacent landuse are agricultural farmings, that certainly present significat impact on stream water quality status particularly on nutrient parameters.

Another characteristic of floodplain is marked by its morphology. As an artificially restored floodplain, Azame-no-Se is purposely designed to create a favourable habitat to floodplain ecosystem and a media to introduce residents to river and wetland environment. Morphology will have impact on the inundation flow pattern. The input channel via creek located in the downstream of floodplain will reduce the velocity of flood water, thus resulting in less damage to floodplain's vegetation. This flow pattern, showed by red line, depicts in Figure 2.18.

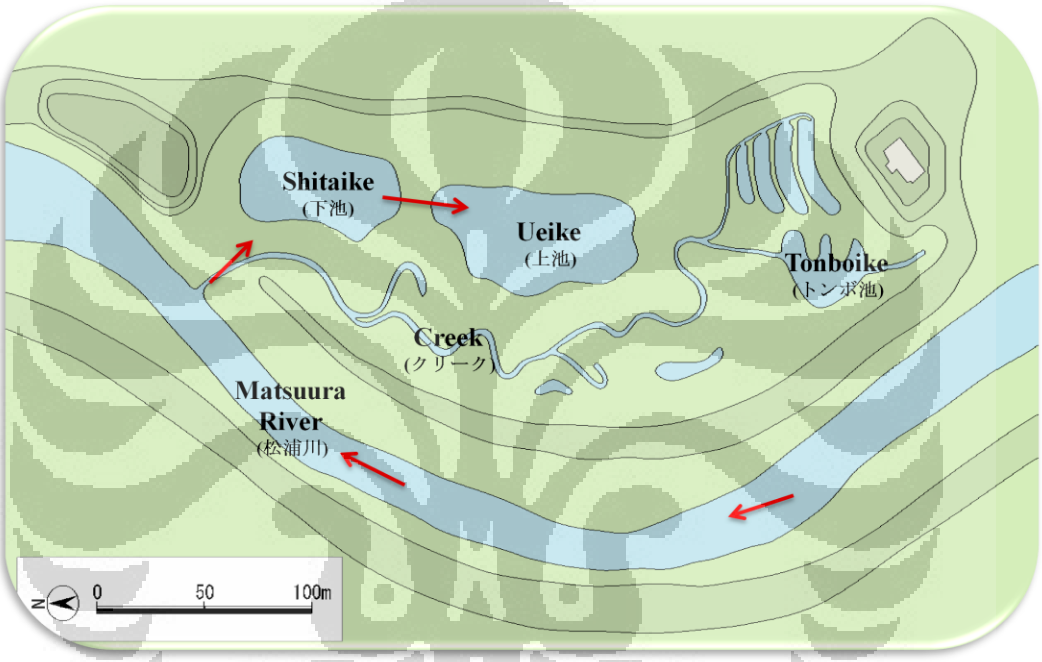


Figure 2.18. Inundation flow pattern in Azame-no-Se

The morphology of Azame-no-Se will not only determine the vegetation pattern on this floodplain, but also the communities that inhabit in distinct ponds. Shitaike pond is a favourable pond for *Trapa japonica* (Figure 2.19). This aquatic plants is in peak blooms in summer. On the contrary, Ueike pond is the habitat for mussel *Unio douglasiae* (Figure 2.20), with cyanobacteria as the main vegetation in this aquatic environment.

(a)

(b)

(c)

Figure 2.19. Shitaike pond:

(a) *Trapa japonica*; (b) Shitaike pond in spring;

(c) Shitaike pond in summer with fully bloom of *Trapa japonica*

Figure 2.20. Mussel *Unio douglasiae*

2.2.5 Issues and Stakes Concerning the Azame-no-Se Floodplain

Due to the increasing flood disaster in Japan, the government tried to construct the river bank. As a result, rainwater can directly flow faster downstream avoiding flood. On the other hand, it created bad effects to the existence of certain flora and fauna because of habitat loss. In the beginning of 1990s, Japanese government promoted river and wetland restoration to tackle this biodiversity issue.

As stated by Keddy (2010), wetland is considered as the most productive habitat in the world, so is Azame-no-Se. Several studies have been conducted in Azame-no-Se, one of them is the study of seed dispersal by Hayashi, Shimatani, & Kawaguchi (2008). They examined sediment transported by flood water in Azame-no-Se floodplain by placing 40 sampling points to collect seeds from flooding sediment from June 2004 and April 2006. Then, sediment samples were promptly removed to germinate them after each flooding event. They found various plants whose seeds were carried by flood water in Azame-no-Se, such as arable weed (*Rorippa islandica* and *Lindernia procumbens)*; marshy plants (*Gratiola japonica* and *Rotala pusilla)*; and alien species (*Eragrostis curvula* and *Solidago altissima L.).* These alien species are considered as threatened Japanese native plants. This study shows that seeds are transported by flood water to the floodplain and distance from the inflow site was related to the seed dispersal in the floodplain.

Other living creatures also exist in this floodplain (Figure 2.21), such as dragon fly in Tonboike pond, and mussel *Unio douglasiae* in Ueike pond. Those various creatures indicate how important Azame-no-Se in providing habitat for certain communities.

Figure 2.21. Illustration of fauna exist in Azame-no-Se

(Takeo Office of River, 2006)

The hydrological connectivity between Azame-no-Se and Matsuura River via the creek allows flood water which is rich of nutrients to enter floodplain. The watershed acitivities contributing to the water quality in the stream will create a potency of eutrophication in the floodplain; thus, flood gives tremendous effects to floodplain ecosystem. Therefore, this study is conducted to understand the pattern of nutrients distribution during flood events based on spatial and temporal variations. Schematically, the research framework of this study is illustrated in Figure 2.22.

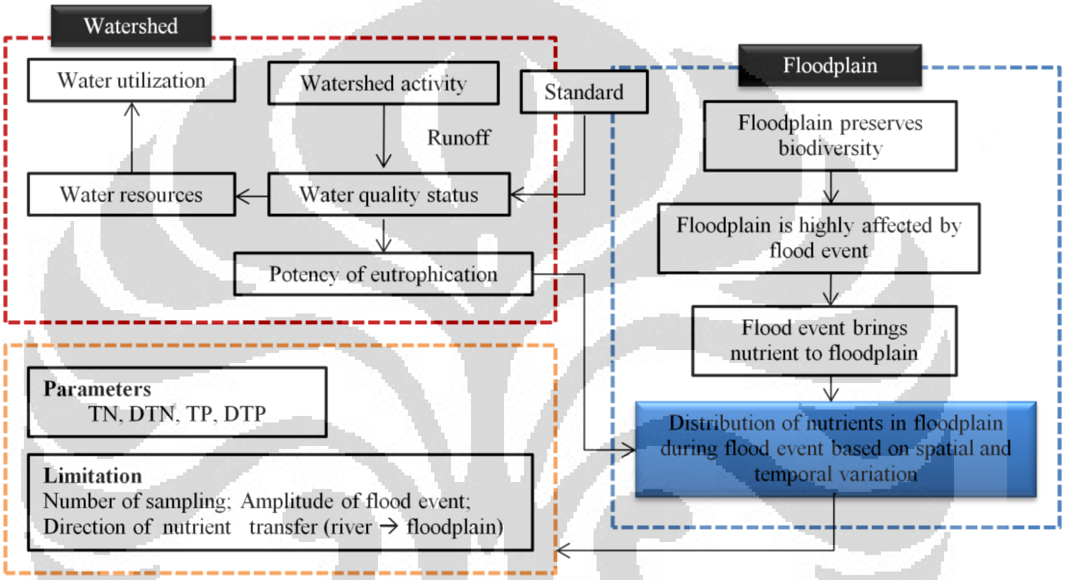


Figure 2.22. Research framework

This study uses quantitative approach where data are gathered and analyzed quantitatively with several factors that can explain the phenomena and clausal relationship within those factors. Study was conducted in laboratory scale by measuring nutrients in the flood water, in which observed parameters are total nitrogen (TN), total phosphorus (TP), dissolved total nitrogen (DTN), and dissolved total phosphorus (DTP).

The following are hypothesis developed for this study:

- The dissolved matter will increase with respect to the increasing of water level; while, particulate matter will present in reverse condition, in which the lowest elevation will contain more particulate matter than the rest elevations.

- Site located in the close proximity to the main channel will contain much nutrient concentrations, dominated by particulate matter. The more distant site, the less particulate matter in water column.
- Nutrient concentrations pre-flood will be much lower than post-flood, which during flood is the highest nutrient content. Temporal variation of surface water will be dominated by dissolved matters.
- The possible source of nutrient concentrations during flood event is agricultural runoff.

The importance of understanding the pattern of nutrient distribution in Azame-no-Se was explained in this chapter; while, the research method, including sampling sites location, sampling equipment, and measurement techniques, will be further explained in Chapter 3.

CHAPTER 3
MATERIALS AND METHODS

3.1 Study Area

a. Azame-no-Se Floodplain

As a floodplain, Azame-no-Se is inundated periodically with input water originates from Matsuura River. This study established four sites and five water elevations of sampling points. Site A located in the main stream was represented water quality of Matsuura River. Site B and C located in Shitaike pond were distinct in the distance to main channel, in which site B is closer to this inflow site. And, site D located in Ueike pond was the furthest site among all (Figure 3.1).

In each sampling sites, five sampling equipments were installed for various elevations, T.P. 3.0, T.P. 4.0, T.P. 5.0, T.P. 6.0, and T.P. 7.0. (Figure 3.2). The unit used is T.P. that stands for Tokyo Peil, mean sea level in Tokyo Bay, Japan. Normal water level in Azame-no-Se is T.P. 2.5. These various sampling sites were expected to be able to represent the flow of inundation and explain the spatial variation of nutrient distribution.

The temporal variation was obtained from surface water sampled one day before and two days after flood event. The comparison of nutrient concentrations before, during, and after flood event is useful to investigate any alteration occuring in floodplain due to inundation.

b. Urban and Environmental Engineering Experimental Facilities, Kyushu University

In Urban and Environmental Engineering Experimental Facilities, Kyushu University, observed nutrient parameters, total nitrogen (TN), total phosphorus (TP), dissolved total nitrogen (DTN) and dissolved total phosphorus (DTP), were measured by using DR/2400 Portable Spectrophotometer.

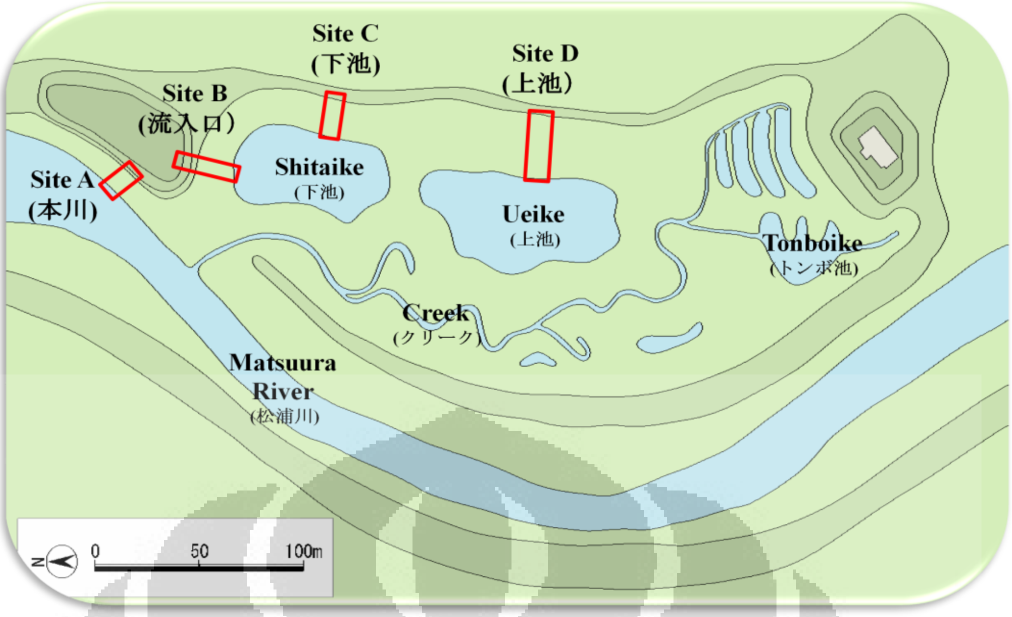


Figure 3.1. Sampling sites

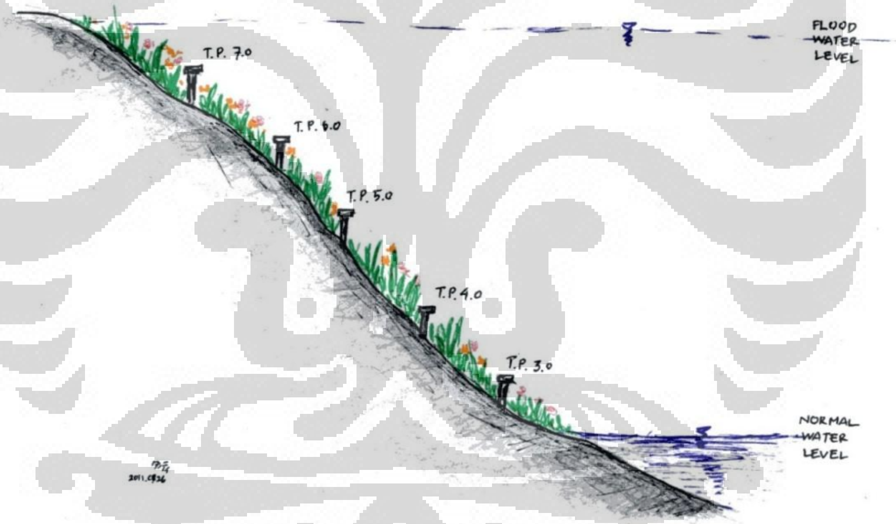


Figure 3.2. Profile illustration of a sampling site

3.2 Sampling Equipments

To get the representative samples, equipment must be able to take water in certain water level at flood event; therefore, equipment was designed and made specifically for that purpose. It was a polyvinyl pipe made by connecting three parts of pipes with 30 cm high and 7 cm diameter. Inside the pipe, there was a ball that retains water whenever water has filled the pipe.

After installed in the study area, pipe must be capped to prevent rainwater coming inside. Once the flood came, cap was opened due to water force, and water will fill the pipe. The ball inside the pipe stopped this process; thus, only water in certain depth filled the pipe. Sampling process is illustrated in the Figure 3.3.

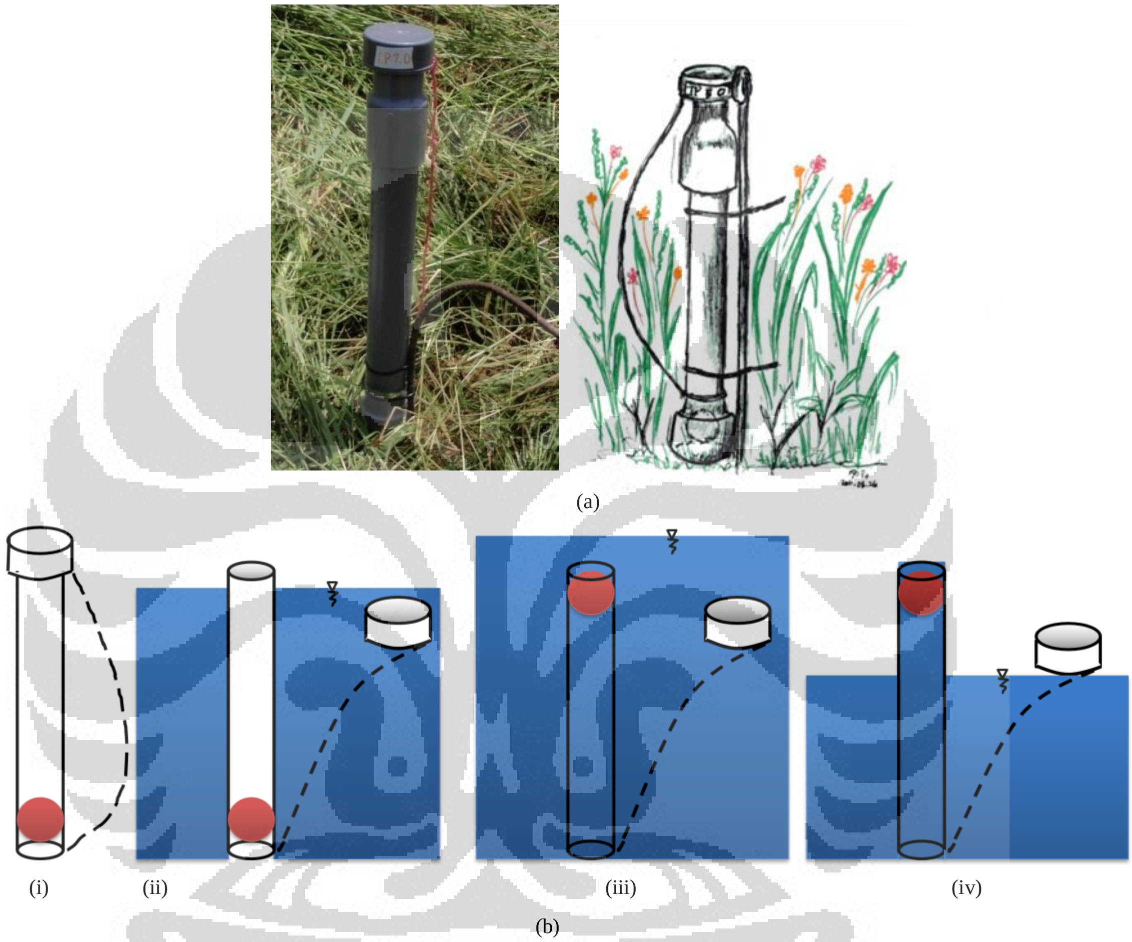


Figure 3.3. (a) Sampling equipment; (b) Sampling process illustration

(i) before flood; (ii) cap opened due to water force; (iii) pipe filled with floodwater when flood water level exceeds the height of the pipe and ball stops the filling process; (iv) water level goes down, sample is ready to be analyzed

Analyzed samples originating from flood water were taken in various sites and elevations. The sampling procedure is schematically shown in Figure 3.4. Flood event cannot be easily predicted; therefore, floodplain water level was monitored frequently. Moreover, the appropriate time to install sampling equipments was determined carefully as it depends on floodplain water level. The lowest sampling site was T.P. 3.0; thus, when installing sampling equipments, floodplain water level must be lower than T.P. 3.0. It was easily monitored by camera that has been installed in the field and can be accessed by internet. Furthermore, the possible time of flood event was also predicted by monitoring rainfall event via weather forecast.

Once sampling equipments were installed, next step was monitoring the evolution of water level in floodplain due to rainfall event. If there was a rainfall event causing water level exceed T.P. 3.0, water filled the pipe must be taken and equipments were re-installed. During inundation, water level mostly exceeds T.P. 7.0 and all the pipes will be filled from T.P. 3.0 to T.P. 7.0. Water trapped inside the pipe must be taken as soon as possible. In this study, samples were collected two days after flood event. Besides, right before and after flood events, floodplain surface water was sampled to be used for establish temporal variation.

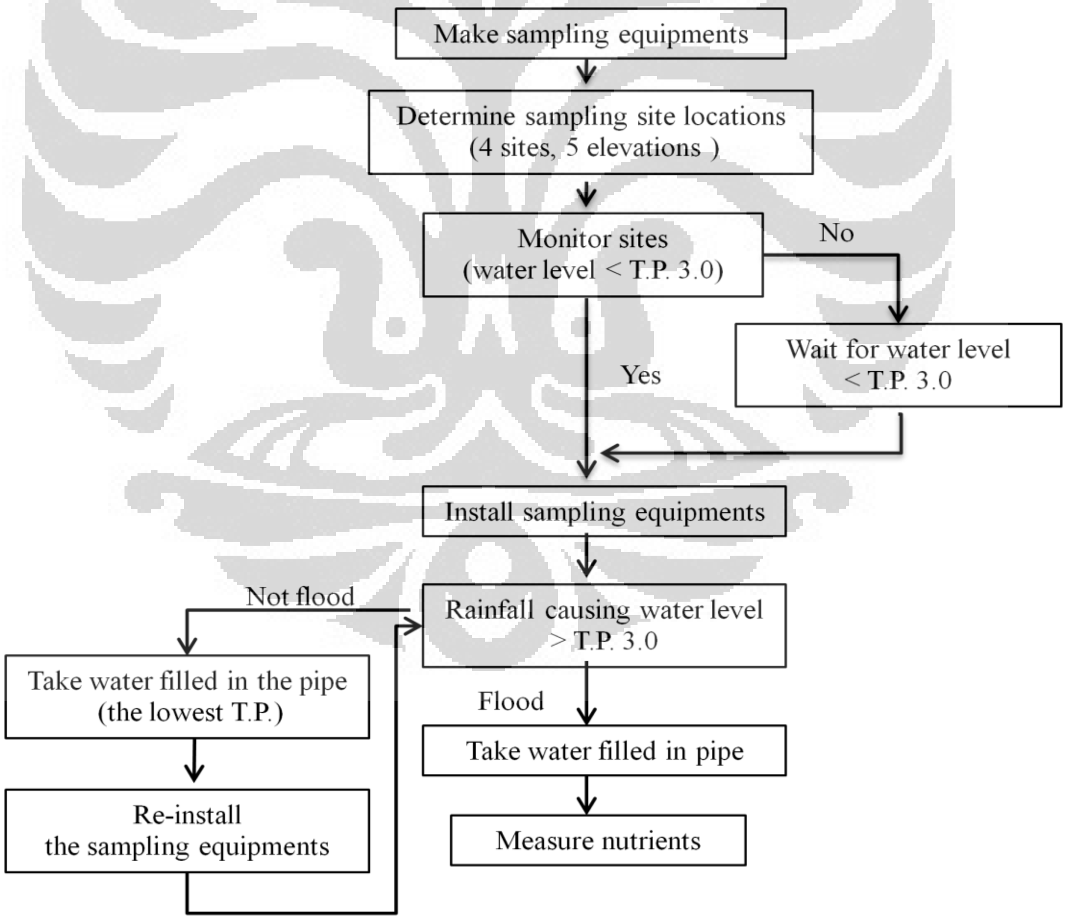


Figure 3.4. Sampling procedure

Samples were then measured in Urban and Environmental Engineering Experimental Facilities, Kyushu University. From the field to the laboratory, samples were preserved in cooling box with temperature of 4^{o}C. The nutrient measurements were not conducted in the same time for all of the samples; therefore, samples were preserved by freezing them with temperature of -20^{o}C. In this case, the preservation with temperature 4^{o}C is also allowable during a month after sampling.

3.3 Measurement Methods

Method used to measure nutrient parameters was the spectrophotometer method by using DR/2400 Portable Spectrophotometer. The DR/2400 detects more than 65 substances using pre-programmed tests that automatically set the wavelength and prompt through the procedure. It has an automatic wavelength selection and calibration feature, thereby reducing possible adjustment errors. A wavelength accuracy of ± 1 nm gives precise performance. In addition, more than 130 Hach methods are permanently stored in the instrument's non-volatile memory. It has high performance optical system that based on a concentric polychrometer with top-notch. The system significantly reduces stray light, which allows for extended range performance. A highly integrated array sensor detects the signal from solid state LEDs (in the visible range). The optics are tested and certified against ASTM Standard E-275-83 (Hach, n.d.).

Wavelength Range: 400-880 nm
Bandwidth: 4 nm ± 1 nm
Wavelength Accuracy: ± 1 nm, 400 - 880 nm
Wavelength Resolution: 1.0 nm
Wavelength Selection: Automatic
Wavelength Scan Speed: 200 nm/minute
Optical System: Concentric Spectrophotometer
Wavelength Calibration: Automatic at power-up
Photometric Range: -3.2 to 3.2 Abs
Photometric Resolution: 0.001 Abs
Photometric Linearity: 5mA from 0.0 to 0.5 Abs; ± 1% from 0.5 to 2.0 Abs

Figure 3.5. DR/2400 Protable Spectrophotometer

(Hach, n.d.)

Total phosphorus (TP) and dissolved total phosphorus (DTP) was measured by 8190 method that mentioned in manual procedure of DR/2400 Portable Spectrophotometer. The difference of TP and DTP measurement was in the filtration process before measuring the sample. If TP measurement used sample directly from the field, DTP measurement used sample that has been filtered by 0,45 μm membrane. This kind of principle was also used to measure total nitrogen (TN) and dissolved total nitrogen (DTN) using 10071 method based on DR/2400 Portable Spectrophotometer manual procedure. Following are the brief procedure of nutrient measurements.

a. Filtration

The filtration procedure to obtain filtered sample for DTN and DTP measurement are explained as follow.

- 0,45 μm membrane (Whatman 25mm GF/F filters (Fisher Scientific)) was used in Vacuum filtration with pumping capacity 10 psi.
- Half of sample was poured slowly into the membrane.
- Filtered sample was used to measure DTN and DTP, while retained matter in the membrane can be used to measure chlorophyll-a contained in the water. However to measure chlorophyll a, sample must be filtered as soon as it is taken in the same day. If it is not directly treated, it will give an inaccurate result since chlorophyll a represents a living matter.

b. Total nitrogen and dissolved total nitrogen

Following are brief procedures for measuring TN and DTN based on 10071 Method DR/2400 Portable Spectrophotometer procedure manual.

- COD reactor was turned on and heated to 105^{o}C.
- Two tubes of Total Nitrogen Hydroxide reagent vials were prepared and Total Nitrogen Persulfate reagent powder pillow was added into the vials. 2 mL of sample was added to a vial (this is the prepared sample), while 2 mL of the deionized water included in the kit to a second vial (this is the reagent blank). As a substitute for the deionized water provided, only water that is free of all nitrogen-containing species can be used. Vials were then mixed and heated for 30 minutes in the reactor.

- Caps were removed from digested vials and the contents of one Total Nitrogen (TN) Reagent A powder pillow was added to each vials and vigorously mixed. Caps were removed from the vials and TN Reagent B powder pillow was added to each vials and mixed well.
- Caps were removed from two TN Reagent C vials and 2 mL of digested, treated sample was added to one vial. 2 mL of digested reagent blank was added to the second TN Reagent C vial. Vials were inverted to mix the reagents and samples were ready to be measured in DR/2400. The unit used is mg/L N.

An alkaline persulfate digestion converts all forms of nitrogen to nitrate. Sodium metabisulfite is added after the digestion to eliminate halogen oxide interferences. Nitrate then reacts with chromotropic acid under strongly acidic conditions to form a yellow complex with an absorbance maximum at 410 nm.

c. Total Phosphorus and Dissolved Total Phosphorus

Following is the brief procedure for measuring TP and DTP based on 8190 Method DR/2400 Portable Spectrophotometer procedure manual.

- COD reactor was turned on and heated to 150^0C.
- By using TenSette Pipet 5 mL sample was added to a Total and Acid Hydrolyzable Test Vial. The contents of one Potassium Persulfate Powder Pillow for Phosphonate was added to the vial and mixed well. The vial then was heated for heated 30 minutes in the reactor.
- After heating, 2 mL of 1.54 N Sodium Hydroxide Standard Solution was added to the vial by using TenSette Pipet. Vial was then capped and mixed.
- Vial was calibrated in DR/2400 as blank standard.
- The contents of one PhosVer 3 powder pillow was added to the vial and mixed, then TP was ready to be measured in the unit of mg/L PO_4^{3-}.

Phosphates present in organic and condensed inorganic forms (meta-, pyro- or other polyphosphates) must be converted to reactive orthophosphate before analysis. Pretreatment of the sample with acid and heat provides the conditions for hydrolysis of the condensed inorganic forms. Organic phosphates are converted to orthophosphates by heating with acid and persulfate. Orthophosphate reacts with molybdate in an acid medium to produce a mixed phosphate/ molybdate complex. Ascorbic acid then reduces the complex, giving an intense molybdenum blue color. Test results are measured at 880 nm.

3.4 Research Schedule

This study was carried out partly in Kyushu University and in Universitas Indonesia. In Kyushu University, sampling and experiments were conducted for about 4 months; while, data were analyzed in Universitas Indonesia. Table 3.1 presents research schedule for this study.

Table 3.1. Research schedule

Plan	May				June				July				August				September				October				November				
Preliminary study	■	■	■	■																									
Installment of sampling equipments				■																									
Preexperiment				■	■																								
Flood event					■																								
Experiment										■	■	■	■																
Data analyzing																	▨	▨											
Chapter 1,2,3																					▨	▨	▨	▨					
Chapter 4,5																							▨	▨	▨	▨	▨	▨	▨

■ : in Kyushu University
▨ : in Universitas Indonesia

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Introduction

Water quality assessment is utterly indispensable in determining the status of water bodies. Several parameters measured in specified locations of river-floodplain system are exhibited in Table 4.1, in the term of temporal variation of flood event, in which June 10 indicates pre-flood data and June 13 indicates post-flood data. Those data was measured by Liu Jia, currently a doctoral student in Kyushu University.

Table 4.1. Water quality parameters on 2011

Location	pH		DO (mg/L)		TN (mg/L)		TP (mg/L)	
	June 10	June 13	June 10	June 13	June 10	June 13	June 10	June 13
Stream	7	6,26	9,38	7,11	0,95	1,2	0,56	0,51
Creek	6,89	6,42	10,1	5,49	2,3	1,1	1,85	0,75
Shitaike	6,85	6,5175	7,865	5,7175	2,3	1,1	1,85	0,75
Ueike	6,745	6,415	9,04	5,615	1	1	0,54	0,48

Location	Temperature (℃)		Turbidity (NTU)		TDS (g/L)	
	June 10	June 13	June 10	June 13	June 10	June 13
Stream	24,15	20,25	446	32	0,164	0,095
Creek	22,01	21,03	34,5	52,6	0,157	0,09
Shitaike	23,8325	21,905	141,9	107,175	0,14775	0,09325
Ueike	23,28	21,11	122,9	24,75	0,131	0,102

Location	Chlorophyll-a (µg/L)		Conductivity (S/m)		Salinity(%)	
	June 10	June 13	June 10	June 13	June 10	June 13
Stream	0	0	2,53E-02	1,46E-02	0,01	0,01
Creek	1,395	0,6975	2,42E-02	1,39E-02	0,01	0,01
Shitaike	90,675	0	0,02275	0,014375	0,01	0,005
Ueike	32,7825	2,79	0,02015	0,01575	0,01	0,01

The typical condition of Matsuura River is indicated by pre-flood data (June 10) whereas the after flood data shows alteration due to inundation. Those data can be adjusted by comparing them with the associated regulation that is used to assess the water quality status in Japan. This regulation has already been mentioned in Chapter 2, Table 2.1. The comparison of observed parameters to the associated regulation is presented in Table 4.2.

Table 4.2. Assessment of Matsuura River water quality compared to regulation (Table 2.1.)

Parameters	Concentration	Remarks
pH	7	Suited to class AA
DO	9,38 mg/L	Suited to class AA
TN	0,95 mg/L	Suited to class D
TP	0,56 mg/L	Does not suit to any class

Refering to Table 4.2, Matsuura River does not match to any designated river class in Table 2.1. It can induce eutrophication in adjacent lakes or reservoirs due to the high nutrient content in this water body. However, sampling in certain locations and frequent monitoring need to be applied to acquire a more comprehensive water quality assessment. Along the river, the water quality is changing due to the physical movement of chemical species that is largely affected by advection due to gravitational movement of mass of water.

The presented adjustment (Table 4.2) is used as a precaution to indicate that certain changes are currently undergoing in Matsuura River. It will significantly influence Azame-no-Se floodplain whose input water originates from Matsuura River. Nutrient content in this mainstream will be carried into floodplain by flood event. The present status of this stream will possibly induce eutrophication in Azame-no-Se due to the escalation of nutrient during inundation.

This issue is confirmed by observed vegetation living in Shitaike pond, *Trapa japonica*. A bloom peak in summer 2011 was observed where it fully covered the surface water of Shitaike pond. This vegetation is characterized by its ability to survive in the eutrophic water. Therefore, this study, the distribution of nutrients in the floodplain during flood event, is of great importance in understanding the pattern of nutrient and nutrient cycle mechanism locally in the floodplain and in more major scale of watershed system.

4.2 Distribution of Nutrients Based on Spatial and Temporal Variation

Flood event occured in Azame-no-Se floodplain in June 11, 2011. During this event, Azame-no-Se and Matsuura River was hydrologically connected by the creek, and 5-m water high inundated the floodplain. Sampling was successfully carried out in the floodplain during that flood event as water filled equipments from T.P. 3.0 until T.P. 7.0. Moreover, surface water was sampled one day before and two days after inundation to establish a temporal variation data. Nutrient measurements were performed using methodology described in Chapter 3, and data follow are presented in various graphs to facilitate data interpretation.

4.2.1 Spatial Variation

a. Water elevation based

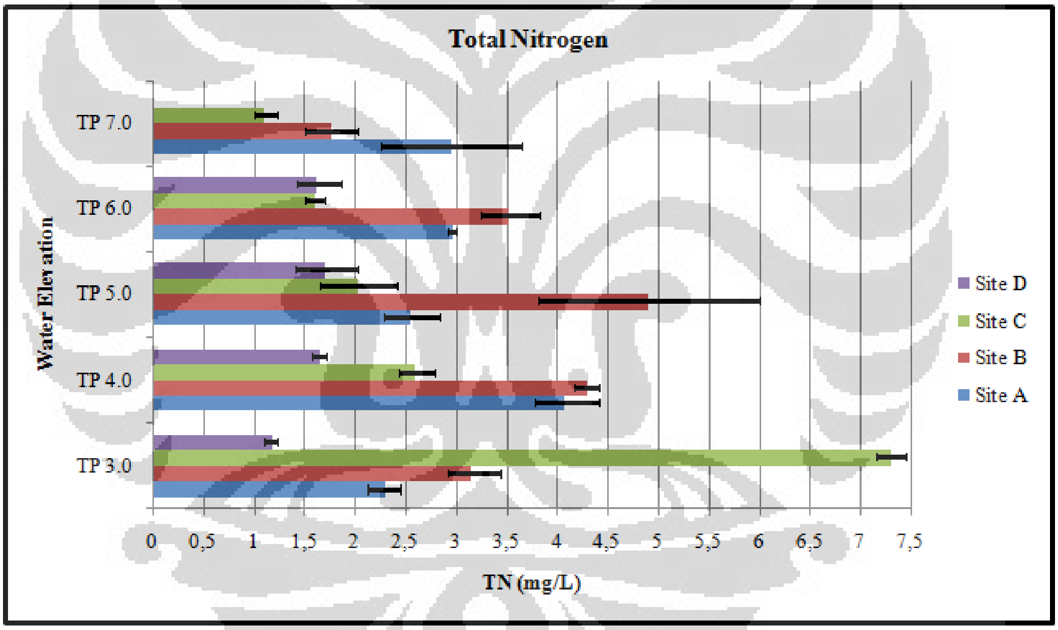


Figure 4.1. Total nitrogen graph – water elevation based

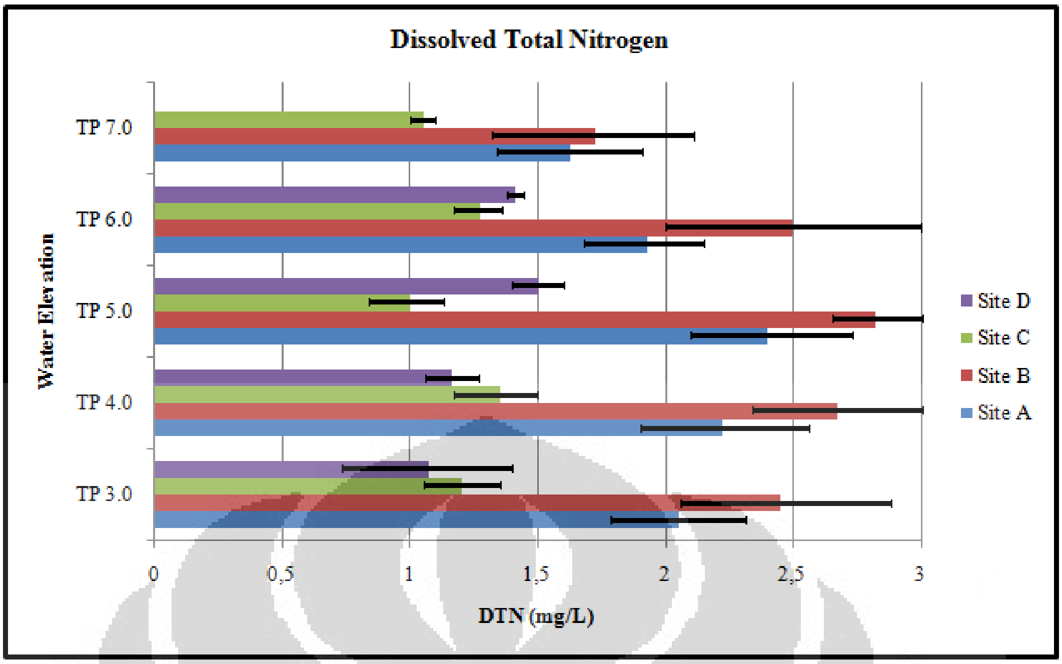


Figure 4.2. Dissolved total nitrogen graph – water elevation based

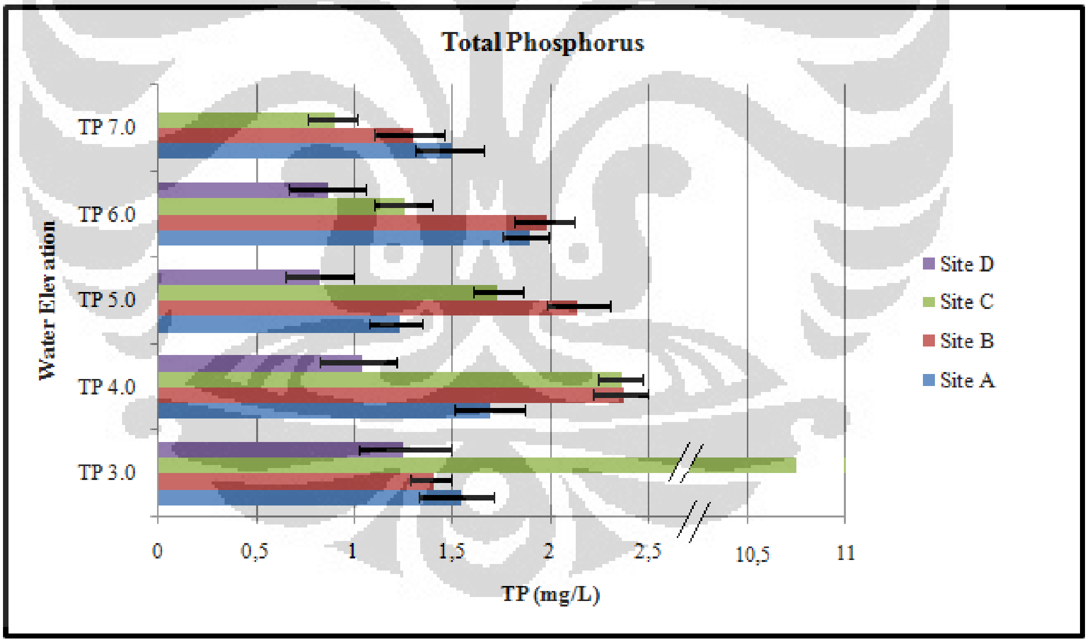


Figure 4.3. Total phosphorus graph – water elvation based

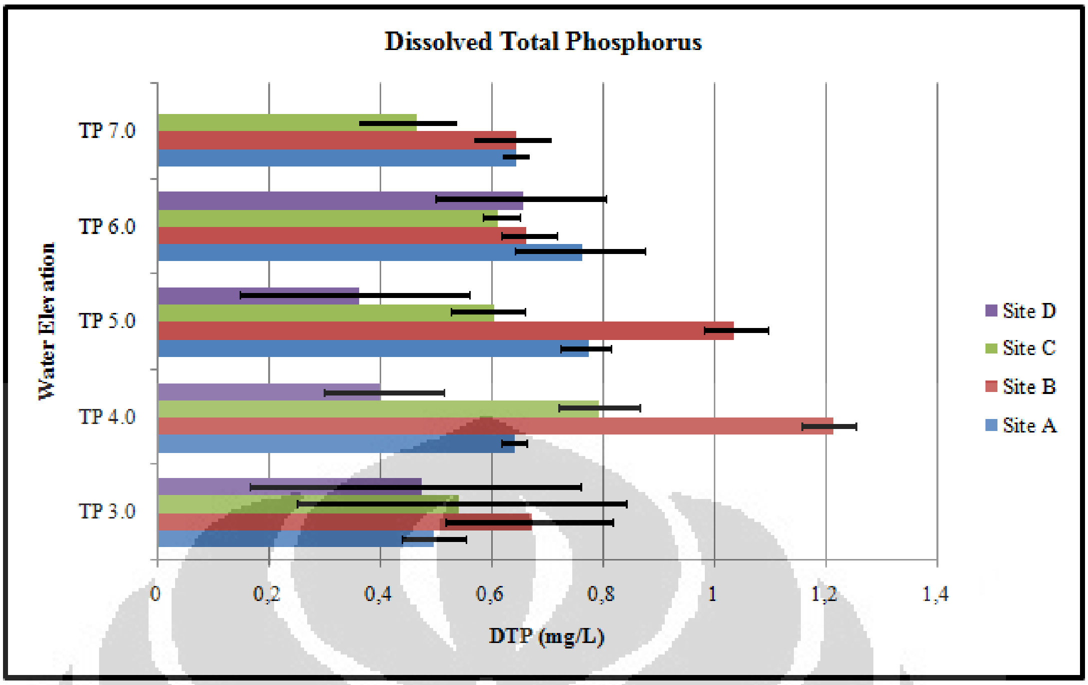


Figure 4.4. Dissolved total phosphorus graph – water elevation based

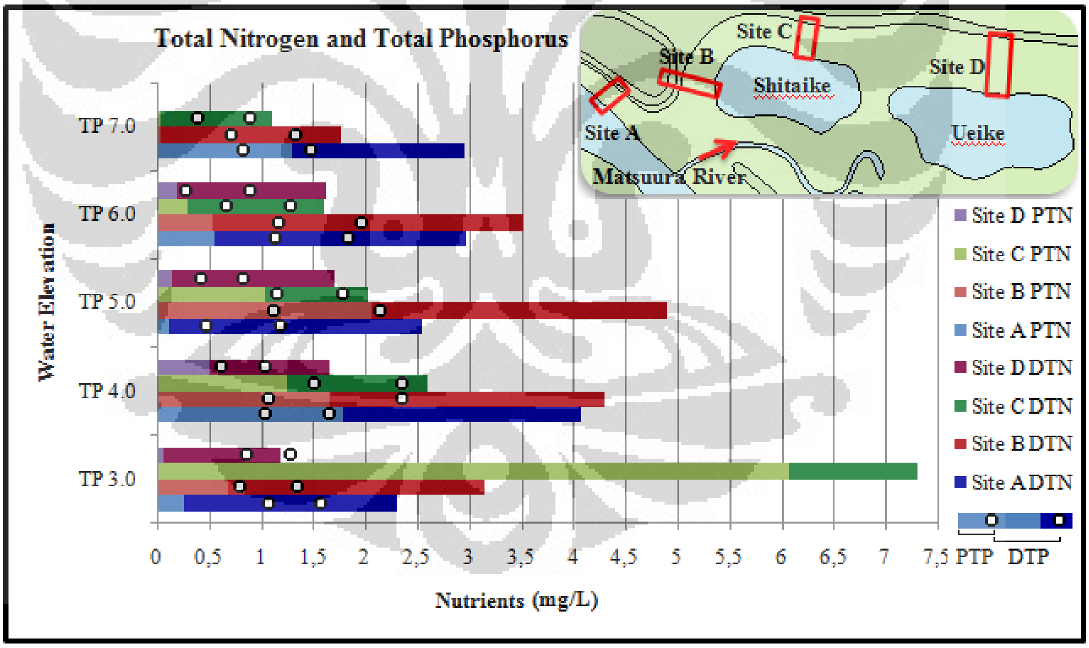


Figure 4.5. Total nitrogen and total phosphorus graph – water elevation based

The above graphs show nutrient distribution based on water elevation. Total nitrogen (TN) and total phosphorus (TP) present a wide range of data, due to nutrient content in T.P. 3.0 site C which is extremely higher compared to the rest. Considering the uncertainty of the data in Figure 4.1, 4.2, 4.3 and 4.4, the distribution of nutrients do not present an exact trend. This finding is also applied to Figure 4.5 depicting relative proportion of PTN, DTN, PTP, and DTP without considering the uncertainty factor. Only site C demonstrates a consistent tendency in the graph. In this site, T.P. 3.0, the lowest water elevation, contains the highest nutrient concentrations, and it decreases with respect to the increasing of water level. Generally, it exhibits that higher elevation results in less particulate content for nitrogen. While for phosphorus, the particulate matter is quite constant for all elevations.

b. Nutrient distribution based on site location

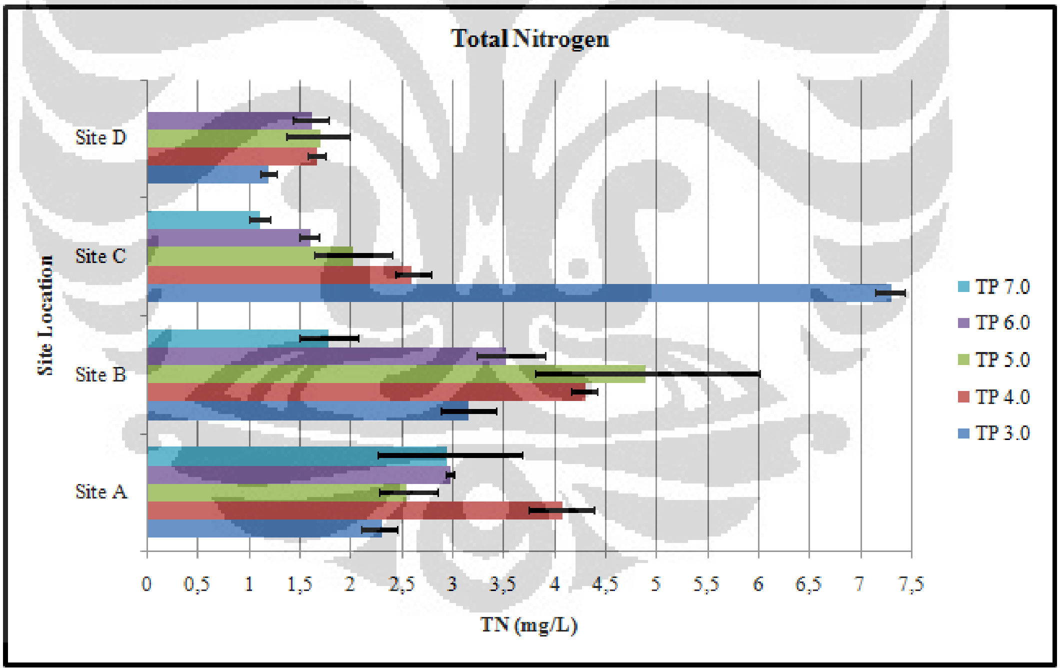


Figure 4.6. Total nitrogen graph – site location based

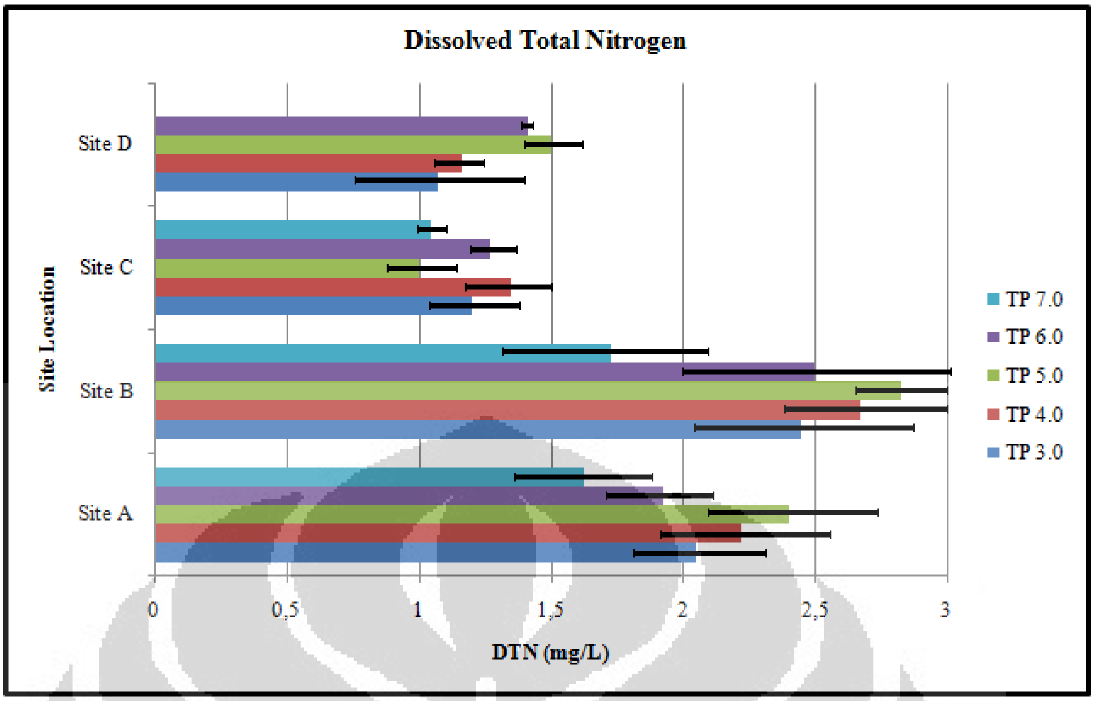


Figure 4.7. Dissolved total nitrogen graph – site location based

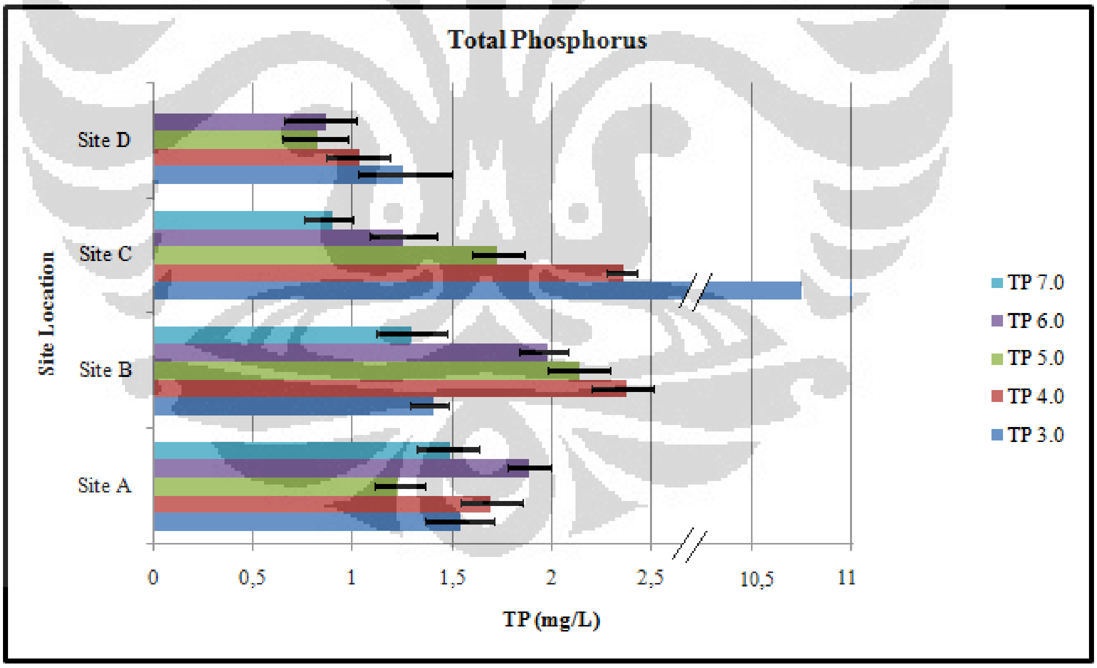


Figure 4.8. Total phosphorus graph – site location based

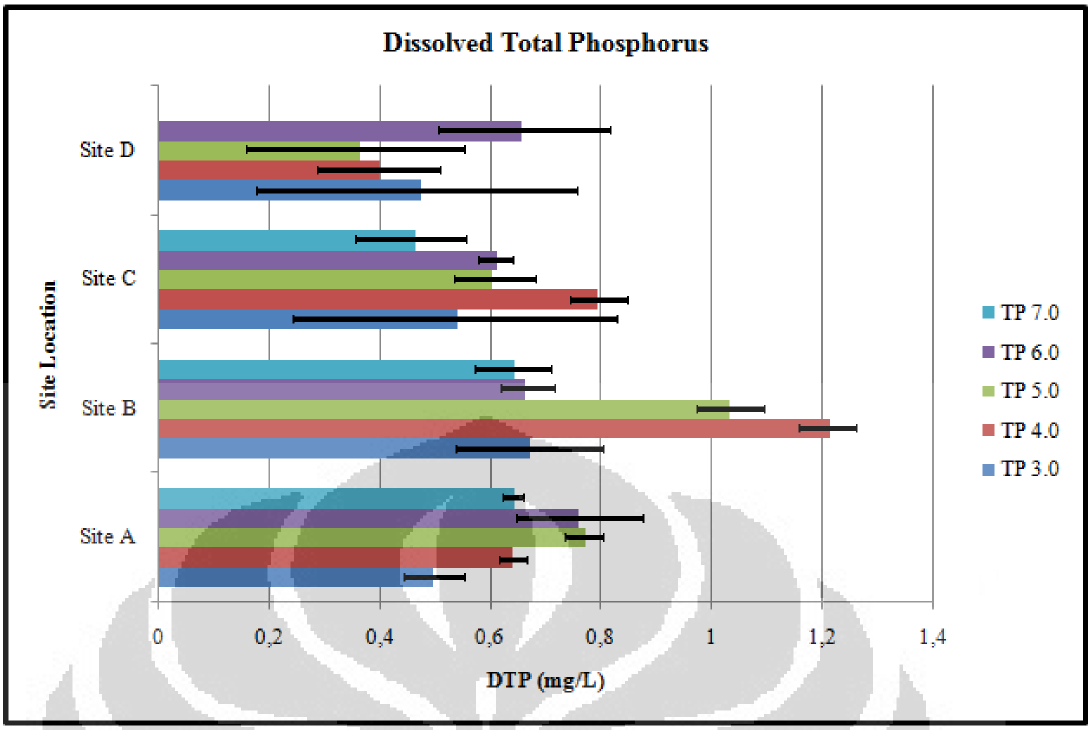


Figure 4.9. Dissolved total phosphorus graph – site location based

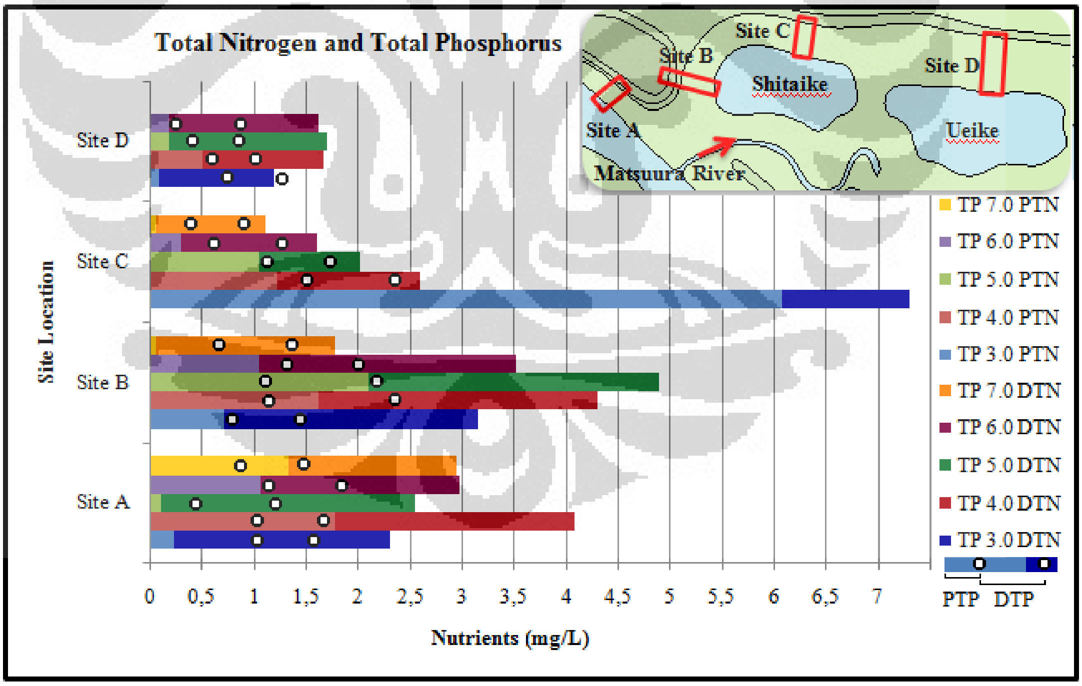


Figure 4.10. Total nitrogen and total phosphorus graphs – site location based

Graphs depicting the nutrient distribution based on site location show that site B contains the highest nutrients for all of the parameters. Site A, C and D follow after. This justification can be applied only to T.P 4.0, T.P 5.0, and T.P 6.0, as T.P 3.0 and T.P 7.0 are in site A and C, respectively. Site A and B seemingly contains much more particulate matter than site C and D, with site D containing the least.

4.2.2 Temporal Variation

The following graphs are comparison of nutrient content in water column of before, during, and after flood event. By examining their contrast, the effect of flood event to the floodplain terrestrial condition can be recognized.

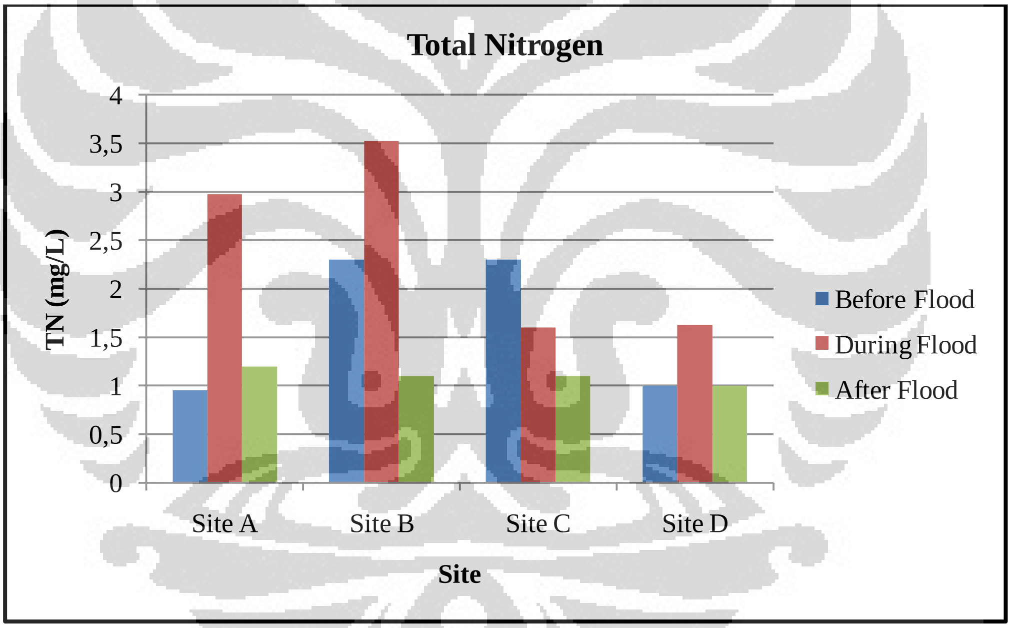


Figure 4.11. Total nitrogen graph – temporal variation

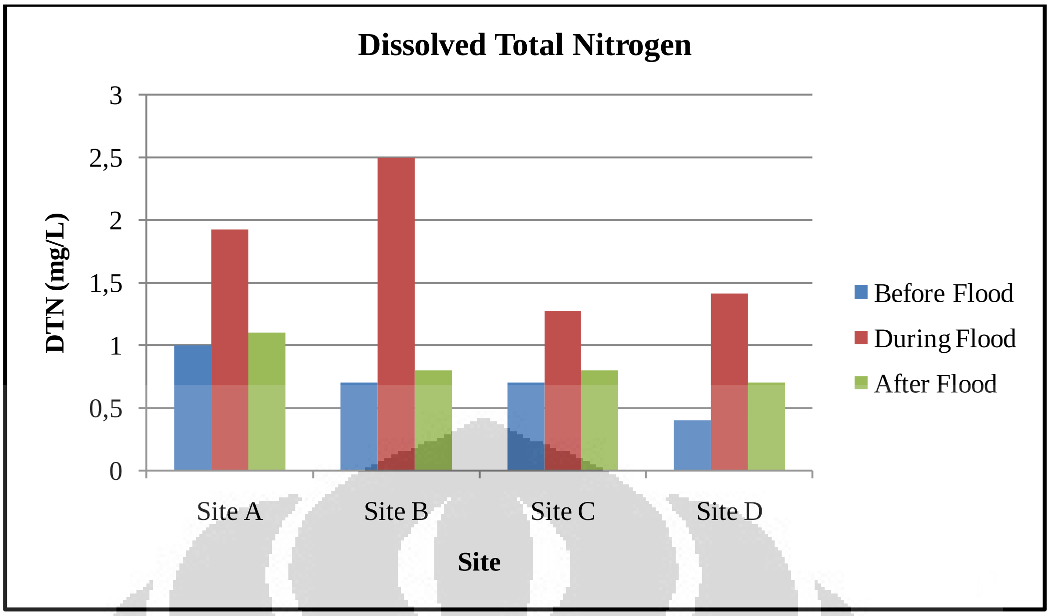


Figure 4.12. Dissolved total nitrogen graph – temporal variation

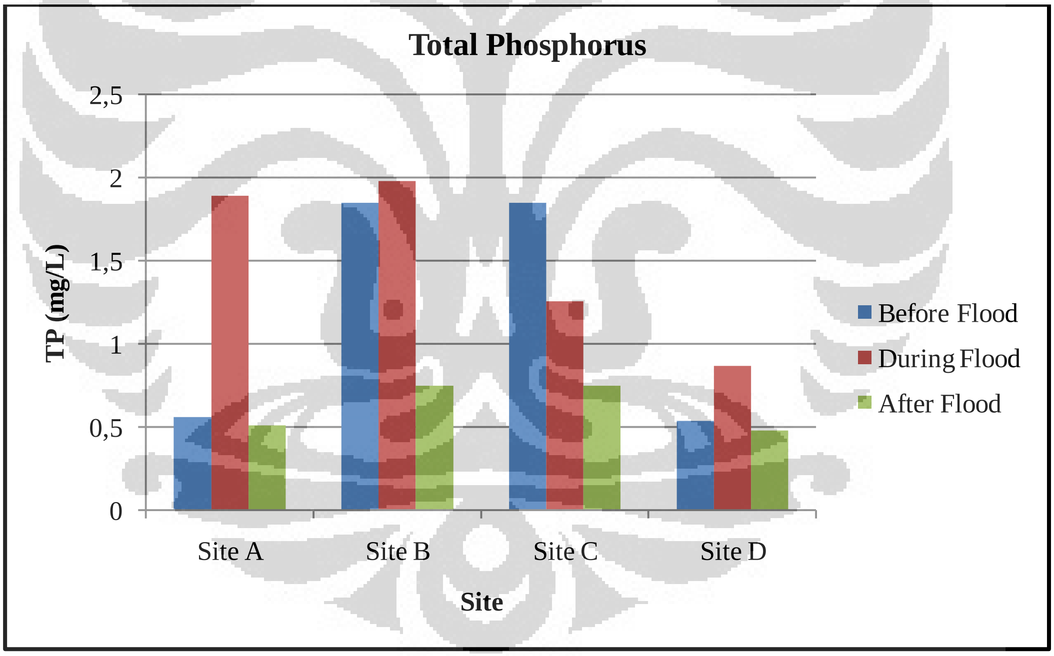


Figure 4.13. Total phosphorus graph – temporal variation

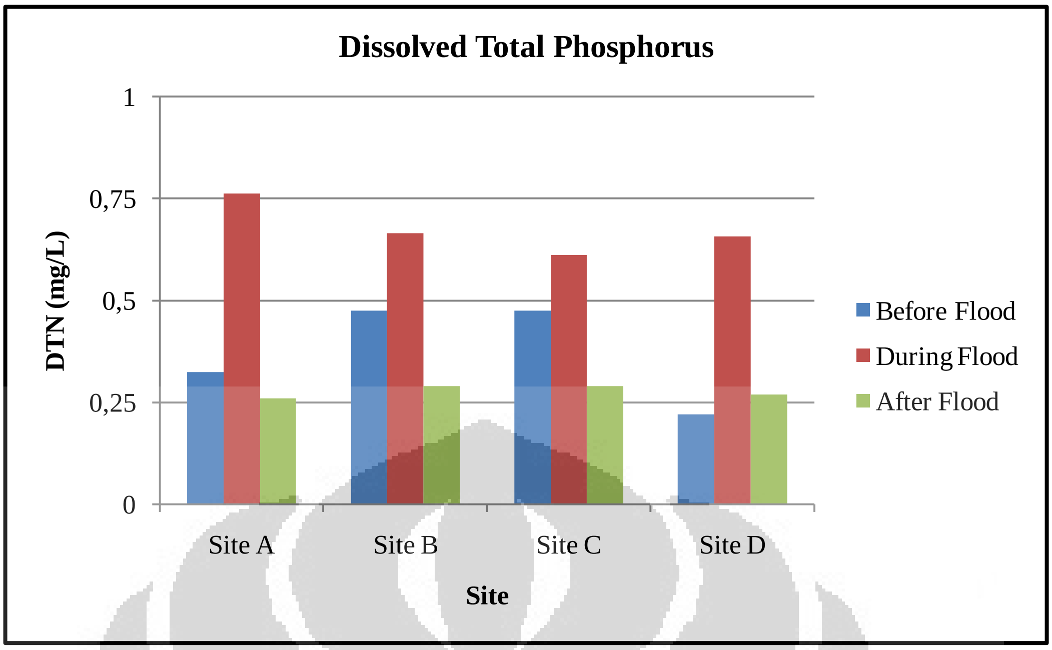


Figure 4.14. Dissolved total phosphorus graph – temporal variation

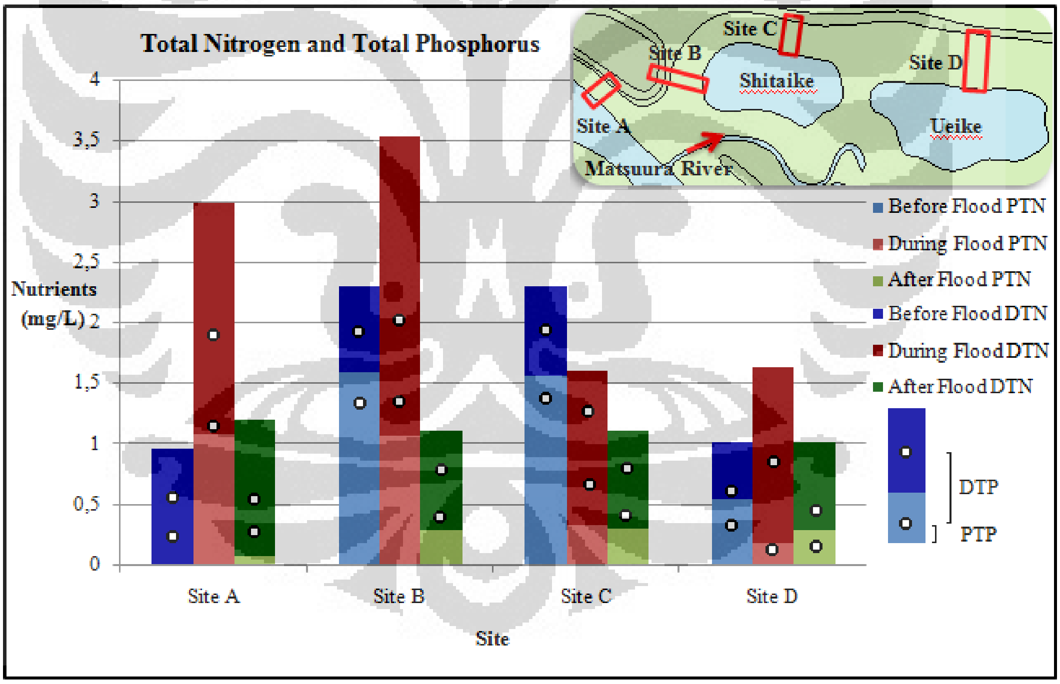


Figure 4.15. Total nitrogen and total phosphorus graph – temporal variation

Former temporal variation graphs enable water quality of flood sequence to be analyzed. Compared data is the surface water, in which T.P 6.0 is applied for during flood event data. For both TN and TP parameters, flood event data is higher than bpre-flood and post-flood data, except for site C, in which pre-flood is the highest among all. In Figure 4.15, DTN is dominating the portion of nitrogen; while, species dominating for phosphorus is PTP. However, this trend does not appear in site D, which contains more DTP.

4.3 Discussion

4.3.1 Spatial and Temporal Variation

In discussing the nutrient transport process occured during flood event in a floodplain, it is important to recognize this process as a complex spatial and temporal structure of nutrient input. Single measurement of water column N and P represents only a “snap-shot” of nutrient condition and may or may not reflect the long-term pattern of nutrient inputs that alter biogeochemical cycles and affect wetland biota (US EPA, 2003). Hence, this study aims to investigate the variability across space and time.

a. Spatial variation based on water elevation

Generally, T.P. 4.0 contains the highest value of nutrient for all parameters. With respect to the increased water level, this value is decreasing. It differs with the hypothesis stating that the highest nutrient content would be in sample in T.P. 3.0 as it has bigger opportunity to get nutrient from the agitation of sediments due to the dynamic flow of inundation.

To discuss nutrients distribution based on water elevation, water level fluctuation depicted by hydrograph should be considered. Figure 4.16 exhibits that water level did not directly raise from T.P. 3.0 to T.P. 7.0, instead it went to several steps to raise to certain level. The usual water level (T.P. 2.5) raised moderately to T.P. 3.0 due to the rainfall event. T.P. 3.0 obviously did not combine to flood event. Thereupon, water level increased in slow manner for about 4 hours. It then suddenly increased, filling sampling equipments in T.P. 4.0, T.P. 5.0, and T.P. 6.0. The rapid increment showed by steep slope in the hydrograph is considered as flood water.

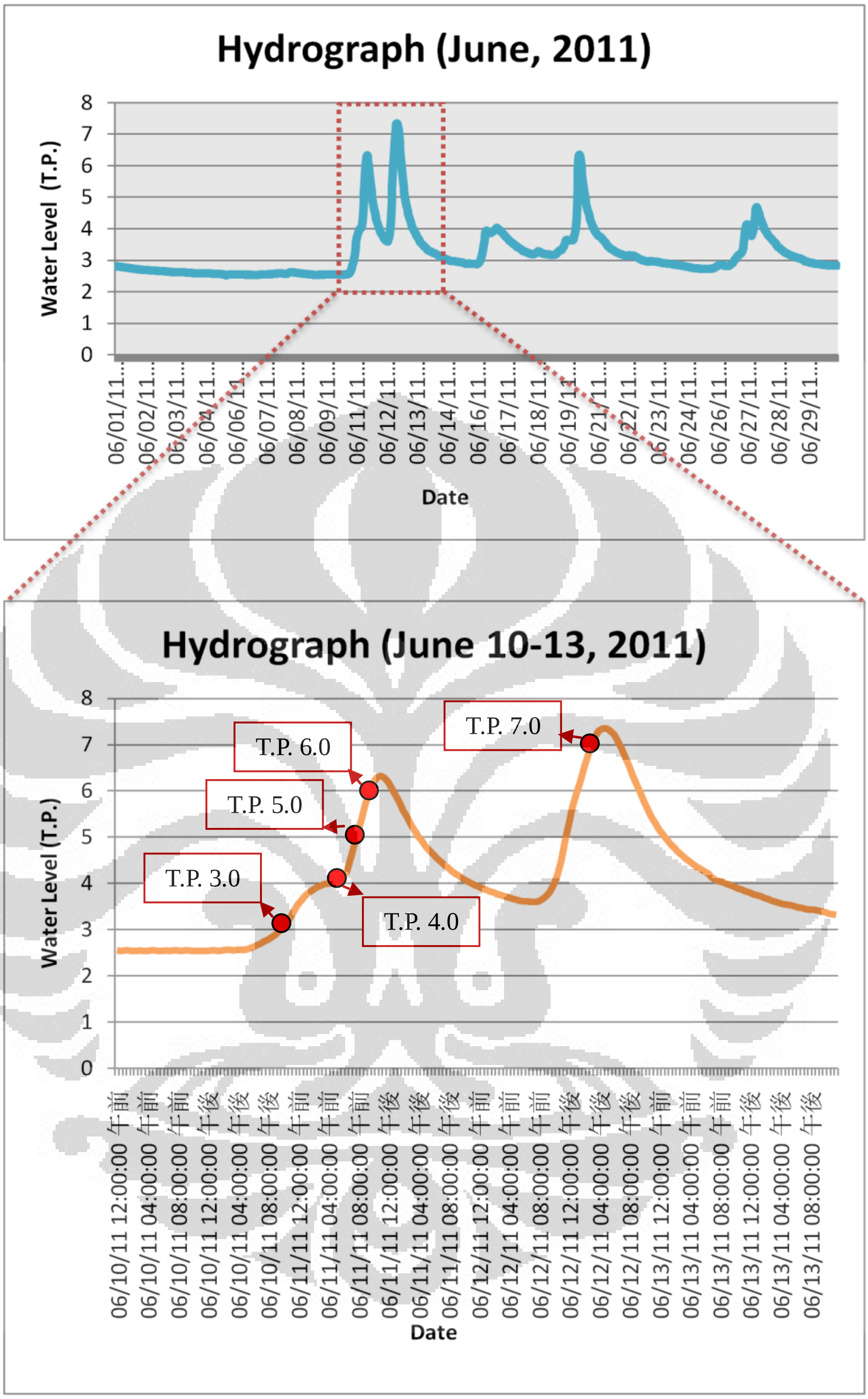


Figure 4.16. Hydrograph showing water level fluctuation in floodplain

Following the previous event, water level receded gradually for about 8 hours. Another vast flood came in June 12, 2011 on 08.00 a.m. Due to this flood event, water level rised from T.P. 3.5 to T.P. 7.0 and filled equipment installed in T.P. 7.0. Thus, samples were collected from two distinct flood events.

Both flood events indeed carried unequal portion of nutrients because they inundated floodplain in a very dynamic movement, hydrologically From Figure 4.5, T.P. 7.0 contains the least part of nutrients, because not only it is the highest elevation, but also it originates from the discrepant flood event. Nutrient carried by latter inundation has lower nutrient content in the flood water, it appears obviously in site B. At the same time, site A located in the mainstream has vast flowing current; hence, the amount of nutrient content is quite steady over time for the different flood event –comparing T.P. 6.0 and T.P 7.0 in site A. The similar assumption can also be applied for phosphorus, where the second inundation results in lower portion of nutrient carried into floodplain, although this discrepancy is not as visible as nitrogen.

The high TN and TP in T.P. 3.0 site C is justified by the raising of water level because of rainfall event. The rainwater percolated the bottom sediments of site C, and surface water trapped inside the sampling equipment. As the result, sample comprised of both water and the trapped sediment. The corresponding mechanism did not appear for other sites in the same elevation, as each site has its own characteristic discussed in latter part.

The relative amount of particulate matter is higher in T.P. 4.0 than another elevations for most of the sites, as shown in Figure 4.5. As the lowest elevation of flood water sample, T.P. 4.0 was greatly affected by the hydrodynamic of flood event causing percolation of bottom sediments. It is associated to the movement of inundation, i.e. directional or bidirectional flow.

It is also apparently discerned that the relative amount of particulate matter decreased with respect to water elevation. This is applicable only to T.P 4.0, T.P 5.0, and T.P 6.0 as it originated from one flood event. Another interesting fact is, the dominant parameter for nitrogen is DTN; while, PTP prevails for most elevation for every sites. This dissimilarity of N and P behaviors are related to their presence phase in river and floodplain.

Overall, the spatial variation based on water elevation mirrors the vertical movement of inundation. Although, it does not present an exact trend of data, the particulate matter tends to accumulate in the lower elevation because of the agitation of bottom sediments of floodplain.

b. Spatial variation based on site location

In normal condition, when floodplain is in terrestrial ecosystem, Shitaike pond and Ueike pond contain a higher nutrients than main stream. This condition is also valid if shallow flood event inundates the floodplain. On the other hand, if large flood occurs –similar to the studied flood event- site A and B located in the main stream demonstrate much higher nutrient concentrations than ponds in the floodplain, site C and D.

The justification of trend based on site location will be emphasized for T.P. 4.0, T.P. 5.0, and T.P. 6.0 which originated from the same flood event. From Figure 4.10, site B is the site containing the highest nutrient content as the mix of nutrient from river and floodplain took place in this site. Site A, C, and D follow after, respectively. This result was indicated by Hayashi, Shimatani, & Kawaguchi (2008) that distance from the inflow site are related to the seed dispersal in the floodplain.

In other words, distance of each site to the input channel of flood is related to its nutrient content. As suited to hypothesis, the closer site located from flood input channel, the more nutrient content trapped in the sample. Moreover, site in the close proximity to main channel (site B) has higher particulate matter than the more distant site (site D). Overall, DTN and PTP prevail over each site, and their proportions are dependent to water elevation. Spatial variation based on site location mirrors the horizontal movement of inundation, in which combination of nutrients carried into and already exist in the floodplain.

Identification of characteristic of each site becomes crucial in addressing the nutrients distribution based on site location. Site A located in the main stream represented the water quality of Matsuura River as the flood water input. The lower nutrient content in its water column than in site B is predicted due to the nutrients source that originated only from river system, i.e. watershed activity, natural process in the river or other possible sources.

Site B was located near creek, channel connecting river and floodplain during flood event. Therefore, it has the highest nutrient content during flood event because of the mixing of nutrient from the river and floodplain took place in this site; whereas site C was separated within a distance of about 100 m from the input channel. Though located in Shitake pond, site B and C were different in their conditions. Site C truly represented Shitaike pond ecological environment with thick and blackish grey sediments and the remarkable aquatic vegetation *Trapa japonica*, that was fully bloom in summer season.

It totally differs from Ueike pond, which was the basis location of site D. The population inhabiting this area is mussel *Unio douglasiae* that is easily found in the bottom of the pond. Its slippery brown sediments differ from Shitaike pond.

As a matter of fact, the discrepancy of ecological environment for both ponds is predicted to be derived from morphology of this restored floodplain. The pattern of inundation flow is highly dependent on floodplain's morphology, hence giving it a particular impact to the distribution of nutrients.

From Figure 2.18, Shitaike pond will be the first pond to be introduced by fresh flood water, then Ueike pond located in the upstream of floodplain. To reach Ueike pond, there are natural barriers composed from wood plants reducing the flood water velocity. It is the main reason why Shitaike pond contained bigger portion of particulate matter than Ueike pond. Consequently, Shitaike pond takes part as sedimentation tank for Ueike pond. Sedimentation is the most important nutrient retention mechanism in floodplains, compared to denitrification and plant uptake (Van Der Lee, Venterink, & Asselman, 2004). This sedimentation principle has similar mechanism with the one designed for water or waste water treatment plant, that is gravitationally settled particulate matter.

As water velocity decreased, only a small portion of particulate matter was then carried into Ueike pond. For this reason, Ueike pond's particulate matter in the water column originates mostly from local source, mainly from the excretion release of mussels. The floodplain growth stage will be another important reason, as those ponds were constructed in different period of time. Shitaike pond was constructed in 2003, while Ueike pond was several years after.

This spatial variation will further determine the establishment of favourable habitat for certain species discussed in the biological indicator section.

c. Temporal variation

One day before and two days after flood event, surface water were sampled in several points representing the inundation flow to investigate the correlation of nutrient distribution in term of temporal variation. It demonstrates the floodplain response, including alteration occured due to flood event. In the restoration of Skejrn River and its valley (Padersen, Andersen, Nielse, & Linnemann, 2007), the alteration of nutrients retention in the restored area follows the extent of flooding and amounted to less than 10% of the total riverine transport. It shows that there are many mechanisms taking place in a dynamic river-floodplain system, not only river carrying nutrients to floodplain, but also floodplain exporting nutrients to river system in function of the nutrient speciation. Data depicted in Figure 4.15 shows that, flooding time presents the highest value of nutrients for all of the parameters in every sampling sites, except for site C.

Site A has the expected trend of temporal variation as flood event contains the highest nutrient concentrations, and the post-flood shows lower nutrient concentrations, but still higher than pre-flood. Dissolved matter is the foremost parameter of pre-flood data due to the characteristic of this site. Located in the main stream, it is profoundly dependent to the river condition. The escalation of both particulate and dissolved matter during inundation was likely due to the runoff from adjacent land use and erosion in the bank of river. The post-flood data is slightly higher than the pre-flood data. It is predicted as a result of the fast flow of the river current. In this manner, it only needs a short time to be in its initial condition, since flow of the river easily carries nutrients downstream.

Site B and C have a similar pre-flood and post-flood data. Pre-flood data is quite high, with particulate matter appears in major part of it. It is due to the shallow water column that was possibly agitated during sampling, so particulate matter in the bottom sediment was trapped in the sample. The portion of particulate matter during inundation in site B is very much alike as site A. If particulate matter in site A was carried by river system, site B was the mixing of particulate from river and floodplain systems. To reach site B, flood water was retained by some woody vegetation decelerating flood water velocity, thus many particulate matter from river settled, replaced by particulate matter locally existed in the floodplain. This replacement yields in quite high particulate matter during inundation time. Dissolved matter also increases, and its source is expected to originate from the river system. As the consequence of the increasing water quantity, the concentrations of dissolved matter in the water column will be much more lower. But it does not appear in this dynamic system of river-floodplain connectivity. It can be stated that flood event carried in significant amount of dissolved matter to floodplain ecosystem.

The particulate matter during flood event in site C is not as high as site B that is predicted due to the settling of particulate matter to reach site C. The post-flood data demostrate sharp decline, specifically for site B, due to the particulate matter that was easily settled and possible transport of nutrients carried away to river system.

The pre-flood data of site D depict the equal portion of particulate and dissolved matter. Once inundation came, particulate matter decreased in surface water as flood water carried less particulate matter to site D. It was due to the woody vegetation planted as barrier to separate Shitaike pond and Ueike pond decelerated the flood water velocity. This mechanism created much dissolved matter reaching this site. The post-flood data show slight discrepancy to pre-flood data, in which particulate matter is higher compared to the inundation time. It is predicted due to the changes of dissolved matter to another phases in the water column.

The trend for total phosphorus is actually in the similar pattern as of total nitrogen; nevertheless, it appears in a lesser portion in the water column. The hypothesis is that, longer isolation time of a pond resulting in lower nutrient content than the freshly inundated one, is only applicable to site A. There is quite dissimilar trend appearing for the rest of the sites due to the complex interaction of many factors in the floodplain, as discussed earlier.

In discussing the temporal variation of nutrient distribution, data showed in Table 4.1 can be used to obtain the more comprehensive insight of the dynamic river-floodplain system. The most visibile alteration of inundation occurs for several parameters, namely pH, turbidity, dissolved oxygen, and chlorophyll a.

Sawyer, McCarty, & Parkin (2003) defined pH as unit to express the intensity of the acid or alkaline condition of a solution. It decreases for all locations. The difference is within the range of 0.3 - 0.75, and the extreme one is in the stream of Matsuura River, where pH went from neutral to 6,26, considered as acid. Although the tendency of pH decreases, it is still within the acceptable range of pH supporting maximum life of organisms.

Another parameter is turbidity that may be caused by a wide variety of suspended materials ranging in size, depending upon the degree of turbulence Sawyer, McCarty, & Parkin (2003). Refering to Table 4.1, the turbidity data are fluctuative. In stream and creek, the post-flood data are higher than pre-flood. They were affected largely due to the river dynamic condition. As river descended from mountain areas onto the plains, it received contributions of turbidity from farming and other operations that disturb the soil. Under flood conditions, most of the turbidity would be due to relatively coarse dispersion because great amounts of topsoil were washed to receiving streams. The increase of turbidity after flood consequently shows suspended matter carried by river water, resulting in high turbidity.

On the other hand, Shitaike pond and Ueike pond show decline of turbidity. Lake exists under relatively quiescent condition. Most of the turbidity will be due to colloidal and extremely fine dispersions. Both initial conditions are quiet similar; however, Ueike pond demonstrates sharp decline in post-flood data. This is probably due to the faster recoverability than Shitaike pond.

Oxygen is classified as poorly soluble, and since it does not react with water chemically, its solubility is directly proportional to its partial pressures at any given temperature (Manahan, 2005). In this case, the difference of temperature, shown in Table 4.1, is not extreme enough to affect the solubility of oxygen, thus dissolved oxygen can be solely analyzed. Before flood, dissolved oxygen in creek, 10,1 mg/L, is the highest compared to other sites. Stream, Ueike pond, and Shitaike pond follow after with 9,38 mg/L, 9,04 mg/L, and 7,865 mg/L, respectively. They present a quite high dissolved oxygen concentrations due to the water current created by flow in stream, and wind drift influence in creek and Ueike pond; however, Shitaike pond performs unsimilar mechanism of dissolved oxygen transfer via surface water. Most of Shitaike pond surface water was covered by vegetation *Trapa japonica,* thus dissolved oxygen was less soluble in its water column.

While, the post-flood data shows that dissolved oxygen suffered an appreciable decline for the whole locations. For the floodplain sites, the decline of dissolved oxygen to a uniform results, 5,5 mg/L, were caused by the anaerobic condition in the aquatic environment created during flood event. The stream location presents the highest dissolved concentration after the flood, 7,11 mg/L, due to the stable current flow allowing oxygen transfer, thus the rate of dissolved oxygen can be maintained, though slightly decreased.

This rate of oxygen also gives significant impact to oxidation rate. The biological oxidation is reflected through chlorophyll-a data, which is a specific form of chlorophyll used in oxygenic photosynthesis. This photosynthetic pigment is essential for photosynthesis in eukaryotes, cyanobacteria and prochlorophytes because of its role as primary electron donor in the electron transport chain.

Living organisms use nutrients to do photosynthesis. Flood event results in nutrient enrichment to the floodplain ecosystem. Organism such as microorganisms, algae, and macrophytes respond to this condition by sequential manner. Nutrient uptake occurs first by increasing the concentration of nutrients (P, N) in their tissues, followed by increasing growth and biomass production, and shifting in species composition as some species disappear and other species replace them (US EPA, 2003). It is confirmed by Beltman, Willems, & Gusewell (2007) who stated that the fertilisation with N generally increased biomass production and reduced species richness.

The rate of productivity cannot be measured solely as a function of dissolved oxygen. Population inhabiting the floodplain can be of major concern to affect the rate of productivity. Refering to Table 4.1, chlorophyll a is very small in stream and creek; while, Shitaike pond and Ueike pond show a high rate of productivity before flood, 90,675 μg/L and 32,7825 μg/L, respectively. Vegetation of *Trapa japonica* living in Shitaike pond largely contributed to this high value;

whereas, cyanobacteria is the main source of chlorphyll a in Ueike pond. It could be higher if measurement was conducted in another season, particularly autumn.

Higher rate of productivity showed by high rate of chlorophyll a data is the expected response of floodplain due to nutrient enrichment carried by flood event. Contrary to this expectation, chlorophyll a declines especially for floodplain's site, Shitaike pond and Ueike pond, 0 and 2,79 μg/L, respectively. The low rate of dissolved oxygen is predicted to be the limiting factor of productivity as all living organisms are dependent upon oxygen in one form or another to maintain the metabollic processes that produce energy for growth and reproduction. The effects of summer floods to reservoir system conducted by Godlewska et al. (2003) also presented the similar result that chlorophyll a concentration after the flood dropped considerably.

4.3.2 Nutrient Transport Process

a. Exchange with sediments

Local nutrient sources in the floodplain originate from its bottom sediments. The agitation of bottom sediments during flood event contribute to nutrients distribution, together with the combination of nutrient input from river system. The characteristic of sediments are totally different from terrestrial soils. Bottom sediments undergo continous leaching, whereas soils do not. According to US EPA (2003), sediments are an accumulation of organic matter, as a results of the balance of C fixation through photosynthesis and losses through decomposition. Rates of photosynthesis in wetlands are typically higher than in other ecosystems, and rates of decomposition are typically lower due to anaerobic conditions, hence organic matter tends to accumulate.

Sediments serve as sites for many biogeochemical transformations, hence providing long and short term storage of nutrients. The microbial transformations also occur in the sediment resulting in a long recovery period of certain pollutant. Incorporation of pollutants by settling from water column into sediments is a particularly important mode of chemical fate and transport under quiescent conditions, during which very small (colloidal) particles are aggregating together (flocculation). If undisturbed, the layers of sediments can provide a record of pollution (Manahan, 2005). It obviously reflects that sediments play an important role in the floodplain ecosystem, even Heath (1992) described that nutrient dynamics of floodplain should focus attention on annualized nutrient budget, sediment-water nutrient exchanges and their dependence on organic matter generated within the ecosystem.

As mentioned earlier, distinct characteristic of sediments was appeared for Shitaike pond and Ueike poind in Azame no Se floodplain. This restored floodplain undergoes several changes in the sediment composition. The original farming soil of Shitake pond became sediment due to the long time ponding and settled materials carried in by flood event. Differently from Shitaike pond, Ueike pond did not receive portion of materials originating from flood event. Instead, the activity of mussels enriched the sediment composition. It is depicted in Figure 4.10 (site B, C,and D; T.P. 4.0) and Figure 4.15 (site B, C,and D; before flood). Site B and C seemingly have higher nutrient content than site D. Exchange with sediments plays a role in making phosphorus available for algae and therefore contributes to eutrophication (Manahan, 2005). It is supported by the high phosphorus data before flood in Figure 4.15, site B and C. While, the effects of drying and re-flooding in the transformation of nutrients taking place in the sediments was greatly explained by Baldwin & Mitchell (2000).

b. Bioavailability

Bioavailability is the degree to which substance can be absorbed into the system of an organism. A substance bound in sediments may be released into water, then passed accross a biological membrane into an organism, or it may transfer directly across a membrane from sediment to an organism (Manahan, 2005).

Both nitrogen and phosphorus must be present in a simple inorganic form before they can be taken up by plants. The readily available forms of nitrogen are ammonia, nitrate, and nitrite. In the case of phosphorus, the utilizable species are some forms of the ortophosphate ion. Ratio dissolved inorganic nitrogen (DIN) to total phosphorus (TP) can also be used to determine nutrient limitation (Persic, Horvatic, Has-Schon, & Bogut, 2009; Perakis, 2002).

Nutrient sources are of major consideration especially the utilization based source from watershed. Adjacent landuse are utilized as farming land. The fertilizer used will likely affect the transport of nutrients in significant amount. Bioavailability of nutrients in the floodplain will be influenced by the alteration of nutrient species because of the usage of fertilizer.

Sawyer, McCarty, & Parkin (2003) presents reaction due to the addition of fertilizing agent to plants. The nitrate serves to fertilize plant life and is converted to proteins (organic nitrogen).

$NO_3^- + CO_2$ + green plants + sunlight → protein

Ammonia and ammonium compounds are applied to soils to supply plants with ammonia for further production of proteins. Urea is one of the popular ammonium compounds because it releases ammonia gradually.

$NH_3 + CO_2$ + green plants + sunlight → protein

While, soluble phosphorus from phosphate minerals are taken up by plants and incorporated into nucleic acids, which make up the genetic material of organisms. Mineralization of biomass by microbial decay returns phosphorus to the salt solution from which it may precipitate as mineral matter (Manahan, 2005). Once rainfall event occurs, runoff from farming lands will enter river system and contributing to flood event in the floodplain.

Unfortunately, the measurement of species that are readily absorbed by plants, such as nitrate and nitrite, is not available. Thus, discussion cannot be elaborated for this issue.

4.3.3 Biological Indicator

Communities inhabit Azame-no-Se floodplain can be simply categorized into two groups, vegetation *Trapa japonica* and mussel *Unio douglasiae* (Figure 2.19, 2.20). These two communities can be used as biological indicator to floodplain condition. Biological indicator is a numerical value(s) derived from actual measurements, and it conveys useful information for environmental decision making. It can be a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components (Grabarkiewicz &

Davis, 2008). However, this study discusses biological indicator in the mean of qualitative study, not the quantitative one.

Trapa japonica is a floating-leaved aquatic plants, eurytopic plants growing in many lentic habitats. The plants cover the water surface with dense foliage and often become the most dominant species in many waters in Japan, especially in nutrient-rich irrigation ponds. Once the seed of *Trapa* has been transported into waters with suitable prevailing environmental conditions, the plant can survive and establish itself successfully because of its high competitive ability throughout its life cycle, e.g., high RGR, rapid shoot elongation, canopy formation, production of large seeds (Kunii et. al. 1988). By producing a small number of large seeds, this plant could succeed in eutrophic waters (Kurihara & Ikusima, 1991). The flourishment of *Trapa japonica* indicates that Shitaike pond is in eutrophic condition, it is also supported by Table 4.2. If both nitrogen and phosphorus are plentiful, algal blooms occur, which may produce a variety of nuisance conditions. Such blooms do not occur when nitrogen and phosphorus or both are present in very limited amounts.

Eutrophication is often a natural phenomenon. However, human activity can greatly accelerate the process (Manahan, 2005). It can threaten the aquatic environment in the floodplain since all surface water supplies support growth of minute aquatic organisms. The main presumption cause of the excessive nutrient in the Shitaike pond is the adjacent agricultural activity in the Matsuura Watershed. The location of Shitaike pond to be the first pond introduced from flood water would also be of concern, as supported by Klaus (2011) stated that strong eutrophication effects induced by sediment deposits are confined to the close proximity to the main channel.

On the other hand, mussel *Unio douglasiae* was easily found in Ueike pond. Ueike pond has marked aquatic vegetation, to be known as cyanobacteria, and mussel *Unio douglasiae* are a good consumer of cyanobateria. Cyanobacteria are chlorophyll-bearing organisms that obtain their energy through photosynthesis; as the result, their growth is influenced greatly by the amount of the fertilizing elements nitrogen and phosphorus in the water. It can reproduce explosively under certain conditions, resulting in algal blooms. Due to the less nutrient content in site D (Figure 4.10) the eutrophication due to cyanobacteria bloom did not occur in Ueike pond. The dissolved oxygen in Ueike pond (Table 4.1) is also relatively higher than Shitaike pond, because of the activity of cyanobacteria and the transfer of oxygen via surface water. Although both ponds have the same concentrations of dissolved oxygen after flood event, Ueike pond performs a higher recoverability to return to its initial condition.

Possesing several characteristics that make it suitable indicator organism, *Unio douglasiae* plays a number of important roles in aquatic ecosystems. As sedentary suspension feeders, they remove a variety of materials from the water column, including sediment, organic matter, bacteria, and phytoplankton (Grabarkiewicz & Davis, 2008).

Mussel *Unio douglasiae* exhibits high sensitivity to environmental perturbations. Sedimentation is one of the processes that may have harmful impacts on freshwater mussel communities. Soft, cohesive substrates and suspended fine sediments are deleterious for most species and may affect respiration, feeding, and growth (Grabarkiewicz & Davis, 2008). This postulation has been proved by the inability of mussel *Unio douglasiae* to live in Shitaike pond. Not only, this pond was fully covered by *Trapa japonica* in certain season creating less oxygen contained in the water column, but also, sedimentation occured in this pond during flood event are of major concerns.

4.4 Nutrient Cycle in the Watershed

Human-induced changes in the hydrologic regime of rivers have direct and severe consequences on nutrient cycling and contaminant retention in adjacent floodplain (Lair et al., 2009), even Kondolf & Mathias (2006) visualized human impacts and restoration efforts in terms of connectivity and flow dynamics. Water quality can be affected when watersheds are modified by alterations in vegetation, sediment transport, fertilizer use, industrialization, urbanization, or conversion of native forests and grasslands to agriculture and silviculture. Previous study was conducted by Walling et al. (2003), he investigated downstream changes in the storage and deposition of heavy metals and nutrients caused due to the alteration of hydological regime in the upper basin.

Nutrient sources of flood can be imported outside, or locally produced in the floodplain by certain mechanism. Since Azame-no-Se located in the middle stream of Matsuura River, upstream source areas, mostly agricultural area, are the possible sources of nutrients in the water bodies. Runoff from adjacent landuse especially fertilizer runoff will immensely contribute to the introduction of particular component to Matsuura River.

Manahan (2005) states that crop fertilizers contain nitrogen, phosphorus, and potassium as major components. Magnesium, sulfate, and micronutrients may also be added. Fertilizers are designated by numbers. Farm manure corresponds to an approximately 0.5-0.24-0.5 fertilizer, showing the respective percentages of nitrogen expressed as N (0.5%), phosphorus as P_2O_5 (0.24%), and potassium as K_2O (0.5%). They can be washed out and enter the river system as runoff water.

The movement of particles in river are in different rates, as water being contact with banks and bottom moves more slowly than water in the middle stream. Point or non point sources along the river will influence the water quality, as turbulent mixing and diffusive transport of dissolved species and colloidal particles originate from those sources. Although stream has the capability to purify itself to be called as self purification system, once the pollutant rate exceeds the rate of purification, it is no longer able to purify itself, particularly in the extremely different condition, e.g. in the high discharge of water.

In the watershed system, floodplain plays significant role in purifiying stream water quality, that will determine the fate of contaminants carried in by flood event. As the consequence, floodplain will act like a sink in this case. The mechanism of this filtration is reflected by Shitaike pond that suffers from eutrophication. It could be the sacrifice of floodplain to maintain its service as filter to downstream area; while, in the same time preserve biodiversity in the ecosystem.

The floodplain life stage could be another important factor to be considered regarding this issue. As a newly restored floodplain, Azame-no-Se may reach any balance condition altering its composition of ecosystem in the future, particularly in the two distinct ponds. Therefore, the annual mean of research is important to be conducted to understand the mechanism of nutrient concentrations in the floodplain from the perspective of watershed nutrient cycle to develop any nutrient criteria for floodplain.

The filtration by floodplain will reduce adverse impact downstream. Li et al. (2003) described a great potential to use wetlands as final filter for nutrient enriched water and reduce the possibility of coastal water eutrophication. In the downstream, Matsuura River flows through Karatsu City, to flow to Sea of Genkai. Karatsu bay is a reclamated land, thus it is very vulnerable to any changing in the upper basin. And Azame-no-se helps in reducing any deleterious contaminants to coastal ecosystem.

Although controlling harmful runoff from watershed is a great challenge, it is indispensable to enlighten the burden of floodplain in maintaining the water quality downstream. These action can be implemented by various means of activities, such as to persuade agricultural interests to use less fertilizer to reduce the area of the dead zone. The application of this lighter fertilizer should reduce harm runoff from farming land. Furthermore, the development of policy by the collaboration of the associated stakeholders is of great importance to solve this nutrient enrichment problem.

4.5 Reflection in Indonesia

The reflections of this study to Indonesia rivers and wetlands condition can be observed mostly from the management and restoration issue. Japan provides an excellent model for integrated catchment management practices, not only because of its relatively small catchments that respond rapidly to management practices, but also because of the strong social linkages between upstream and downstream human communitites (Nakamura, Tockner, & Amano, 2006).

In the frame of sustainable development, the observation performed in Japanese rivers are in two concerns: protection to human health and conservation of living environment. Protection to human health regards to water utilization to watershed activities. It is widely known that Japan suffered from Minamata diseases due the water pollution of Mercury in Minamata Bay. Conservation of living environment is thus becoming one of Japan’s great concern, due to many endemic species that are in endangered status. This is due to the alteration of their natural habitat during fast economic growth in the era of 1960s.

Furthermore, Japan has clear management procedure in controlling river across several distinct authorized areas. The authority to control this kind of river is under the Ministry of Land, Infrastructure, Transport, and Tourism. Hence, policies implemented for associated rivers will be syncronized to the national policy applied.

Indonesia's 2004 Water Law provides the establishment of river basin management units *Balai Besar Wilayah Sungai* (BBWS) under the Ministry of Public Works. This institution has resposibility to manage rivers flow accross several authorized areas. Several BBWS for distinct rivers are collaborated in policy making, e.g BBWS Citarum, Cisadane-Ciliwung, and Cidurian-Ciujung-Cidanau Rivers has been designated as one planning unit under the policy guidance of a single Basin Council (Kementerian Pekerjaan Umum, n.d.).

However, there are many obstacles regarding the enforcement of policies to manage rivers in Indonesia under BBWS. For instance, the number of districts in one catchment area is large and their technical capacity to discharge their responsibilities effectively is very limited in many cases. Furthermore, "fragmentation" of decision-making can lead to inconsistencies in water policies from one area to the next; and a high degree of coordination is required at higher levels (Kementerian Pekerjaan Umum, n.d.). Therefore, the rapid improvement in rivers management to effectively overcome any problems in the entire catchments that currently increased in population and deforestation is important. Japan's valuable lesson learned regarding the issue of management of rivers and wetlands can be of major input as Indonesia's current condition is similar to Japan's in the past, though some climatology aspects are different .

Restoration in Japan is a daunting business because of the high human population density, urbanization, and harsh environmental condition More than 23,000 river restoration projects have been conducted during the last 15 years in this country (Nakamura, Tockner, & Amano, 2006).

Indonesia, like Japan, is an archipelago country, as the result it has long coastal line and is rich of wetlands. But due to the fast economic growth in its central island, Java, many deterioration of rivers and wetlands are not a brand new issue. For instance, the conversion of mangrove forest to other types of utilization, e.g. fishpond, has an adverse impact to most of coastal areas in Indonesia. As a consequences, abrasion occurs and threatens human in those areas. Moreover, continued watershed degradation combined with increasing water demands for agriculture, industry and drinking water are bound to create water scarcity problems in the coming years. Hydrologic flow regimes have been adversely changed by land degradation, notably the loss of adequate forest cover and the prevalence of hillside farming in the upper catchments.

Moreover, both Indonesia and Japan are vulnerable to flood disaster. However, Japan gave big efforts to overcome this disaster by linking restoration and risk management. It is a new philosophy in river management, namely to reduce flood risks by ecological restoration. Many European countries have been recently implemented this new philosophy adapted from Japan (Nakamura, Tockner, & Amano, 2006). The nature-oriented restoration has emerged as a worldwide phenomenon and is becomingly a highly profitable business (Nakamura, n.d.).

There have been many attempts to “re-green” parts of water basin in Indonesia, for instance Citarum Basin. Since 1976, seven attempts have been conducted, all these, including the recent Citarik Upland Plantation and Land Development Project, have failed in this regards (*Fakta Citarum,* n.d.). It is widely considered these failures are because projects have not sufficiently educated villagers about the importance of their role in such activities, have not empowered villagers and have tried to accomplish reforestation in short time frames. Implementation of watershed management activities as they relate to biodiversity conservation will largely take place at the level of groups of villages. The promoted action carried by government is a system of reward “payments for environmental services” (PES), purposed in encouraging upland villagers mitigate activities that are inimical to water, forests and protected area services.

In implementing the restoration adopted from Japanese rivers and wetlands, the distinct characteristics of rivers and wetlands should be considered The significant factor to the implemetation of restoration in Indonesia is in steady temperature due to the tropical climate. Moreover, the pollutant loadings, mostly uncontrolled in the urban areas, must be of major concern. Restoration can create the more livable aquatic environment. The orientation of restoration should be based on natural condition, e.g. keeping the meandering of the river, maintaining the original shape (dykes, oxbow, etc). By restoring the original meandering course, sedimentation in the lowland can be reduced (Nakamura et al., 2002).

In rural areas of Indonesia, there are still many pristine rivers and wetlands. Proper management is important to maintain this system in the terms of preserving biodiversity and protecting human life. Several initiative efforts have been promoted, like in the eastern part of Indonesia. The rehabilitation of coastal ecosystem by planting mangrove trees has been iniatiated in Sikka district, East Nusa Tenggara (Bachrudin, 2011).

In this chapter, the results of spatial and temporal variation of nutrients distribution was presented. There is no significant trend of spatial variation; nevertheless particulate matter tends to present in lower elevation. While, temporal variation perfoms a more obvious trend in which inundation time shows the highest concentrations compared to pre-flood and post-flood data., however the correlation between pre-flood and post-flood data can not be defined.

The discussions were elaborated for nutrient transport process taking place in the floodplain, exchange with sediments and the bioavalability status. Biological indicator was analyzed qualitatively in this study to show clausal relationship between nutrient enrichment and floodplain response. The nutrient cycle in the watershed was also discussed to identify the most possible sources of nutrients carried into floodplain by flood event. Moreover, the reflections of this study to Indonesia's rivers and wetlands condition emphasized in management and restoration issues was persented in the last part of this chapter.

CHAPTER 5
CONCLUSION

5.1 Conclusion

From the results and discussions in the former chapter, following are the conclusions of this study:

1. Samples were assembled from various sources, in which T.P 3.0 did not combine to flood event; T.P 4.0, T.P 5.0, and T.P 6.0 originated from one flood event; and T.P 7.0 was from the latest flood event.
2. The spatial variation indicated that site B contains the highest nutrients, dominated by particulate matter. It is due to the combination of nutrients transported by flood event and locally presented in floodplain. Site A, C, and D followed afterwards. The distance of site to input channel is positively correlated to the nutrient content in the water column. It is only applicable to elevations whose source from the same flood event, i.e. T.P. 4.0, T.P. 5.0, and T.P. 6.0, in which particulate matter tends to accumulate in the lower elevation.
3. Temporal variation indicates that the highest nutrient concentrations occur during flood event, carrying in a significant amount of dissolved matter. For most of the sites, post-flood shows a sharp decline from inundation, and pre-flood contains the least part of nutrients. It does not suit to the hypothesis stating that, after flood will comprise of more nutrient concentrations compared to before flood.
4. Most key parameters demonstrated appreciable decline during flood event, such as pH, turbidity, dissolved oxygen, and chlorophyll a. It is mainly due to the nutrient transport process altering the aquatic environment.
5. The behaviors of total nitrogen and total phosphorus are quite similar in its distribution, in which phosphorus appears in a lesser portion. Most nitrogen species are present in dissolved phase; whereas, phosphorus is present in particulate phase. It is as a consequence of their speciation in nature.
6. The excess of nutrient content showed by spatial and temporal variation is a signal of eutrophication in the floodplain. Furthermore, this issue is also

indicated by vegetation *Trapa japonica* in Shitaike pond, one of the largest pond in Azame-no-Se, that was fully covered its surface water in summer season.

7. Shitaike pond and Ueike pond are inhabited by remarkably different communities, vegetation *Trapa japonica* and mussel *Unio douglasiae*, respectively. Both can be used as biological indicator in Azame-no-Se floodplain. In this study, it is measured qualitatively to indicate any changing in the aquatic environment affecting the habitat for those communities.
8. Possible nutrient sources of flood event are adjacent agricultural runoff and local sources of the agitation of floodplain's bottom sediments.

5.2 Suggestion

Suggestions will be divided into suggestions related to the implementation in Indonesia and to the development for further research, particularly to the nutrient cycle research in Azame-no-Se that is curently conducted by doctoral student in Kyushu University.

1. Implementation in Indonesia

- Japan and Indonesia differ in the characteristic of rivers and wetlands influenced by climate, pollutant loading, hydrological regime, etc. However, both countries have similar policies to manage their water resources, i.e. river normalization in ancient time and restoration in modern way.
- Although Indonesia has BBWS (*Balai Besar Wilayah Sungai*) to manage rivers accross several authorized areas, the implementation of comprehensive management of rivers utilization, e.g. the pollutant control from watershed activity, is not proven yet. Therefore, the japanese management strategy can be adopted by considering necessary adjustments, as Indonesia currently suffers rapid deterioration due to human intervention in the entire catchments of the river basins.
- Direct measures should also be applied to prevent any further damages. One of this is by implementing the nature-based restoration for certain rivers and wetlands, in which Japan has thousands of experiences regarding this issue.

2. Future development:

- In the context of hydrological term, if the flood event can be categorized as flux, the development of mass balance analysis is possible. It will be very useful in creating a model of nutrient transfer process in the floodplain.
- Adressing the nutrient cycle in the floodplain, the nutrient concentrations of bottom sediments including the organic matter generated withtin the ecosystem is of great importance to be analyzed. It is related to the sediment-water nutrient exchanges and annualized nutrient budget of the floodplain. Furthermore, the more detailed speciation of nitrogen and phosphorus can be used to calculate the decay rate and bioavailability rate. It also can reveal the more detailed relationship between floodplain response and nutrient enrichment.
- The nutrient transfer from floodplain to river is also of major concern as it will affect water quality downstream. The nutrient transfered to stream may be present in different speciation compared to the reverse direction.
- To formulate an effective measures for nutrient enrichment in floodplain, the identification of all possible sources from the entire catchments contributing to the dynamic river-floodplain system is indispensable. Thus one of the functions of floodplain to support biodiversity can be maintained.

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APPENDIX A

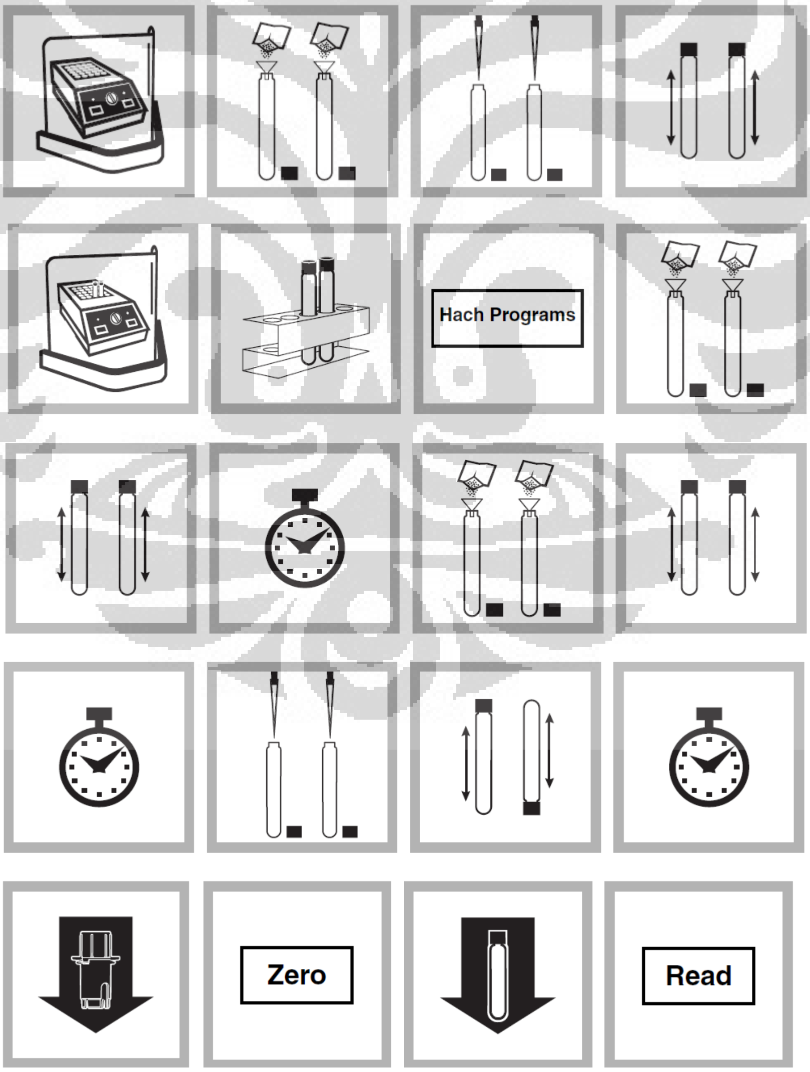
Nutrient Measurement Procedure

Total Nitrogen dan Dissolved Total Nitrogen

Following are the procedures for measuring TN and DTN based on 10071 Method DR/2400 Spectrophotometer procedure manual.

1. COD reactor is turned on and heated to 105^0C.
2. Two tubes of Total Nitrogen Hydroxide reagent vials is prepared and Total Nitrogen Persulfate reagent powder pillow is added into the vials. Reagent that may get on the lid or the tube threads is wiped off.
3. 2 mL of sample is added to a vial (this is the prepared sample), while 2 mL of the deionized water included in the kit to a second vial (this is the reagent blank). As a substitute for the deionized water provided, use only water that is free of all nitrogen-containing species.
4. Both vials are capped and shaked vigorously 30 seconds to mix. The persulfate reagent may not dissolve completely after shaking. This will not affect accuracy.
5. Vials are placed in the reactor and heated for exactly 30 minutes.
6. Using finger cots, hot vials are removed from the reactor and are cooled to room temperature.
7. In DR 2400 spectrophotometer, “hach” program buttom is pressed and “350 N Total TNT” program is selected.
8. Caps are removed from digested vials and the contents of one Total Nitrogen (TN) Reagent A powder pillow is added to each vials.
9. The tubes are capped and shaked for 15 seconds.
10. Timer icon is touched and a three-minute reaction period will begin.
11. After the timer beeps, caps are removed from the vials and TN Reagent B powder pillow is added to each vials.
12. Tubes are capped and shaked for 15 seconds. The reagent may not dissolved completely after shaking. This will not affect accuracy. The solution will begin to turn yellow.
13. Timer icon is touched and a two-minute reaction period will begin.

14. After the timer beeps, caps are removed from two TN Reagent C vials and 2 mL of digested, treated sample are added to one vial. 2 mL of digested reagent blank is added to the second TN Reagent C vial.
15. Vials are capped and inverted ten times to mix. Slow and deliberate inversion is used for complete recovery. The tubes will be warm.
16. Timer icon is touched and a five-minute reaction period will begin. The yellow color will intensify.
17. The 16-mm adapter is installed. Reagent blank is wiped and placed into the adapter.
18. “Zero” button is touched. The display will show 0.0 mg/L N.
19. Reagent vial is wiped and placed into the adapter.
20. “Read” button is touched. The result will appear in mg/L N.



Total nitrogen and dissolved total nitrogen measurement procedure using DR/2400 Spectrophotometer

Total Phosphorus dan Dissolved Total Phosphorus

Following is the procedure for measuring TP and DTP based on 8190 Method DR/2400 Spectrophotometer procedure manual.

1. COD reactor is turned on and heated to 150^0C.
2. In DR 2400 spectrophotometer, "hach" program buttom is touched and "536 P Total/ AH PV TNT" program is selected.
3. 5 mL sample is added to a Total and Acid Hydrolyzable Test Vial by using TenSette Pipet.
4. By using a funnel, the contents of one Potassium Persulfate Powder Pillow for Phosphonate is added to the vials.
5. Vial is capped tightly and shaked to dissolve.
6. Vial is placed into the COD Reactor.
7. Timer icon is touched and 30-minute heating period will begin.
8. When the timer beeps, hot vials are carefully removed from the reactor and are cooled to room temperature.
9. By using TenSette Pipet, 2 mL of 1.54 N Sodium Hydroxide Standard Solution is added to the vial. Vial is then capped and mixed.
10. The outside of the vial is wiped with a damp cloth followed by a dry one, to remove fingerprints or other marks.
11. The 16-mm adapter is installed. Vial is placed into the adapter.
12. "Zero" button is touched. The display will show 0.0 mg/L PO_4^{3-}.
13. Add the contents of one PhosVer 3 powder pillow to the vial.
14. Vial is capped tightly and shaked to mix for 10-15 seconds. The powder will not dissolved completely.
15. Timer icon is touched and a two-minute reaction period will begin. Sample can be read within 2 – 8 minutes after the timer beeps.
16. After the timer beeps, the outside of the vial is wiped with a damp cloth followed by a dry one, to remove fingerprints or other marks.
17. Prepared sample vial is placed into the adapter.
18. "Read" button is touched. The result will appear in mg/L PO_4^{3-}.

Total Phosphorus and Dissolved Total Phosphorus Measurement Procedure using DR/2400 Spectrophotometer

APPENDIX B

Spatial Variation Data

First Measurement

Site A (本川)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	2,45	1,8	1,7	0,44
TP 4.0	4,4	1,9	1,565	0,61
TP 5.0	2,3	2,1	1,155	0,73
TP 6.0	2,95	1,7	1,8	0,65
TP 7.0	2,25	1,35	1,345	0,655
Site B (流入口)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	2,9	2,05	1,315	0,535
TP 4.0	4,2	2	2,235	1,185
TP 5.0	3,8	2,35	1,995	0,975
TP 6.0	3,25	1,95	1,855	0,615
TP 7.0	2,05	1,35	1,145	0,585
Site C (下池)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	7,2	1,05	>	0,25
TP 4.0	2,75	1,2	2,435	0,735
TP 5.0	1,65	0,85	1,64	0,54
TP 6.0	1,7	1,2	1,105	0,59
TP 7.0	1	1,1	0,775	0,38
Site D (上池)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	1,175	0,75	1,015	0,19
TP 4.0	1,725	1,075	0,875	0,29
TP 5.0	2	1,4	0,67	0,17
TP 6.0	1,8	1,425	0,695	0,5

(continued)

Second Measurement

Site A (本川)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	2,15	2,3	1,39	0,555
TP 4.0	3,75	2,55	1,815	0,675
TP 5.0	2,8	2,7	1,31	0,82
TP 6.0	3	2,15	1,98	0,875
TP 7.0	3,65	1,9	1,635	0,635
Site B (流入口)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	3,4	2,85	1,495	0,81
TP 4.0	4,4	3,35	2,51	1,245
TP 5.0	6	3,3	2,28	1,095
TP 6.0	3,8	3,05	2,105	0,715
TP 7.0	1,5	2,1	1,455	0,705
Site C (下池)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	7,4	1,35	10,75	0,835
TP 4.0	2,45	1,5	2,29	0,855
TP 5.0	2,4	1,15	1,82	0,67
TP 6.0	1,5	1,35	1,41	0,635
TP 7.0	1,2	1	1,02	0,555
Site D (上池)				
Water Level	**TN**	**DTN**	**TP**	**DTP**
TP 3.0	1,2	1,4	1,49	0,76
TP 4.0	1,6	1,25	1,2	0,51
TP 5.0	1,4	1,6	0,98	0,56
TP 6.0	7,45	1,4	1,045	0,815

APPENDIX C

Temporal Variation Data

Parameters	Before Flood (June 10)	During Flood (June 11)	After flood (June 13)
TN			
Site A	0,95	2,975	1,2
Site B	2,3	3,525	1,1
Site C	2,3	1,6	1,1
Site D	1	1,625	1
DTN			
Site A	1	1,925	1,1
Site B	0,7	2,5	0,8
Site C	0,7	1,275	0,8
Site D	0,4	1,4125	0,7
TP			
Site A	0,56	1,89	0,51
Site B	1,85	1,98	0,75
Site C	1,85	1,2575	0,75
Site D	0,54	0,87	0,48
DTP			
Site A	0,325	0,7625	0,26
Site B	0,475	0,665	0,29
Site C	0,475	0,6125	0,29
Site D	0,22	0,6575	0,27