Graduate Program in Sustainability Science
Graduate School of Frontier Sciences
The University of Tokyo
2010-2011
Master's Thesis

Farmers and Wastewater Irrigation Governance

A Case Study of Integrated Urban Wastewater Management and Agriculture in Hanoi, Vietnam

Supervisor: Professor YAMAJI Eiji
Advisor: Associate Professor ONUKI Motoharu
Submitted in August, 2011

47- 096832 NGUYEN Huong Lan

"This page is intentionally left blank"

Approval

The thesis attached hereto entitled

"**Farmers and Wastewater Irrigation Governance: a *Case Study of Integrated Urban Wastewater Management and Agriculture in Hanoi, Vietnam***",

prepared and submitted by NGUYEN Huong Lan under the guidance of Professor YAMAJI Eiji at the International Studies Department of Graduate School of Frontier Sciences, University of Tokyo, in partial fulfilment of the requirement for the master's degree in Graduate Program in Sustainability Science is hereby accepted.

Principal Supervisor
Professor YAMAJI Eiji

Date: August 9th, 2011

Declaration

I, NGUYEN Huong Lan, hereby declare that the thesis attached hereto entitled

"**Farmers and Wastewater Irrigation Governance:** ***a Case Study of Integrated Urban Wastewater Management and Agriculture in Hanoi, Vietnam***",

is of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

NGUYEN Huong Lan

Date: August 9th, 2011

Acknowledgment

First and foremost, I would like to convey my sincere and deeply thank to my supervisor Professor Yamaji Eiji of International Studies Department for his grateful support to the completion of this thesis and my study in Master Program in Sustainability Science. For 2 years period, I have received continuous support in academic field as well as training to be stronger and independent. He has his very own way in giving guidance and led me to the end of my research successfully.

I would like to express my thank to my co-advisor, Associate Professor Onuki Motoharu of Graduate Program in Sustainability Science (GPSS) for his support and valuable comments as well as great contribution to my thesis. I would like to convey my thankful to his supportive role and assistance to overcome challenges that I faced during the completion of this thesis.

I also would like to convey my grateful thank to Dr. Anbumozhi Venkatachalam at Asian Development Bank Institute (ADBI); Japan, Associate Professor Tran Duc Ha, Associate Professor Nguyen Viet Anh, M.Sc. Nguyen Quoc Hoa, Dr. Tran Viet Nga, Mr. Tran Hoai Son, Ms.Ngoc and Mr.Son at Institute of Environmental Science and Engineering (IESE), Hanoi University of Civil Engineering; Mrs.Nam at Dong Ba Agriculture Cooperative and Mr.San at Thanh Liet Agriculture Cooperative for their assistance and supportive contribution when I was doing my field research in Hanoi.

I wish to convey my deeply thank to professors and staffs at GPSS and Asian Program for Incubation of Environmental Leaders (APEIL) for delivering valuable lectures and offering me opportunities to achieve advanced academic knowledge in the field of environmental and sustainability science. To name few, special thank to Professor Mino Takahashi, Professor Makoto Yokohari, Professor Yarime Masaru, Dr. Psyche Photanos, Dr. Akiyama Tomohiro, and Ms. Ojima Yumi. I would like to give my deeply acknowledgment to the Japanese Ministry of Education, Science, Technology, Sports and Culture (MEXT) for providing the financial support throughout I stay in Japan and to the University of Tokyo for the opportunity to study.

I am gratefully appreciating the enormous assistance of members in Ago-environmental Engineering Laboratory (AEE labo) directed by Professor Yamaji Eiji. I wish to convey my sincere thank to Ms. Inoue Kako, Dr. Jun Tsurui, Dr. Ishikawa Akemi, Mr. Yukio Wakimoto, Mr. Ikenoue Simon, Mr.Takahashi Ryo, and Ms. Ohashi Myuki for their supportive assistances on my research. I am thankful to Mr. Morio Sato and Mr. Azuma Junji for helping me with the field work. Special thanks to all seniors and friends of AEE laboratory members and GPSS for their kind help, friendship and valuable comments, suggestions to my research as well as inspiring my life in campus.

Next, I wish to deeply thank to the support of teachers, staffs and tutors from Kashiwa International Office (KIO), International Liaison Office (ILO), and Student Affair Office. Special thank is given to Ms. Matsuoka Mari, Dr. Watanabe Michiko for their support before and during my stay in Japan, for I could learn Japanese and get to know Japanese culture. I wish to convey my sincere thank to Ms. Noto Katsuko, my host family for her kindness and support to my life in Japan.

Last but not least, I wish to thank my family, my mother and father, my brother and my love for always being there for me, whenever I needed, and for sharing me every ups and downs, inspiring me and encourage me to go to the very end. I dedicate this work to you.

NGUYEN Huong Lan

Date: August 9th, 2011

Abstract

Owing to the improper management of wastewater in many cities in Vietnam, a large number of urban and peri-urban farmers are engaged in the practice of wastewater for irrigation and aquaculture. Especially in Hanoi, total area irrigated with wastewater is 43,778 ha and involved 658,300 farmers(L Raschid-Sally & Jayakody, 2008). Despite the amount of wastewater utilized by urban farmers are expected to increase due to the larger amount of wastewater generated from urban population, and the contribution of urban farmers to generate vast quantity of urban waste including solids and wastewater through agriculture practices (Brody Lee, 2010), these activities are very little recognized by municipal's management authorities (Do et al., 2006) nor looked down by the community. Therefore, wastewater unitization by urban farmers remains as informal, unplanned and spontaneous practices.

The purpose of this study was to investigate into farmers' managerial capacity wastewater irrigation. Individual aspect of farmers' wastewater irrigation management capacities are personal characteristics and skills (including drives and motivations, abilities and capabilities and biography). Farmers perform their tasks in the environment that is influenced by various factors. Boehlje and Eidman (1984) distinguish four major dimensions: (1) the institutional environment; (2) the social environment; (3) the physical environment; and (4) the economic environment .

By applying sustainability science and system dynamic approach, this research sought answers for following questions: (1) How farmers practice wastewater irrigation? (2)How they perceived of risks /benefits of wastewater irrigation? (3) Are they willing to adopt measurements to reduce risks while engaging in wastewater irrigation? (4) What are factors affecting farmers' managerial capacity toward wastewater irrigation management?

This research selected 2 communities: Thanh Liet, Dong Ba in peri-urban area of Hanoi according to its typical practices of wastewater irrigation in Vietnam. GIS device was used to map the study area, irrigation systems, water sampling points and cropping pattern. Quality of irrigation water was analyzed both on site and in laboratory by using simple test kits and portable water quality meter. General information of the communities and agriculture activities of the farmers were obtained from key informants. Combined informal interviews and participatory observation were applied for farmers either at the field when working or at their homes

Total 29 farmers were interviewed in both areas. The number of female participated were outnumbered men (18 female /11 male farmers). All farmers interviewed were literate with primary and upper education and most of them were involved in rice cultivation. Farmers in Thanh Liet were exposed more to wastewater than Dong Ba farmers in terms of exposure time and concentration of wastewater. Most farmer households have access to hygienic latrines with septic tank while fewer farmer households could access to tap water. Data from water sampling showed that many water quality parameters in both areas do not meet the standards, especially very high number of detected E.coli and Total Coli forms. However, when distributing into the plots, the quality of water is improved by flowing through long distance of channels and undergone natural treatment.

From preliminary assessment of water quality, it can be seen that wastewater irrigation has some potential to be reused for farmers in terms of nutrient recovery (Table 7) and income generation as well as bring s high risk for human health relating to pathogens (i.e., the risk of diarrheal disease associated with consuming salad crop irrigated with wastewater in Thanh Liet was $2x10^{-5}$. This is 2 times higher than WHO's tolerable risk of infection of 10^{-3} per person per year, but lower than the estimated incidents of diarrheal disease in Western Pacific region, i.e.,0.72 pppy (WHO, 2009)).

Farmers in Thanh Liet have more experiences in wastewater agriculture compare to farmers in Dong Ba. They have more knowledge about the contaminants and risk posed by wastewater, mainly by physical appearances and experience of diseases. Dong Ba farmers on the other hand are more concerned about invisible risks since they were informed by various channels such as the media or relatives or neighbors , but they insisted that the irrigation water in Dong Ba is from Red river, therefore it is clean.

Many farmers in Thanh Liet are observed to wear protective clothes especially gloves and boots to protect the skin from contacting with the wastewater. This practice is either seen on women or men. In contrast, very few farmers in Dong Ba answered that they wear gloves and many of them said it is not necessary and uncomfortable.

The quality of water seems to affect the crop pattern. Thanh Liet farmers shows more adaptation than Dong Ba farmers, they shift from rice to other aquatic vegetables

Regarding to willingness of farmers to adopt measures in 2 study areas, 59% farmers agreed that wearing protective cloth; 76% keep hygienic of food and drinks are effective to protect their physical health (Figure 53).

This research found that wastewater irrigation in Hanoi peri-urban agriculture and urban wastewater management were integrated system. Despite of being linked in urban wastewater and urban food chain, wastewater farmers behaved independent and self interested among peers and others which results in some short terms measures such as generate income from wastewater fed fish ponds, aquatic plants or non-food crops, reduce occupational health risks or keep cleanliness of food and drinks to improve health.

The study found out that the factors influenced farmer's capacities of wastewater irrigation governance are:

- Internal factors are: (1) age of farmers, (2) experience in wastewater irrigation, (3) knowledge and skill in wastewater irrigation, (4) motivation in wastewater agriculture.
- External factors are: (1) institutional environment includes regulation on wastewater use in agriculture, decentralised/centralised wastewater management, spatial separation on governance responsibilities of different department, state of participatory in local cooperatives; (2) physical environment such as climate change, diseases outbreak, constituent in wastewater; (3) social environment consists of social linkage and norms; (4) economic environment: consumer buying behaviour and income from wastewater agriculture.

Farmers' behaviour where more driven by economical and physical factors, while institutional and social factors appeared to discourage farmers to have high performance of farming.

This research proposes two mechanisms for strengthening farmers' managerial capacity on wastewater governance via wastewater irrigation, i.e. strengthening social participation and institutional involvement of farmers.

TABLE OF CONTENTS

List of figures

List of tables

List of Abbreviations/ Acronyms

DARD	Department of Agricultural and Rural Development
DEWATS	Decentralised Wastewater Treatment System
DNREL	Department of Natural Resources and Environment and Land
ECOSAN	Ecological Sanitation
FAO	Food and Agriculture Organization
MONDRE	Ministry of Natural Resources and Environment
PIM	Participatory Irrigation Management
QMRA	Quantitative microbial risk assessment
SADCO	Sanitation and Drainage Company
URENCO	Urban Environment Company
UWWM	Urban Wastewater Management
WEPA	Water Environment Partnership in Asia
WHO	World Health Organization
WWIA	Wastewater Irrigated Agriculture

Chapter 1

Introduction

1.1. Background

The use of wastes (including latrines waste, animal manure and wastewater) in agriculture and aquaculture has been long time widespread among Vietnamese farmer households. The integration of the homestead, garden, live- stock, and the fishpond is called the VAC[1] system or VACR[2] system. This integrated farming system is not only a traditional approach to ensure food security in the poor, rural regions of Viet Nam(FAO, 2000), (T. H. Le, 2003) but also has a benefit of generating and managing agriculture wastes effectively. In this system latrines waste and animal manure is used directly to fertilize gardens, fish pond and paddies. Pond water is used to irrigate gardens and pond mud is annually taken out and used as fertilizer. Although this system has proven to be effective and bring benefits to farmers (T. L. Le, 2001) as well as ensuring sustainable rural environment, it is still only a common practice on a household scale and mostly in rural areas(Trinh, 2001).

Urban and peri-urban farmers, on the other hand, mainly engaged in the practice of wastewater for irrigation and aquaculture. Especially in Hanoi, total area irrigated with wastewater is 43,778 ha and involved 658,300 farmers, whilst the corresponding numbers in Hochiminh are 75,906 ha and 135,000 farmers(L Raschid-Sally & Jayakody, 2008)

1.1.1. Problem statement and justification

Wastewater brings back benefits in terms of nutrition supplement for city through perishable food, improved livelihoods as well as the threats of public health mainly diarrheal, skin and worm diseases, and risks for environment degradation.

According to current studies, the amount of wastewater utilized by urban farmers are expected to increase due to the larger amount of wastewater generated from urban

[1] [2] refers to the Vietnamese words V for garden, A for ponds, C for cattle sheds and R for paddy fields

population (commonly untreated or very little treated before discharging into water bodies)(Quadir et al., 2010), and the contribution of urban farmers to generate vast quantity of urban waste including solids and wastewater through agriculture practices(Lee, Binns, & Dixon, 2010). However these activities are very little recognized by municipal's management [Do et al., 2006] authorities nor looked down by the community. Therefore, wastewater unitization by urban farmers remains as informal, unplanned and spontaneous practices.

Conventional approaches to sanitation and waste disposal see wastewater and faecal sludge as environmental and public-health problems; thus, management solutions comprise costly means of preparing them for unproductive disposal but do not see wastewater as a resource of nutrient that could be reuse as fertilizer source (Huibers F. et al, 2010). New concepts that integrated the reuse of wastes (wastewater) in to waste(water) management system such as DEWATS[3], ECOSAN[4] proven to have success. Several authors have already suggested studying the use of city waters in an integrated water management approach, both in the context of reuse wastewater, economic and social view of reuse and institutional aspect of the integrations (Bouwer, 1994; Haruvy, 1997; Pescod, 1992; van-Lier & Huibert, 2004). However, there is hardly a framework that attempts to integrate those concepts to optimize the management efficiency in the system.

There is a need for studying farmers managerial capacity in wastewater irrigation farming related to urban wastewater management because farmers are more likely to participate in irrigation management if they have more motivation in wastewater agriculture and they could account for wastewater irrigation as the provision of their livelihood.

1.1.2. Research objective

The purpose of this study was to investigate into farmers' managerial capacity wastewater irrigation. Individual aspect of farmers' wastewater irrigation management capacities are personal characteristics and skills (including drives and motivations, abilities and capabilities and biography). Farmers perform their tasks in the environment that is influenced by various factors. Boehlje and Eidman (1984) distinguish four major dimensions: (1) the institutional environment (e.g., regulations

[3] DEWATS: Decentralised Wastewater Treatment System
[4] ECOSAN: Ecological Sanitation

on water, land and air pollution); (2) the social environment (e.g., the family of the farmer); (3) the physical environment (including the weather and the state of the technology); and (4) the economic environment (which determines prices of inputs and products).

By applying sustainability science and system dynamic approach, this research sought answers for following questions:

(1) How farmers practice wastewater irrigation?
(2) How they perceived of risks /benefits of wastewater irrigation?
(3) Are they willing to adopt measurements to reduce risks while engaging in wastewater irrigation?
(4) What are factors affecting farmers' managerial capacity toward wastewater irrigation management?

1.2. Research outcome

The main goal of this research is to provide to the literature and planning authorities with the integrated approach to solve the existing problems of urban wastewater management in the developing countries from the point view of sustainability science. In addition, this study would like contribute possible solutions and recommendations to strengthen farmers' capacity to sustainable management of wastewater irrigation.

1.3. Overview the thesis

The remainder of this thesis is structured in to five chapters. Chapter two will highlights the theoretical frameworks, where some basic terminologies, concepts and reviewed literatures on key issues such as urban wastewater management, wastewater irrigated agriculture, and farmer's motivation and capacity to management wastewater agriculture are introduced. Chapter three provide information of the case study with an overview of the study areas. Chapter four highlights the methodology of the research which explains detail the process of collecting and analysing data from the field. Chapter five shows the result of analysis and discussion of the findings of the study. Chapter six gives the conclusion and ending with the provision of possible solutions and recommendations. Apart from main chapters, annexes were embedding to give detail information of questionnaire survey, research process and detailed GIS analysis of the wastewater quality.

"This page is intentionally left blank"

CHAPTER 2

THEORETICAL FRAMEWORK

2.1. Wastewater irrigated agriculture

2.1.1. Definitions of wastewater irrigated agriculture

The term of wastewater agriculture in this study refers to practice of farmers growing crops that irrigated with wastewater. This practice is widely seen in many cities of developing countries that urban wastewater become the irrigation source for farmers in urban and peri-urban areas (L Raschid-Sally & Jayakody, 2008)

The definition of wastewater used could have different quality from raw to diluted wastewater (L Raschid-Sally & Jayakody, 2008; WHO, 2006)

- Urban wastewater is usually a combination of one or more of the following:

  - Domestic effluent consisting of black water (excreta, urine and associated sludge) and grey water (kitchen and bathroom wastewater)
  - Water from commercial establishments and institutions, including hospitals
  - Industrial effluent where present
  - Storm water and other urban runoff
- Treated wastewater is wastewater that has been processed through a wastewater treatment plant and been subjected to one or more physical, chemical, and biological processes to reduce its pollution or health hazard.
- Reclaimed (waste)water or recycled water is treated wastewater that can officially be used under controlled conditions for beneficial purposes such as irrigation.
- Use of wastewater:

  - Direct use of untreated urban wastewater from a sewage outlet is when it is directly disposed of on land where it is used for cultivation.
  - Indirect use of untreated urban wastewater: when water from a river receiving urban wastewater is abstracted by farmers downstream of the urban center for agriculture. This happens when cities do not have any comprehensive sewage collection network and drainage systems are discharging collected wastewater into rivers
  - Direct use of treated wastewater: When wastewater has undergone treatment before it is used for agriculture or other irrigation or recycling purposes.

Multiple-barrier approach: Protection against contaminants occurs at each step along the water to food pathway, beginning at the wastewater source, continuing at the treatment facility and extending through the farm and market chain to the kitchen where the food is prepared and eventually served.

2.1.2. Current status of wastewater use in agriculture

In many cities in developing countries, wastewater practice in irrigation still remains as informal practice among urban and peri-urban farmers, which bring challenges for researchers and authorities to estimates the scale of this practice. However, recently different studies have attempted to gather from various sources to make a roughly estimation. For example: Raschid-Sally and Jayakody (2008) from the Global Assessment of Wastewater Irrigation in Developing Countries compiled from various sources reported that total number of farmers irrigating worldwide with treated, partially treated and untreated wastewater is estimated at 200 million; farming on at least 20 Mha of land; another data provided from Quadir et al (2010) stated worldwide more than 800 million farmers are engaged in urban agriculture. Of this group, about 200 million practice market-oriented farming on open spaces, often using poor-quality irrigation water when good-quality water is not available.

Table 1. Cities with largest extend of wastewater agriculture

Region	**City**	**Country**	**Population (mil.)**	**WW irrigated area (ha)**	**WW farmers**
LA	Mexico city	Mexico	21.3	83,060	73,632
AS	Ho Chi Minh	Vietnam	5.55	75,906	135,000
AS	Hanoi	Vietnam	3.09	43,778	658,300
LA	Santiago	Chile	5.39	36,500	7,300
AS	Ahmedabad	India	2.88	33,800	-

*LA: Latin America; AS: Asia

*Source: adapted from Raschid-S et al. (2008)

2.1.3. Risks and benefits of wastewater use in agriculture

The use of wastewater in irrigation has been viewed as pros and cons. Wastewater brings back benefits in terms of nutrition supplement for city through perishable food, improved livelihoods as well as the threats of public health mainly diarrheal, skin and worm diseases, and risks for environment degradation.

The primary risk while engaged in wastewater irrigation is health risk. Farmers and their families exposure to pathogens including helminth infections, and secondly, organic and inorganic trace element(Quadir, et al., 2010). Generally, for those in contact with wastewater have higher prevalence of diarrheal disease as well as skin, nail and worm infections(L Raschid-Sally & Jayakody, 2008). Epidemiological studies in different countries have established that the highest risk to human health of using wastewater in agriculture is helminth infections, bacterial and viral infection(WHO, 2006). Besides pathogens, chemical contamination also concerned health issues. A survey along the Musi River in India, revealed the transfer of metal ions from wastewater to cow's milk through Para grass fodder irrigated with wastewater. Milk samples were contaminated with different metal ions like Cd, Cr, Ni, Pb and Fe ranging from 12 to 40 times the permissible levels(Minhas & Samra, 2003). Leafy vegetables accumulate greater amounts of certain metals like cadmium than do non-leafy species. Generally, metal concentrations in plant tissue increase with metal concentrations in irrigation water, and concentrations in roots usually are higher than concentrations in leaves(Quadir, et al., 2010).

Other related concerns with wastewater use in irrigated agriculture are negative environmental risks. Depending on the characteristic of wastewater comes from domestic or industrial activities, wastewater can pose negative effect on crop (i.e. heavy nutrient load in domestic wastewater might affect the growth of plant resulting in low yield (L. Raschid-Sally, Tuan, & Abayawardana, 2004). The existence of inorganic or other metal trace elements in industrial wastewater also poses soil contamination; contaminate ground water, or remaining in crops.

2.1.4. Multi-barriers approach for health risks mitigation

Conventional approach was long believed to be the ultimate solution to reduce risks for wastewater irrigation. However, the effectiveness of conventional treatment systems in removing pathogens is of particular concern in many developing countries and also about some emerging organic chemical compounds, such as pesticides and their residues, pharmaceutically active compounds and endocrine disrupting substances (WHO, 2006)

Considering the apparent limitations of conventional approach that conventional wastewater treatment only focus to address environmental concerns and not human health risks, the WHO's third edition of guidelines recommended the application of multi-barriers approach for risk mitigation in wastewater irrigated agriculture. The approach consists of both conventional and non-conventional wastewater treatment method as well as health protection methods to meet health target for farmers and consumers, covers from wastewater generation to on-farm and off farm risk mitigation.

So far, the application of multi-barrier approach recommended by WHO has not been systematically studied, however for several limited studies have shown that this approach appeared to be feasible in the content of pathogen reduction (Table 2).

Table 2. Pathogen reductions achievable by selected health-protection measures

Scope	**Measures**	**Reduction** (log unit)	**Comments**
Conventional and Non-conventional treatment	Wastewater treatment (primary + secondary)	1-4	Reduction usually achieved by wastewater treatment depending on the type and functionality of the treatment system.
On-farm measures	Drip irrigation used for: Low-growing crops	2	Root crops and crops such as lettuce that grow just above, but partially in contact with the soil.
	High-growing crops	4	Crops, such as tomatoes, fruit trees, the harvested parts of which are not in contact with the soil.
Post harvest measures, off-farm measures	Pathogen die-off	0.5-2 per day	Die-off on crop surfaces that occurs between last irrigation and consumption. The log unit reduction achieved depends on climate (temperature, sunlight intensity, humidity), time, crop type, etc.
	Produce-washing with water	1	Washing salad crops, vegetables and fruit with clean water
	Produce disinfection	2-3	Washing salad crops, vegetables and fruit with a weak, often chlorine-based disinfectant solution and rinsing with clean water.
	Produce peeling	1-2	Fruits, cabbage, root crops.
	Produce cooking	6-7	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction

*Adapted and revised (Source: Robert Bos et al.,2010)

2.2. Urban wastewater management related to wastewater reuse in irrigation:

2.2.1. Definitions of urban wastewater management

Urban wastewater management is generally understood to be a combination of facilities and services that manage the wastewater generated within or around the urban boundaries to protect the public health and the environment.

Urban wastewater management consists of following components (Andersen, 2005; Karia & Christian, 2006; Tchobanoglous G. et al, 2003):

- On-site treatment that using latrine, septic tank or other compact treatment facility that treat wastewater at the household scale prior to discharge to the infiltration drains, street gutters, open canals, municipal drainage system

- Wastewater collection is the generally term for systematically collecting and removing the wastewater from the community. The wastewater could be mix with excreta, or slop water from domestic or industrial process, or urban runoff due to rain water or both in the conventional collection system; or only transportation of wastewater with or without mixing with storm water in the separate or semi-separated collection system. The discharging point of wastewater from the sewage system could be the wastewater treatment facilities or the environment.

- Wastewater treatment: means the partial reduction or complete removal of excessive impurities present in wastewater. The excessive impurities imply to the constituent(s) concentration(s) that is more than acceptable level(s) for disposal or suitable reuse of treated wastewater.

- Wastewater discharge/ disposal: refers to the ultimate return of used water to the environment. Disposal points distribute the used water either to aquatic bodies such as oceans, rivers, lakes, ponds, or lagoons or to land by absorption systems, groundwater recharge, and irrigation

- Wastewater reuse: refer to use of treated wastewater for a beneficial use, such as agricultural irrigation and industrial cooling

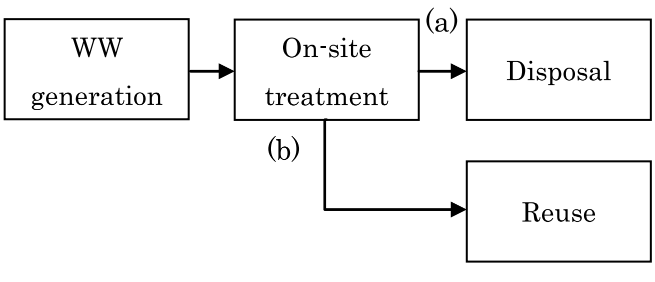


Figure 1. Decentralized Wastewater Management with (b) or without reuse (a)

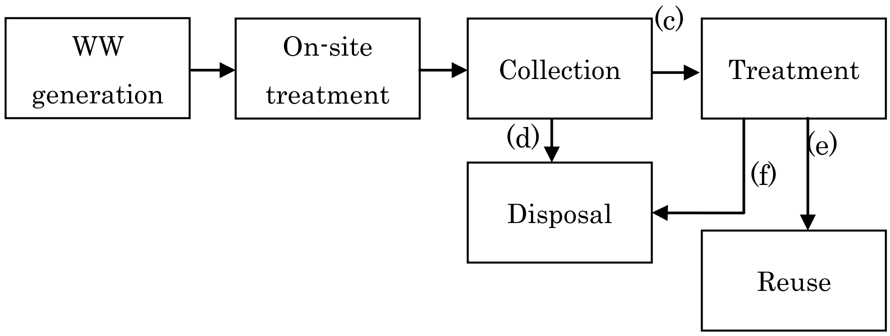


Figure 2. Centralized Wastewater Management
with treatment and reuse (c,e) or without treatment (d) or without reuse (f)

The management strategy could be divided as decentralized, where the wastewater is primarily treated or disposed of on-site or near the source (Figure 1) or centralized, where all the wastewater is collected and conveyed to a central location for treatment or disposal (Figure 2) or a combination of both strategies, called semi-centralized system.

2.2.2. Conventional and decentralised approach to wastewater governance:

Conventional approaches to sanitation and waste disposal see wastewater and faecal sludge as environmental and public-health problems; thus, management solutions comprise costly means of preparing them for unproductive disposal but do not see wastewater as a resource of nutrient that could be reuse as fertilizer source (Huibers F. et al, 2010)

In developing countries, population growth, urbanization and economic development result in ever increasing wastewater flows exceeding present capacities of management, treatment and proper handling. It was estimated by Ujang and Henze (2006) that 95 per cent of wastewater generated enters the environment with no proper treatment.

The combined research by the UN also concluded that the conventional model of collection, treatment and discharge of wastewater often fails due to high costs and low capacity to pay, problems associated with governance and overemphasis on technologically driven processes (UN-Habitat, 2006). Such technology-driven, centralized or decentralized systems aim at quality levels acceptable to protect the natural environment. This implies that developed-country standards are often applied in developing countries whether or not there exists the capacity, both financial and institutional, to manage systems to meet these standards.

Huibers F. (2010) hypothesized that conventional models of wastewater management do not work as they insufficiently take into account the downstream users of wastewater and do not appropriately value the social, economic and health implications of wastewater flows. For this reason, decentralized water services such as closed-loop, source separation and other ecological sanitation techniques may have a better chance of success, because they rely on principles of integration, prevention and resource recovery, rather than treatment and disposal. The decentralized wastewater management system could be more suitable to optimize the reuse of wastewater in agriculture and aquaculture in the peri-urban areas.

2.3. Integrated system of urban wastewater management and agriculture:

- *"Linear approaches to problems, in which resources are used and converted into wastes, only to be disposed of, represent a failure in human ingenuity and a flaw in technology design."* (Dr Steven A. Esrey, UNICEF)

Wastewater management is now taking the system approach that understands wastewater as the resource within the natural and human system rather than wastes, thinking about the relationship between wastewater management and the social and economic systems or structures that encompass the community (Gunn, Ferguson, & Dakers, 2003).

2.3.1. Definitions of sustainability and resilience

Sustainability and resilience

Sustainability has several meanings from dictionary, sustainability refers to sustain, endure or support. From UN definition, sustainability consists of three pillars environment, social and economic (World Summit, 2005). However, this is not universally accepted and has undergone various interpretations depending on particular circumstances.

Resilience is defined as the capacity of system to respond to change or disturbance without changing its basic state(Walker & Salt, 2006). Resilience demands new way to thinking about sustainability in a non-equilibrium view.

Sustainability science

Sustainability Science is a new academic discipline emerged in the 21st century and has developed a core research agenda with growing numbers of universities committed to teaching its methods and findings (Clark, 2007)

Among scholars and institutions participation in the field of Sustainability Science, IR3S[1] is one of the group of collaborating institutions that sought to clarify the concept of Sustainability Science. IR3S defined Sustainability Science as a discipline that points the way toward a sustainable society. In addition to addressing such problems as that of inter-generational equity, as emphasized in the concept of sustainable development (Komiyama & Takeuchi, 2006)

Sustainability science is an interdisciplinary field that shares principles, goals, knowledge and operating methods with sustainability and resilience theory. Sustainability science is problem-solving focused. It addresses the dynamic interactions between nature and society, considering both how social change influences the environment and how environmental change shapes society. Sustainability science aims to provide knowledge "co-produced" by scholars and practitioners to inform decision making for sustainable development(Clark & Dickson, 2003). Sustainability science also addresses the behaviour of complex self-organizing systems (e.g., cities) supporting social "actors" to engage sustainability and resilience challenges in the face of uncertainty and limited information (Kates, Clark, Robert Corell, Hall, & Jaeger, 2001).

2.3.2. Sustainability and resilience approach for urban wastewater governance:

New concepts that integrated the reuse of wastes (wastewater) in to waste(water) management system such as DEWATS[2], ECOSAN[3] proven to have success. Several authors have already suggested studying the use of city waters in an integrated water management approach, both in the context of reuse wastewater, economic and social view of reuse and institutional aspect of the integrations (Bouwer, 1994; Haruvy, 1997; Pescod, 1992; van-Lier & Huibert, 2004). However, there is hardly a framework that attempts to integrate those concepts to optimize the management efficiency in the system.

[1] IR3S: Integrated Research System on Sustainability Science - http://en.ir3s.u-tokyo.ac.jp/
[2] DEWATS: Decentralised Wastewater Treatment System
[3] ECOSAN: Ecological Sanitation

By applying resilience theory that views the urban wastewater system from a non-equilibrium perspective, the urban and peri-urban system could be referred to vulnerability, uncertainties and prone to unexpected change. This suggests building the wastewater system that could able to adapt to unprecedented and unexpected changes without changing its basic state based on five strategies:

- Multi-functionality could be archived through intertwining/ combining functions, stacking or time-shifting, involved in associated stakeholders: agriculture could be functioned as wastewater treatment , farmers could be involve as active stakeholder.
- Redundancy and modularization referring to strategies that avoid "putting all eggs in one basket", spreading the risks along the system, e.g. The function of wastewater treatment could be achieved with decentralised system instead of centralised infrastructure that vulnerable to failure
- (Bio and social) diversity: referring to resource recycle, nutrient recycle with the practice of agriculture and aquaculture
- Multi-scale networks and connectivity along the wastewater chain. Sewage system could be inter connected with open irrigation channels, fish ponds and agriculture fields
- Adaptive planning and design: multi-barrier risks mitigation strategies, adaptive to change and failure.

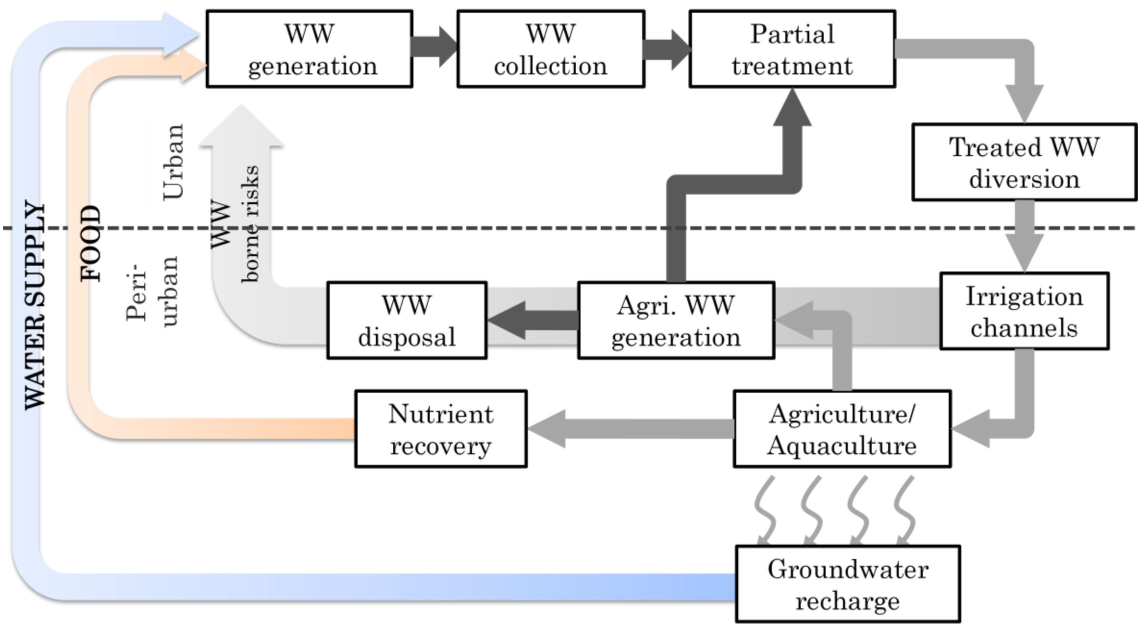


Figure 3. Integrated approach to urban wastewater governance and agriculture conceptual framework

2.4. Participatory wastewater irrigation management (PWIM)

2.4.1. Definitions of PIM and IMT

a. Participatory Irrigation Management (PIM)

From the World Bank (1996) definitions, PIM is defined as the involvement of irrigation users in all aspects and all levels of irrigation management

– "Involvement" is flexible, ranging from light involvement like information sharing, consultation, and joined assessment of problems to real involvement like shared decision-making, collaboration, and full say by the water users;

– "Users" refer to water users. The World Bank employs the word *userism* to express the essence of PIM, because it is management of the users, by the users and for the users. The concept of PIM is then also related to the concept of Water Users Associations (WUAs);

– "All aspects" include the initial planning and design of new irrigation projects or improvements, as well as the construction, supervision, and financing, decision rules, operation, maintenance, monitoring and evaluation of the system;

– "All levels" include tertiary, secondary, main system level as well as project and sector level.

b. Irrigation Management Transfer (IMT)

According to Vermillion and Sagardoy (1999) IMT is the relocation of responsibility and authority for irrigation management from government agencies to NGOs such as WUAs. It may include all or partial transfer of management functions. It may include full or only partial authority. It may be implemented at sub-system levels, such as distributary canal commands, or for entire irrigation systems or tubewell commands.

2.4.2. Framework for PWIM

PWIM could be defined as the integration of decentralised (a) or semi-centralised (b) urban wastewater management and PIM (Figure 4). This means that wastewater users could be involved in all aspects and all levels of the wastewater irrigation management. Or in another way, PWIM could be referred as transferring responsibility or authorities for wastewater management and wastewater irrigation management from the government agencies to wastewater users associations or private entities.

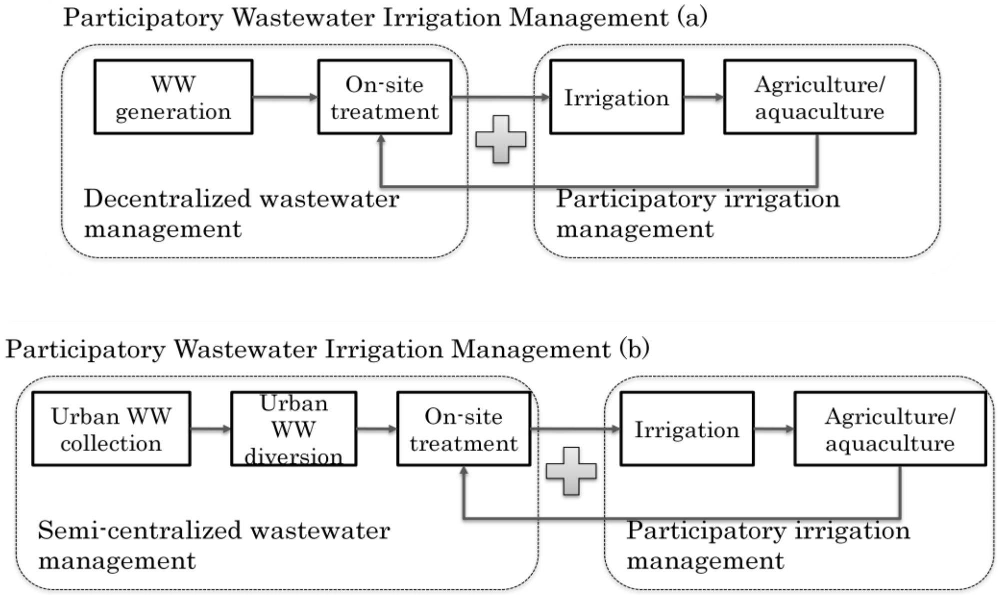


Figure 4. Conceptual framework for 2 types of PWIM (a,b)

The essential component of PWIM system is the integration of both wastewater management and irrigation management with the involvement of wastewater users. Wastewater users could be farmers or group of farmers that utilizing (un)treated wastewater for irrigation, wastewater user associations or private entities.

More specifically the involvement of farmers (wastewater users) in management of the system could improve the irrigation performance of wastewater in terms of water resources management and nutrient recovery optimization. And in return, PWIM could empower farmers' capability governing wastewater irrigation by allowing farmers to increase their responsibility and authorities in management process, i.e., including planning, design, operation, maintenance, rehabilitation, resource mobilization and conflict resolution.

2.5. Farmer's capacity to govern wastewater irrigation

2.5.1. Definitions of Capacity and motivation

From the definition from dictionary, capacity is referred to the ability or power to do or understand something, while motivation is defined as a reason or reasons for acting or behaving in a particular way (Oxford dictionary)

Within the concept of this research, management capacity is defined as having the appropriate personal characteristics and skills (including drives and motivations, abilities and capabilities and biography), to deal with the right problems and opportunities in the right moment and in the right way (Carin W. et al,1998)

2.5.2. Dynamics of farmer's management capacity

Capacity to govern wastewater irrigation by taking the systemic and non-equilibrium is a view of farmers' wastewater management practice in the environment which change over time, unpredictable due to uncertainties and risks. Individual aspect of farmers' wastewater irrigation management capacities are personal characteristics and skills (including drives and motivations, abilities and capabilities and biography). Farmers perform their tasks in the environment that is influenced by various factors. Boehlje and Eidman (1984) distinguish four major dimensions: (1) the institutional environment (e.g., regulations on water, land and air pollution); (2) the social environment (e.g., the family of the farmer); (3) the physical environment (including the weather and the state of the technology); and (4) the economic environment (which determines prices of inputs and products).

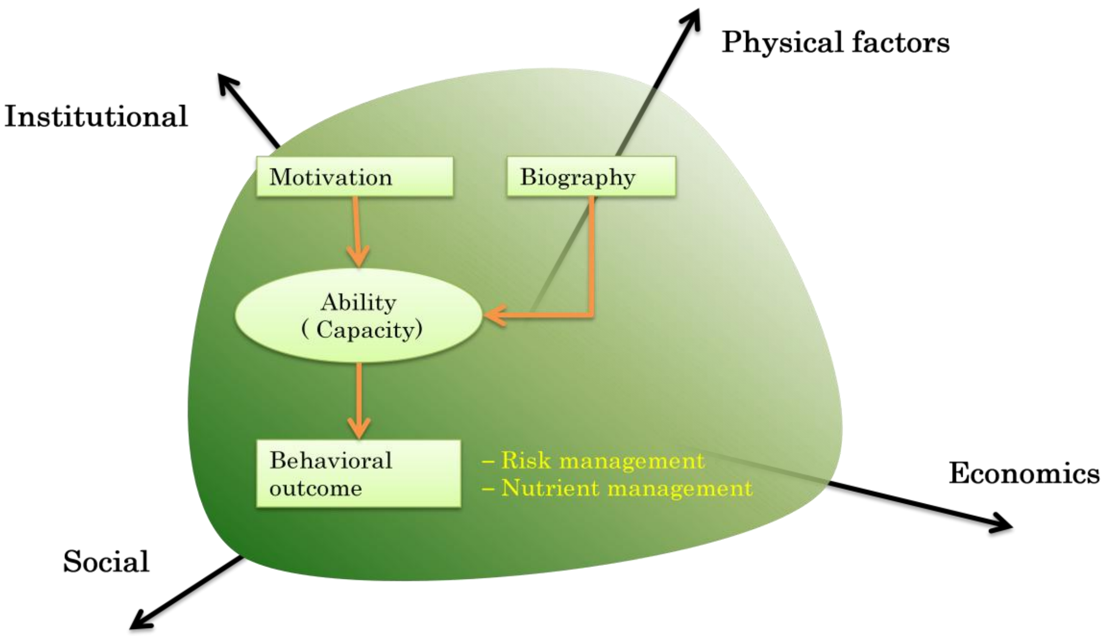


Figure 5. Farmer's management capacity related to exogenous factors

"This page is intentionally left blank"

CHAPTER 3

OVER VIEW OF THE STUDY AREA

3.1. The state of sewage and drainage management in Hanoi

3.1.1. Wastewater generation, collection, treatment and discharge

Hanoi, the capital of Vietnam, is the cultural and political centre of the Vietnamese nation. Hanoi, with a total area of 3,344.6 km^2 (of which urban area is 186.22 km^2) and a population of 6.5 million, average population density of 1955 persons per km^2 (HSO, 2010) is one of the 2 biggest city in Vietnam in term of population (following Hochiminh city).

This large number of people and high population density consequently produce a large volume of wastewater. It is estimated that Hanoi city discharges nearly 790,000 m^3/day of domestic wastewater, 37,000 m^3/day of wastewater coming from industry zones/parks located within Hanoi, exclude about more than 300,000 m^3/day of wastewater from industry establishments outside of industry zones/parks and services, 6,083.6 m^3/day of wastewater from hospitals, medical and private clinic centres(MONRE,2009).

The effluents drain to the south of Hanoi to settling ponds in the Thanh Tri district before eventually discharging to the Red River. Drainage and sewerage form a combined system that flows by gravity into lakes, ponds and rivers. In the urban areas, storm water and wastewater is discharged into rivers, regulating lakes and ponds through combined sewers and channels. There are big lakes and ponds, which are interconnected with the Kim Nguu and Set rivers. These water bodies help regulate drainage and wastewater flow, provide water for agriculture use and enable ground water recharge (Figure 6).

The ratio of sewer length per capita in Hanoi city is about 0.3 m/person. The ratio is still much less for small sewers in alleys and living areas (the tertiary network) where total length of sewers is 190 km, equal to 29% of 641 km of total length of the roads (with width > 2 m). Among those, only 72 km or 11% is under SADCO's enterprises whilst the rest of the network is under management of local authorities such as ward/commune Peoples Committees (SADCO, 2002).

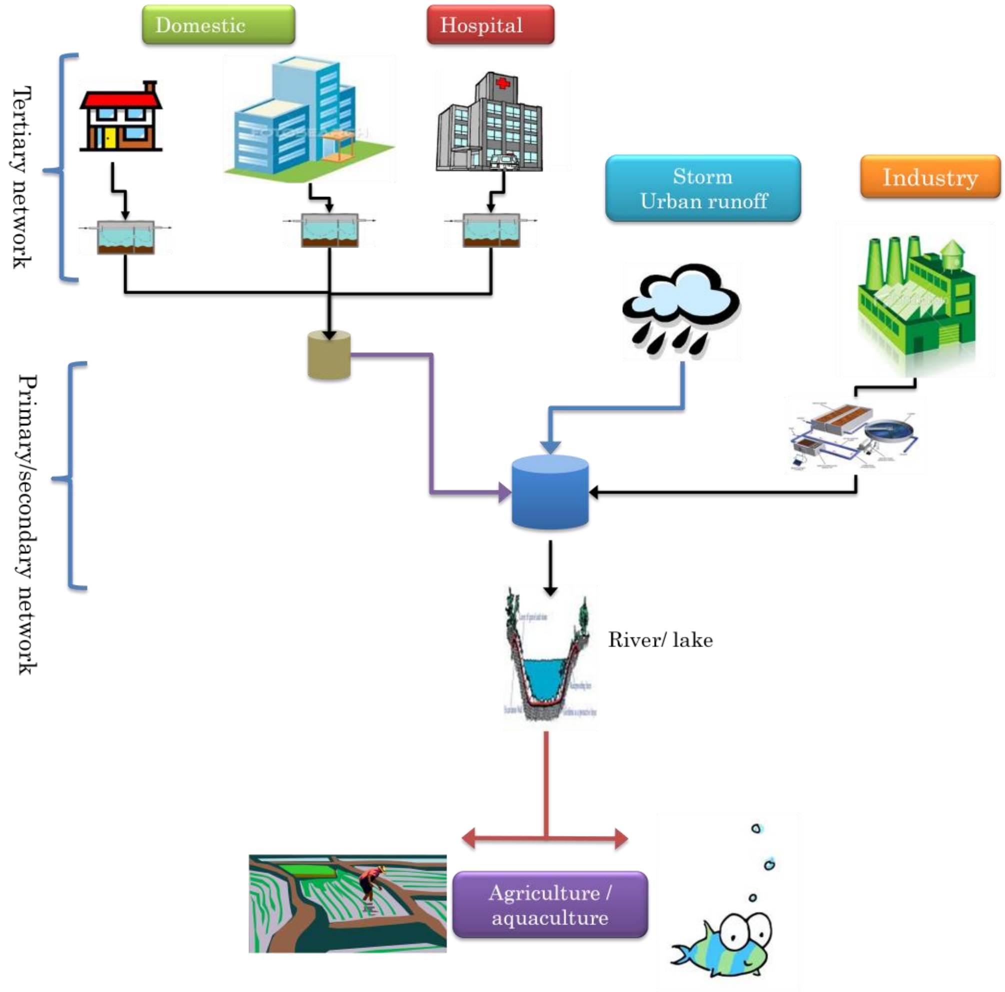


Figure 6. Sewage and drainage system in Hanoi

Inner parts of the city have an underground drainage network, while outer parts still rely entirely on open drains. Three types of systems for domestic wastewater disposal at the household level exist in Hanoi. On-site systems include double vault, bucket and hanging latrines. About 32% of Hanoi's population is served by septic tank, 21% by double vault latrines and 23% by on-site systems. The remaining 24% are not served by any system at all. Wastewater from toilets, where possible, passes through septic tanks before disposal into sewer. If these are properly maintained the water is treated before conveyance. Wastewater from kitchens and bathrooms is removed either by septic tank or disposed directly into the sewers(Viet Anh, Barreiro, & Parkinson, 2005)

3.1.2. Existing laws and regulations on wastewater management

The Vietnam Law on Environment Protection was implemented from January 10, 1994. The Government has also promulgated other laws and regulations concerning environment protection such as Forest Protection and Development Law (1991); the People Health Protection Law (1989); Land Use Law (1993); Law of Oil and Petrol (1993), Mineral Resources Law (1996), Water Resources Law (1998); Dykes Protection Ordinance (1989); Criminal Affair Law (reformed 1999); Ordinance of Resources Taxes (1989); Ordinance of Aquatic Resource Protection (1989), Ordinance of Radiation Safety and Control (1996); Ordinance of Vegetation Protection and Quarantine (1993), etc. Hundreds of legal documents to elaborately instruct the implementation of the above laws and ordinances have been issued by the Government and line ministries.

Regarding water quality management tools, Viet Nam has an extensive set of Water Quality Classifications and Standards: Class A is water resource for domestic use (subject to appropriate treatment), Class B – for other users. There are separate standards for agriculture and aquaculture purposes (Figure 7).

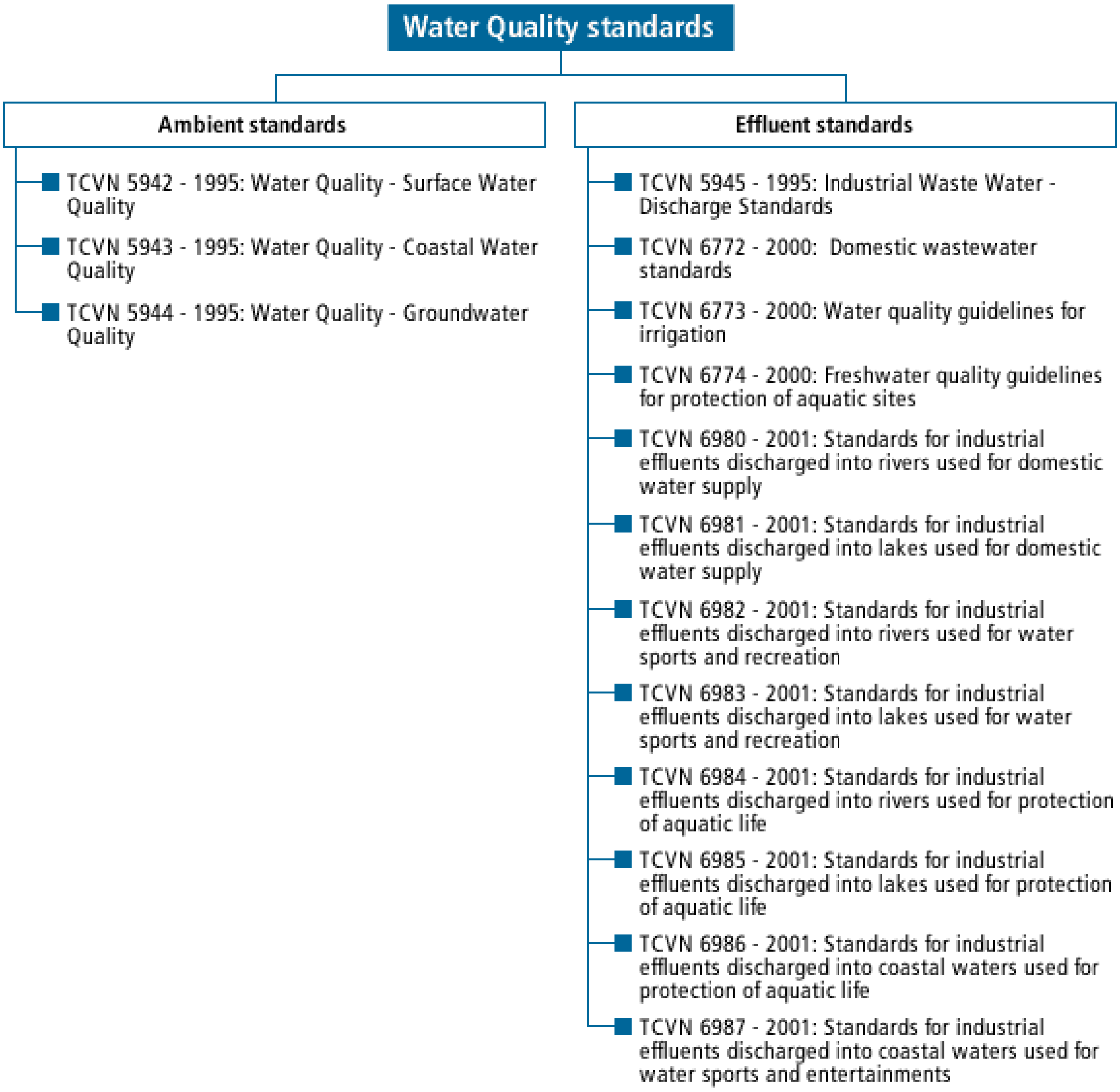


Figure 7. Vietnam water classification and standards

(Source: MONDREA and WEPA)

Despite the protection of water environment by laws, the requirements or effluent standards for industrial wastewater discharges are followed to a certain extent, especially for new, foreign and joint-venture industrial enterprises. The effluent standards set for domestic wastewater are only official, but wastewaters from residential areas are often not treated at all and discharged without control. Apart from effluent standards, there are limited appropriate policies and as well as limited effectiveness of existing legislative documents.

In addition, there were no regulations or standards relating to the reuse of wastewater, and lacking of microbiological standards especially Helminth eggs in discharged effluents except for total coliform and Fecal colifrom criteria.

3.1.3. Institutional aspect of urban wastewater management

The Hanoi Sewerage and Drainage Company (SADCO), a public utility under Hanoi PC, is responsible for treatment and disposal of both domestic and industrial wastewater. SADCO is responsible for the provision, operation and maintenance of the sewerage and drainage network in the core urban area of Hanoi. Hanoi SADCO manages the primary and secondary network (ditches channels, city's sewers and rivers, as well as other sewerage and drainage facilities). It is one of several public utility enterprises under the Department of Transport and Urban Public Works (DTUPW), which has overall responsibility for the management and implementation of capital development projects.

As stated in report by Evers J G. et al.(2006), there is a spatial separation on governance responsibilities of different departments in the so-called urban districts and the peri-urban districts of Hanoi municipality respectively. In addition, responsibilities concerning the different chain elements are divided among different departments. Consequently, SADCO had almost no responsibility on the reuse of wastewater by peri-urban farmers, and either does others public entities.

3.2. Wastewater use for agriculture in peri-urban area of Hanoi

3.2.1. Current status of wastewater irrigation

The use of wastes (including latrines waste, animal manure and wastewater) in agriculture and aquaculture has been long time widespread among Vietnamese farmer households. The integration of the homestead, garden, live- stock, and the fishpond is called the VAC system or VACR system. This integrated farming system is not only a traditional approach to ensure food security in the poor, rural regions of Viet Nam(FAO, 2000), (T. H. Le, 2003) but also has a benefit of generating and managing agriculture wastes effectively. In this system latrines waste and animal manure is used directly to fertilize gardens, fish pond and paddies. Pond water is used to irrigate gardens and pond mud is annually taken out and used as fertilizer. Although this system has proven to be effective and bring benefits to farmers (T. L. Le, 2001) as well as ensuring sustainable rural environment, it is still only a common practice on a household scale and mostly in rural areas(Trinh, 2001). Urban and peri-urban farmers, on the other hand, mainly engaged in the practice of wastewater for irrigation and aquaculture. Especially in Hanoi, total area irrigated with wastewater is 43,778 ha and involved 658,300 farmers, whilst the corresponding numbers in Hochiminh are 75,906 ha and 135,000 farmers (L Raschid-Sally & Jayakody, 2008). Despite the amount of wastewater utilized by urban farmers are expected to increase due to the larger amount of wastewater generated from urban population (commonly untreated or very little treated before discharging into water bodies)(Quadir, et al., 2010), and the contribution of urban farmers to generate vast quantity of urban waste including solids and wastewater through agriculture practices(Lee, et al., 2010), these activities are very little recognized by municipal's management (Do, et al., 2006), authorities nor looked down by the community. Therefore, wastewater unitization by urban farmers remains as informal, unplanned and spontaneous practices.

3.2.2. Risks and benefits of wastewater irrigation

The primary risk for reusing wastewater is health risk. Farmers and their families exposure to pathogens including helminth infections, and secondly, organic and inorganic trace element(Quadir, et al., 2010). Generally, for those in contact with wastewater have higher prevalence of diarrheal disease as well as skin, nail and worm infections(L Raschid-Sally & Jayakody, 2008). Epidemiological studies in different countries have established that the highest risk to human health of using wastewater in agriculture is helminth infections, bacterial and viral infection(WHO, 2006). However, several studies had been made to investigate into the link between health risks and the use of wastewater in Vietnam. Among reliable results is the follow up study done in Hanoi from year 2002 to 2004

- *The study conducted on 400 households in Yen So commune in the South of Hanoi involved 636 adults aged 15-70 years living in a wastewater irrigated area. The study found out the incidence rate of diarrhoeal diseases was 28.1 episodes per 100 per- son-years at risk and the incidence rate of skin ailments was 32.5 episodes per 100 person-years at risk. Results from nested case-control analysis revealed wastewater contact was the principal risk factor for diarrhoea in this population and act as the determinant of skin ailments.* (Do, et al., 2006)

Other related concerns with wastewater use in irrigated agriculture are negative environmental risks. In Vietnam, wastewater use arisen spontaneously and unplanned (often untreated or very little treated). Depending on the characteristic of wastewater comes from domestic or industrial activities, wastewater can pose negative effect on crop (i.e. heavy nutrient load in domestic wastewater might affect the growth of plant resulting in low yield (L. Raschid-Sally, et al., 2004)). The existence of inorganic or other metal trace elements in industrial wastewater also poses soil contamination (i.e. heavy metal pollution of agriculture soil in urban and peri-urban agriculture(Ho, 2001); contaminate other water bodies (i.e. water quality in drill wells in Thanh Tri district of Hanoi (Nguyen, Hoang, Nguyen, & Tran, 2001) , or remaining in crops.

Whilst the risks, benefit from wastewater reuses was also notable. According to Viet Anh (2004), the efficiency gained through the reuse of wastewater was the integration of fish farming and the rearing of domestic animals such as pigs, chickens and ducks. In the commune, the application of the garden-fish farming-livestock breeding model (the VAC model) is rather widespread, especially in those households with proximity to the fish ponds supplied with wastewater. Water from the ponds is often used for irrigation of the households' gardens as well as surrounding rice and vegetable fields. The rearing of pigs, chicken and ducks has contributed to the increase of fish productivity because of surplus feeds and manure used for aquaculture, at the same time, sub-standard fish could be supplemented as extra foods for the animals.

From the base line survey on wastewater reuse in aquaculture and agriculture in some peri-urban district of Hanoi in 2006, average productivity of fish from ponds in Yen So (a commune in Thanh Tri district) is estimated to be between 800 – 1000 tons per year. Aquaculture contributes 30% of total income of the community, while rice and vegetable cultivation brings in another 30%. A fishpond operator spends about US$9375 annually for land rent, labour cost, utility bills and taxes. A kilogram of fish sells for approximately US$1 but prices vary according to availability and quality. Thus, the profit from this investment is about 4-5 times the expense and income from fish sale is about US$37,500 - US$50,000. The reuse of wastewater increases production in farms and fishponds and most of wastewater-fed fishponds are highly productive. Vegetable sales generate an income of about US$500 - US$625 with a crop of 5 tons per hectare per year, although some vegetables are for “own consumption” and therefore are not accounted in this estimation. Hoang Mai district income from wastewater reuse amounted to US$6250 in six months of 2004.

Nevertheless, risks and wastewater demand for urban agriculture and aquaculture practice in Hanoi to regenerate nutrients and resource are vital for future development of urban wastewater management and peri-urban agriculture.

3.3. Study area description

3.3.1. Selection of study area

2 sites in peri-urban area of Hanoi were chosen according to its different practices of wastewater irrigation. In concurrence to framework of integrating urban wastewater management and irrigation management proposed in chapter 2, two different scenarios of participatory irrigation management is included:

- Scenario 1: *Thanh Liet Commune* (Figure 8) is about 9km to the southwest of Hanoi and located along the 2 major drainage rivers of metropolitan areas of the city (Tolich River to the east and Nhue River to the southwest). Domestic and industrial effluent from urban areas of Hanoi is diverted to the field through pumping stations along the Tolich River.

- Scenario 2: Dong Ba Hamlet (Figure 9) is located about 15km northwest from the centre of Hanoi. In dry season due to water shortage, 24ha of agricultural area is irrigated with diluted wastewater which is the mixture of rainwater and wastewater generated by the hamlets' daily activities.

3.3.2. Socio-Economic status of study area

Thanh Liet commune belongs to Thanh Tri district and Dong Ba village belongs to Thuong Cat commune, Tu Liem district. These 2 districts share border with central urban area of Hanoi and categorized as sub-urban area of Hanoi.

Thanh Liet commune has the area of 4 km^2 and average population is 12,000 people. Average annual income was US$600 per person per year (2010). Although land price in Thanh Liet has increase due to the urbanization process of Hanoi city, large amount of agriculture and aquaculture still remaining and contribute sufficient income for local farmers.

Thuong Cat commune has total area of 3.8 km^2 and average population is 8,300 people. Average income was US$1000 per person per year (2010). Dong Ba villagers' main income source are from non-agriculture sector especially logging and construction.

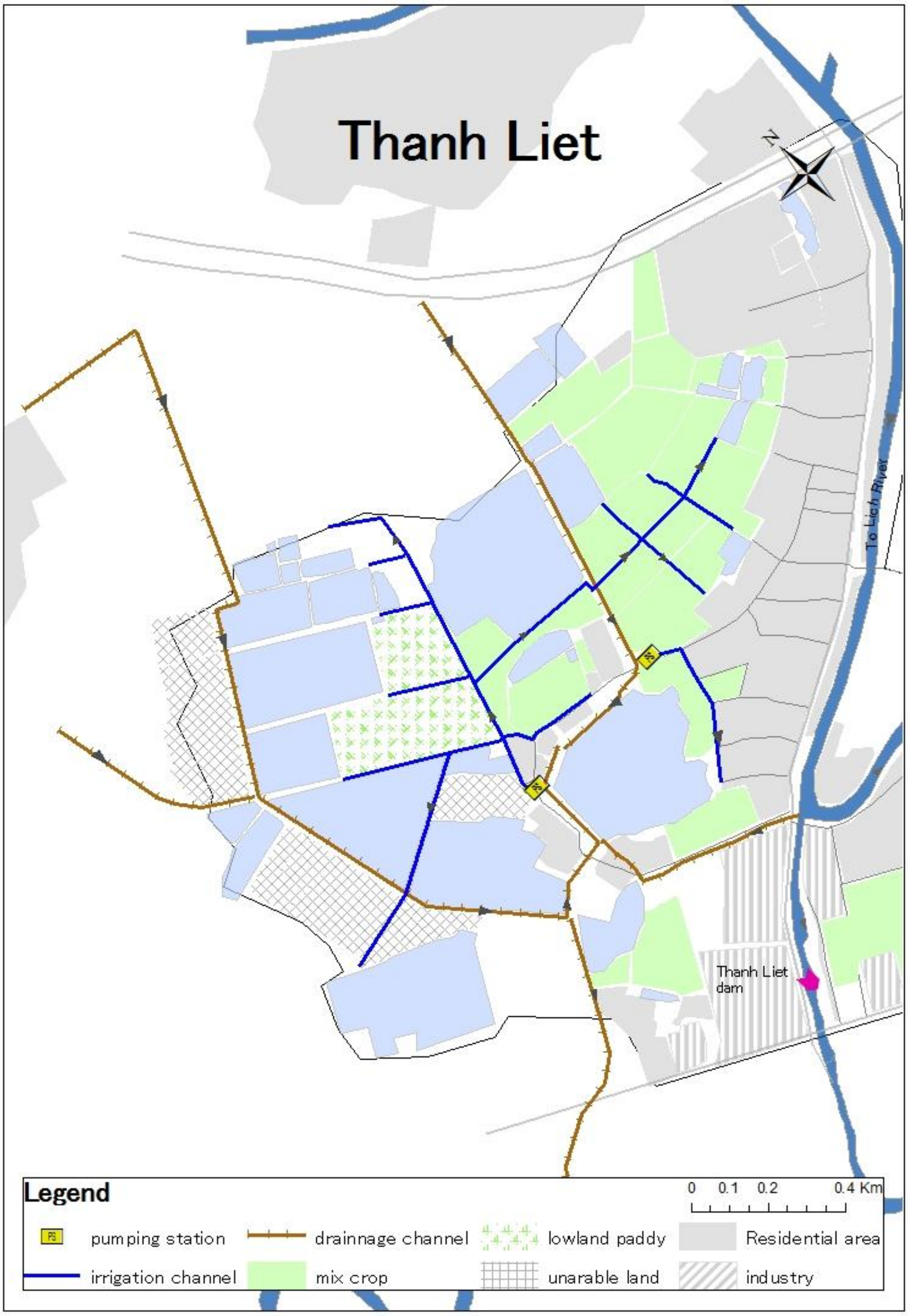


Figure 8. Map of Thanh Liet

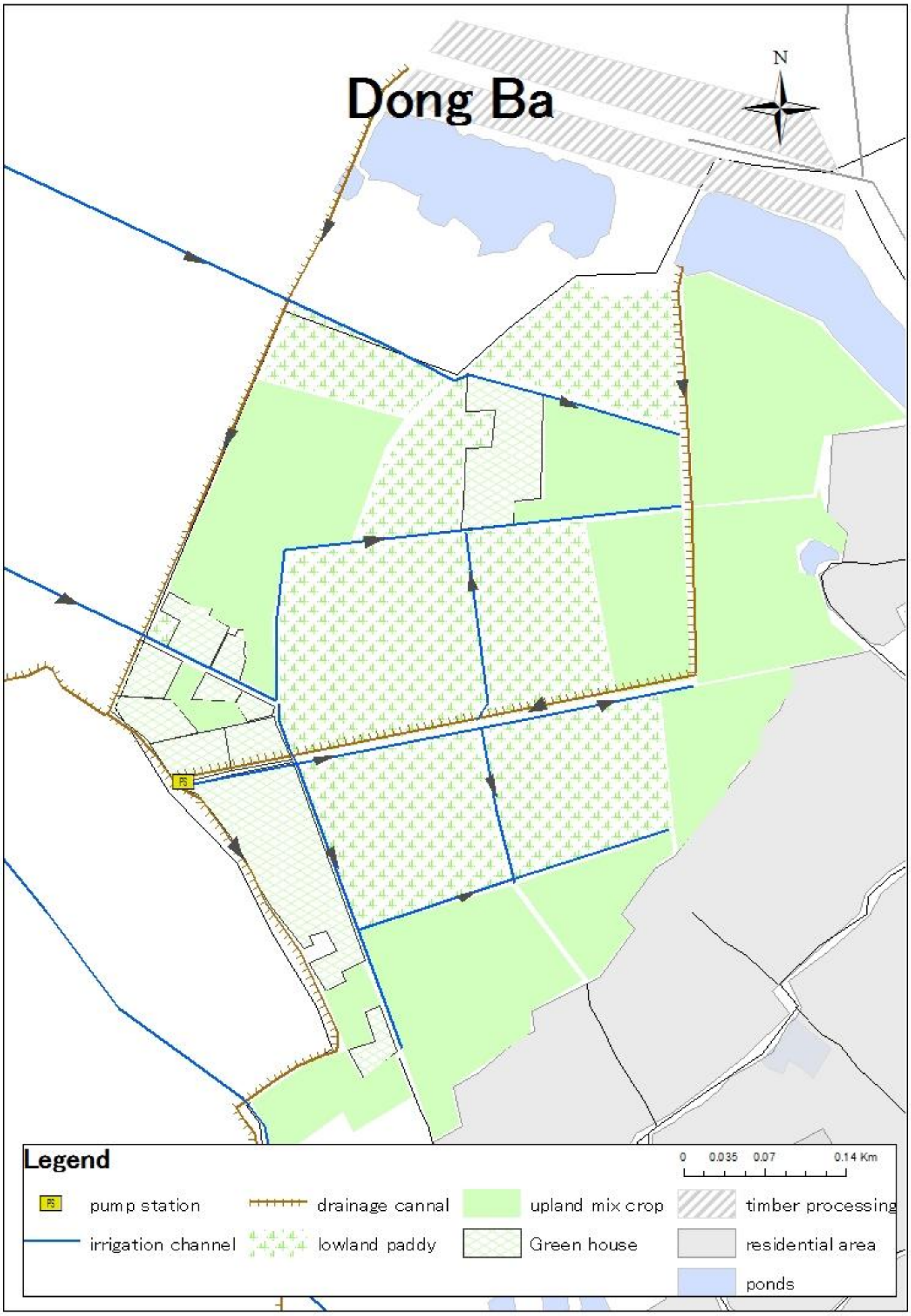


Figure 9. Map of Dong Ba

3.3.3. Some agricultural characteristics study area

Thanh Liet Agriculture service cooperative has total of 194.51 ha of agriculture land which involved 201 FHHs. There was 105ha of agriculture land were used for cultivating rice, however due to contamination of wastewater, those rice paddy was converted to integrated rice paddy, aquatic plant and fish pond. Fish and aquatic plant cultivation generate main income for farmers in Thanh Liet.

Dong Ba Agriculture service cooperative has smaller agriculture land 27.26 ha but employed 524 FHHs compared with Thanh Liet. The dominant crop is rice with yield of 5.15 ton/ha. Farmers in Dong Ba only produce rice for their family consumption. Compare to Thanh Liet, agriculture production in Dong Ba do not have much economical value.

Table 3. Agriculture status in the study area

		Thanh Liet	Dong Ba
Agriculture land	ha	194.51	27.26
- Rice Paddy	ha	105.00	14.26
- Vegetable	ha	89.51	1.00
- Flower	ha	-	9.00
- Horticulture	ha	-	3.00
Fish	ha	85.00	-
Rice yield	ton/ha	4.66	5.15

*Source: Interview result

Relating to agriculture land use right, agriculture land is categorized as 2 main groups:

- *Group 1: Land distributed based on quotas for local farmers. The agriculture land in the village is assigned by state; each household is leased about 0.5 sao/person agriculture production land[1].*

- *Group 2: Leased land, mostly for farmers immigrated from other villages. They are leased the land by the local farmers or cooperatives in agreement of the rental fee. This fee is different according to the purpose of production land:*

    - *For aquaculture production (in Thanh Liet) the unused agriculture land is gathered and placed on the bid to transfer to fish ponds by the cooperative.*

[1] Land Law 2003, chapter 2, section 3, article 33

Normally the fishermen pay to the cooperative 100kg rough rice/sao/year. In some cases, fishermen directly make contract with the farmers in agreement of the rental fee, and then farmers have to pay to the cooperative 15kg rough rice/sao/year for agricultural services. The aquaculture area replacing paddy field is increasing since more fishermen are attracted to this area

- *For flower production (in Dong Ba), normally these immigrant farmers directly make contract with the local farmers. The price for rent is about 500,000 vnd (equivalent to 100kg rough rice/sao/year) but the price can be varies depend on the location of plot and irrigation/drainage advantages. The local farmers then pay for the cooperative 30kg rough rice/sao/year for agricultural services.*

3.3.4. Existing irrigation, drainage and sewage system and wastewater irrigation practice in the study area

In Thanh Liet, irrigation water is mainly from the 2 main sources To Lich River and Ba Xa drainage canals while in Dong Ba, water comes from Red river and drainage canals. The water is distributed to each plot through irrigation systems or exploited by individual farmers.

Schedule of distributing water is managed by the cooperatives, normally 2 or 3 times per week, or by the state if the water is taken from Red River through Dan Phuong water gate (about 1.5 km away to Dong Ba), or on demand for farmers who exploit their own water (mostly fishermen and flower growing farmers).

Since the water comes from Dan Phuong water gate is not reliable sources, water comes from the drainage canals is therefore the main source of irrigation in Dong Ba.

The water sources for agriculture in the studied areas are considered as wastewater according to following characteristics:

- Tolich river is one of the biggest wastewater canal in Hanoi (Figure 10 and Figure 11)
- Other drainage canals received wastewater from nearby areas (Figure 12)
- There are no wastewater treatment facilities to treat the wastewater before distributing to the fields.
- In Dong Ba, wastewater is diluted with water comes from Red river through Dan Hoai water gates (Figure 15) and ponds. According to the cooperatives, the amount of water from drainage canals and ponds is about 30% of total irrigation.

Figure 10. Part of Tolich river

Figure 11. Thanh Liet water gate

Figure 12. Drainage canal in Thanh Liet

Figure 13. Irrigation water from Pump station in Thanh Liet

Figure 14. Drainage canal in Dong Ba

Figure 15. Irrigation channel from Dan Hoai water gate

(Photos taken in March, 2011)

Sewage and drainage systems in Thanh Liet and Dong Ba were not served by SADCO but were provided by the local irrigation, drainage and sewerage sector under the Commune's PCs. Wastewater discharged from the communes' everyday activities were collected through combined covered sewage ditch. These ditches transport wastewater to open drains or nearby ponds, water area in the commune without having any treatment of effluent. Some ditched connected directly to irrigation channel or drain channel in the agriculture areas.

Figure 16. Open drains in Thanh Liet

Figure 17. Sewage ditches in Dong Ba

(Photos taken in March, 2011)

CHAPTER 4

METHODOLOGY

4.1. Research method and choice of Case study design

4.1.1. Research method

This research employs case study method which according to the author is suitable to address the research questions of "how" and "why" when a researcher wants to investigate situations that require no control over behavioural events, and when the research focus is on contemporary events within a real-life context. Specifically, the author aim to investigate into "how" and "why" farmers perceive, behave toward wastewater irrigation management and their participatory into urban wastewater management through reuse of urban wastewater for irrigation purposes.

4.1.1. Case study design

This case study method involves both qualitative and quantitative approach. Quantitative approach is to support qualitative findings over exploring and refining theory type of case study. Case study methods that explore and refine theory were selected because the author wanted to explore whether certain aspects or variables of theory are consistent with empirical data and phenomena and ascertain whether the theory needs to be refined.

While much case study research focuses on a single case, often chosen because of its unique characteristics, the multiple-case studies design allows the researcher to explore the phenomena under study through the use of a replication strategy. Yin (2009) compares the use of the replication strategy to conducting a number of separate experiments on related topics. Replication is carried out in two stages-a literal replication stage, in which cases are selected (as far as possible) to obtain similar results, and a theoretical replication stage, in which cases are selected to explore and confirm or disprove the patterns identified in the initial cases. According to this model, if all or most of the cases provide similar results, there can be substantial support for the development of a preliminary theory that describes the phenomena (Eisenhardt, 1989).

According to Yin (2009), a multiple embed case study approach would illustrate the theoretical framework when a particular phenomenon is likely to be found by supporting similar results or contrasting results for predictable reasons when it is not likely to be found. More generally, theoretical framework is the vehicle for generalizing to new cases; if empirical cases do not work as predicted, modifications must be made to the theory.

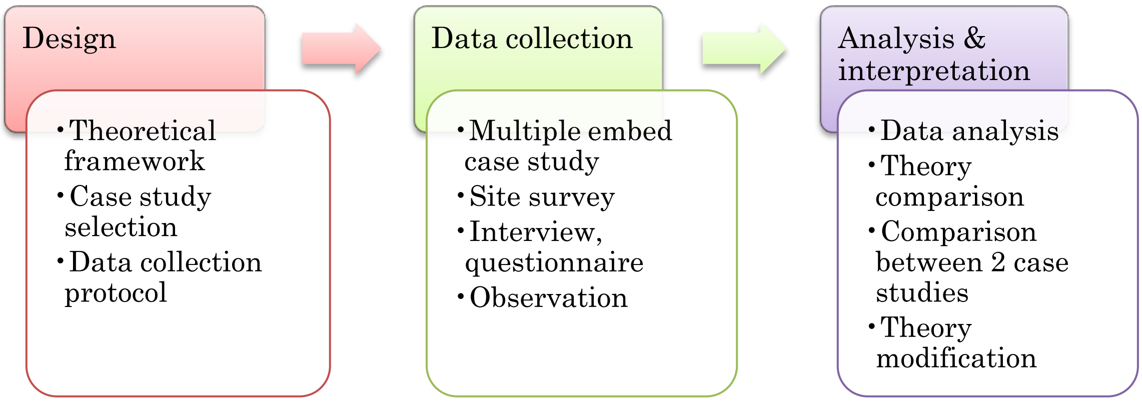


Figure 18. Diagram of multiple embed case study method adapted for this research

The multiple embed case study method adapted consists of 3 main phases (Figure 18):

- Design phase: Theoretical framework was developed based on literature review. Then the result of literature reviewing was used to set criteria for selection of case study and designing of data collection protocol.

- Data collection phase consist of information gathering though site survey, interview and questionnaire to the key informants and FHHs, observation of farming practices.

- Analysis and interpretation phase was carried out with the review of literature in comparison with the case study results. Modifications and refining of the previous studies was then developed.

4.2. Site survey

The purpose of the site survey is to provide with sufficient information of the study area, including geographical characteristics, land use, irrigation water types, irrigation water quality, infrastructure features, etc. Since the case study was carried out at a local communal level, information regarding wastewater irrigation practice was difficult to obtain and there was almost no related database. Two research assistant were employed to assist the work including mapping site and taking water sample.

4.2.1. Mapping area:

Firstly, satellite images were downloaded from Google Earth application for free of use at good resolutions (highest resolution could be 15m per pixels) and images could be downloaded at different time line. The drawbacks of these images were the unknown acquisition data, cloud cover, and the image might not be up to date.

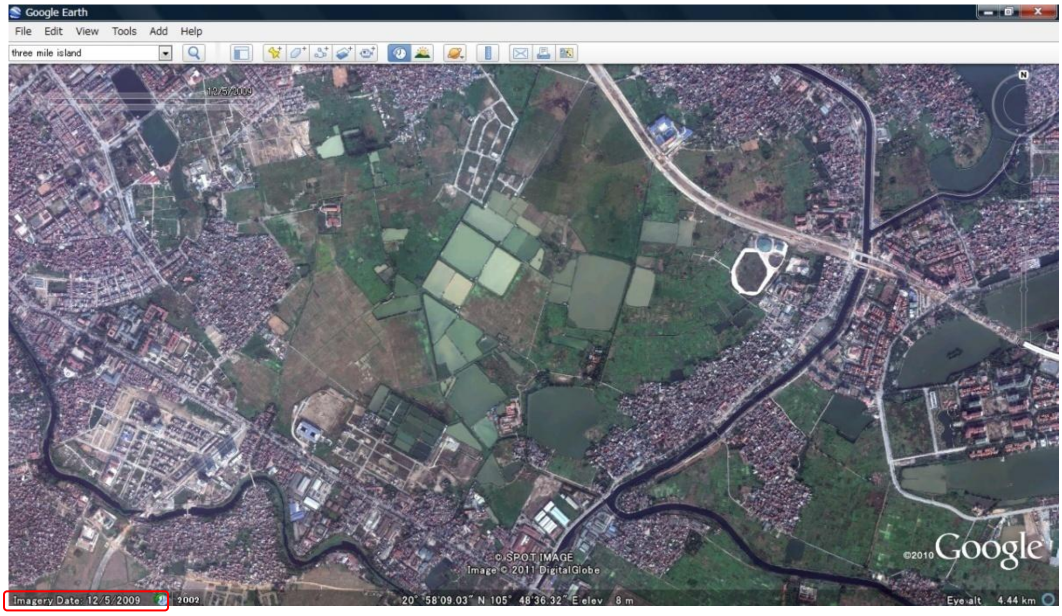


Figure 19. Screen image of Thanh Liet area downloaded using Google Earth – the date of the image is 5/12/2009

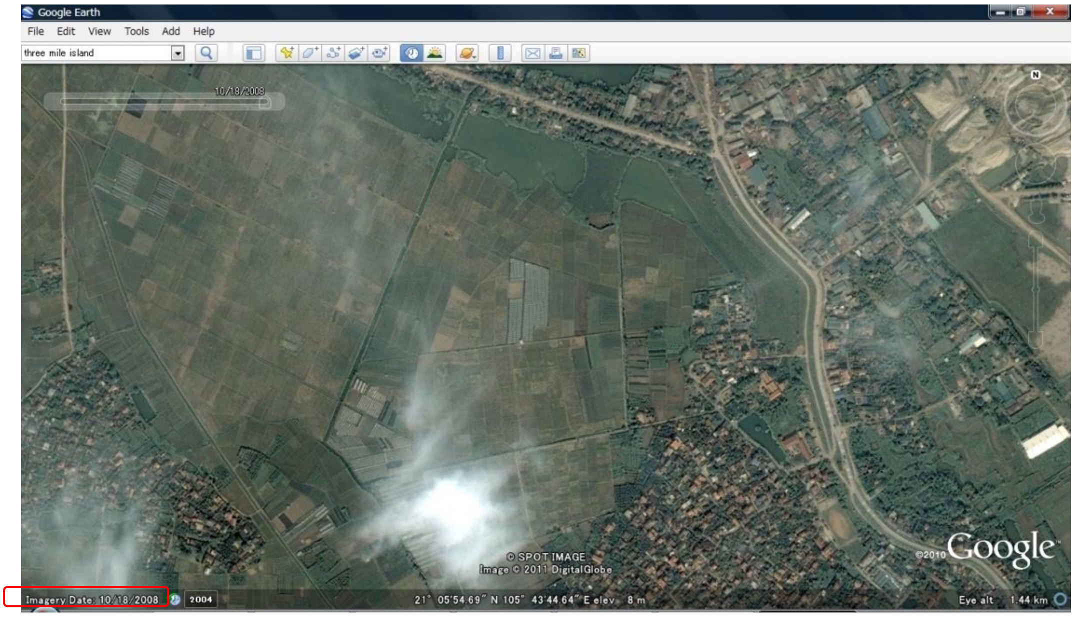


Figure 20. Screen image of Dong Ba area downloaded from Google Earth – the date of the image is 18/10/2008

In addition to the aerial photos, GPS mapping on field were carried out in the field in March 2011 with the assistant of the key informants. This activity is especially important to get up-to-date data for features that are subjected to change (for example: vegetation coverage, cropping area, land uses, etc…)

Garmin GPSMAP® 62s device were employed to navigate locations and note down important way points. Those data were carefully recorded and imported to personal computer using BaseCamp software version 3.1.3[1]

Figure 21. Garmin GPSMAP® 62s (Source: manufacturer's website)

Figure 22. Marking location of irrigation pump outlet using Garmin device (Photo taken in March, 2011)

[1] BaseCamp software version 3.1.3 is the software that helps to view and manage data from Garmin devices could be downloaded free from Garmin homepage

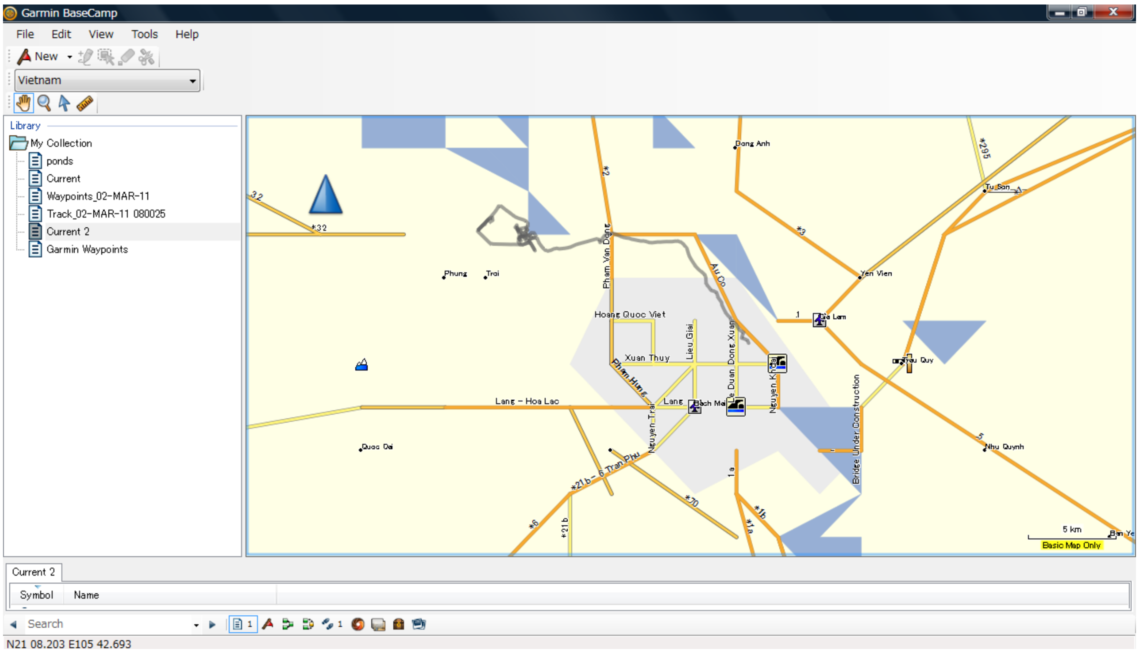


Figure 23. Screen image of BaseCamp software version 3.1.3

4.2.2. Water sampling

Irrigation and drainage water sampling were collected in the end of dry season in March, 2011. The water sample is representing quality of water in dry season therefore the timing of water sample to make sure that the irrigation water were not diluted with storm water.

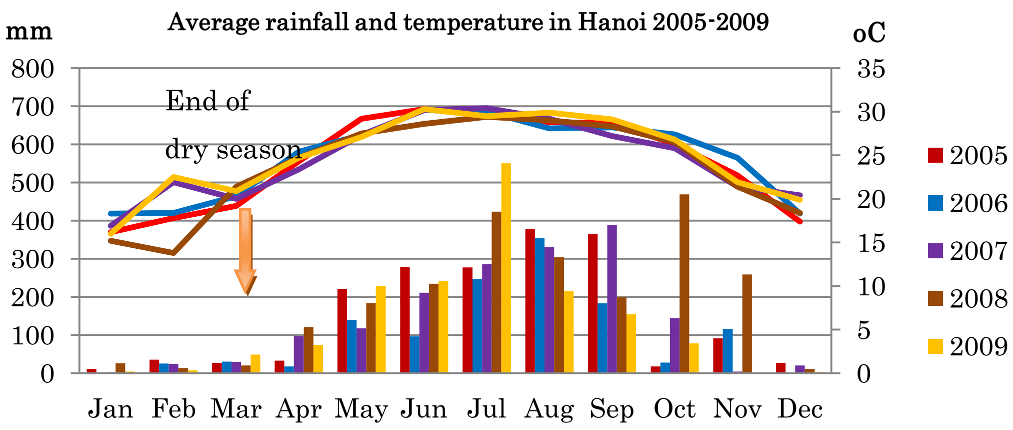


Figure 24. Average rainfall and temperature in Hanoi 2005-2009
(Source: Hanoi statistical yearbook 2010)

Grab sampling method were employed at random points of water streams (at ponds, along irrigation channels). Grab sample was collected by using hand held plastic container for water in channels or shallow water surfaces and sampling bucket and rope for water in ponds or at location has difficulties accessing to water bodies(Figure 25).

Figure 25. Taking sample with Sampling bucket and rope
(Photo taken in March, 2011)

Water sample is then stored in the clean Polyethylene terephthalate (PET) bottle 0.5ml and transport to laboratory to analysis in same day.

Figure 26. Water sample after transported to laboratory
(Photo taken in March, 2011)

4.3. Interview and questionnaire

4.3.1. Key informant interview

Head of Thanh Liet and Dong Ba farmer's cooperatives were selected to be key informants. Interviews were conducted with the men from irrigation section of both cooperatives, head of the villages (Figure 27 and Figure 28). General information of the communities and agriculture activities of the farmers were also obtained and the key informants facilitated to contact directly with farmers.

Figure 27. Thanh Liet cooperative office

Figure 28. Dong Ba cooperative office

(Photo taken in March, 2011)

4.3.2. Semi structured questionnaire

Accidental sampling was employed to select the respondents in the targeted population. Depending on the voluntary of farmers to be involved and willingness to answer openly to the researcher's questions, thirteen and sixteen individual interview reports in Thanh Liet and Dong Ba respectively were chosen to be analyzed. Farmers are either interviewed at the field when working (Figure 30) or at their homes (Figure 29). Interview is also combined with various methods such as participatory observation, informal interview. The questions were asked in different ways and different situations to make farmers feel comfortable and not to be ashamed of their wastewater practice.

The topics of these interviews included: how they managed to practice wastewater irrigation; protective measures while contacting with wastewater and hazardous substances (pesticides); perception on risks posed by wastewater irrigation; willingness to adopt measurements to reduce those risks and other additional topics related with the use of pesticides, fertilizer. This method is useful to understand how farmers perceives, their behavior and actions they could take to get control over the risks of wastewater practice.

Figure 29. Interview at Mr. Hao's house **Figure 30.** Interview Mrs. Chi on field

(Photos taken in March, 2011)

4.4. Data analysis

4.4.1. Water sampling analysis

On field water quality parameters where measures using portable measurement and water test kits. Ecoli and Total coliform parameters were examined in laboratory (Table 4). Analysed result were recorded and saved as Excel and GIS Database.

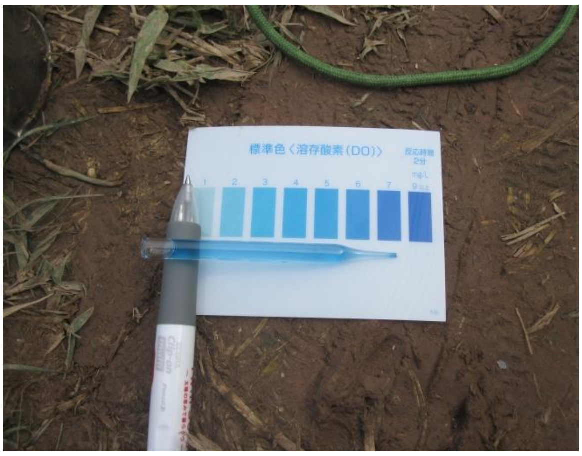


Figure 31. Measuring DO on field **Figure 32.** Analysis in laboratory

(Photos taken in March, 2011)

Table 4. Water quality parameters and testing instruments

No	Parameter	Testing instrument	Manufacturer
1.	Temperature (^oC)	HI 98130 Combo pH/EC/ TDS/Temperature Tester with High Range EC	Hanna Instruments - USA
2.	pH		
3.	Conductivity(mS/cm)		
4.	TDS(ppt) (mg/l)		
5.	Ammonia NH_4^+(mg/l)	WAK-NH4	Kyoritsu Chemical-Check lab.,corp. - Japan
6.	Nitrate NO_3^- (mg/l)	WAK-NO3	
7.	Phosphate PO_4^{3-}(mg/l)	WAK-PO4	
	Phosphate PO_4^{3-} (C) (mg/l)	WAK-PO4(C)	
8	DO(mg/l)	AZ-DO-30	
9.	COD(mg/l)	WAK-COD	
	COD(mg/l)	WAK-COD(H)	
10.	Cu(mg/l)	WAK-Cu	
11.	Zn (mg/l)	WAK-Zn	
12.	Pb(mg/l)	SPK-Pb	
13.	Fe total (mg/l)	Sibata type Fe	Sibata Scientific Technology Ltd. - Japan
14.	E.coli(MPN/index 100ml)	Suncoli X type	Sun Chemical Co.,Ltd.-Japan
15.	Total Coliform count (MPN/index 100ml)	Suncoli coliform detected paper	

4.4.2. ArcGIS analysis

GIS application was employed to bring together information collected. In particular, the spatial orientation of the information collected was very useful in the visualisation and understanding the major trends in wastewater agriculture, distribution of irrigation types, and its implications for livelihoods.

The GIS software used in this study was ArcGIS desktop version 9.3 by ESRI. Authorised licence was given to student of University of Tokyo by Centre for Spatial Information Science (CSIS)

4.4.3. Interview/questionnaire analysis

Excel software was used analyse the data collected on respondents. Information of respondents was saved as excel database categorised into: socio-economic, behaviour outcome, perceptions and motivations characteristics.

4.5. Limitations and challenges

Regarding assessment on wastewater irrigation quality, the method for analysing water parameters by employing water quality test kits was not appropriate since the results used for scientific papers are required to be carried out in certified laboratory. However, with the constituents of time, labour and for the fact that data on water quality are used as supporting data of the research, result of test kits analysis is therefore acceptable.

Accidental sampling employed in farmers' interview and questionnaires, hesitation of farmers when talked about wastewater irrigation would lead to biased of results and therefore generalization on the entire population could not be made. Thus, quantitative data collected aimed to support qualitative assessment which focusing more on explanation in detail of how and why respondents perceived and behaved toward wastewater irrigation.

The result would have been more reinforced if more stakeholders have been included, especially buyers and authorities and their attitudes toward wastewater irrigation.

Nevertheless, the author had made efforts to overcome those challenges to make analysis and conclude over the collected data.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1. Environmental and socio-demographic characteristics

5.1.1. Quality of irrigation water

Many water quality parameters in both areas do not meet the National technical regulation on surface water quality - QCVN 08: 2008/BTNMT nor National Standard -Water quality guidelines for irrigation - TCVN 6773:2000, especially very high value of detected E.coli and Total Coli forms (Table 5).

Lack of regulations relating to wastewater reuse in Vietnam made difficulties to evaluate the quality of irrigation water in the study areas. Both QCVN and TCVN are applied for general irrigation water only; therefore many of the required parameters are stricter.

For further reference, the author compared irrigation water quality according to Tchobanoglous, et al.(2003). From Table 6, it can be said that although some parameters in wastewater quality does not meet Vietnam standard regarding the degree of restriction on use for irrigation, the water could be accepted for irrigation practice. In addition, the quality of wastewater seems to be improved when distributing into the plots, by flowing through long distance of channels and undergone natural treatment (Figure 34, see more in Annex 2). However, there is no official treatment, the concentration of pollutants remaining high especially the number of detected coliform.

Figure 33. Eichhornia crassipes cultivated in along the drainage canals
(Photo taken in March, 2011)

Table 5. Irrigation water quality in the study area at different points in March 2011

Parameter	QCVN	TCVN	Dong Ba		Thanh Liet			
Sample ID			DI31	DD9	TD22	TD24	TD31	TD32
pH	5.5~9	5.5~8.5	8.56	7.52	7.37	7.42	7.46	7.46
Conductivity (mS/cm)			0.27	0.32	0.67	0.65	0.89	0.99
Dissolved oxygen (mg/l)	≥4		>9	6	4	<1	<1	<1
Total Dissolved Solid (mg/l)		≤1000(1)	130	150	345	342	460	500
Chemical oxygen demand (mg/l) – $KMNO_4$ method	≤30		5	20	20	45	120	120
Chemical oxygen demand (mg/l) – $K_2Cr_2O_7$ method	-		-	-	-	71.2	-	102.4
Ammonia Nitrogen(mg/l)	≤0.5		1	5	>10	>10	>10	>10
Nitrate-Nitrogen (mg/l)	≤10		2	2	2.2	0.1	0	0
Phosphate –Phosphorus (mg/l)	≤0.3			0.2	1.5	1.1	2	2
Total Iron Fe^{3+}+Fe^{2+} (mg/l)	≤1.5		<0.3	<0.3	0.4	0.8	0.5	0.5
Copper Cu(mg/l)	≤0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc Zn (mg/l)	≤1.5	≤1(2) ≤5(3)	0.2	0	0.5	0.5	0.5	0.2
Lead Pb (mg/l)	≤0.05	≤0.1	-	-	0.2	0.5	0.5	0.5
E.coli (MPN/100ml)	≤100	200(4)	200	-	233	1400	-	-
Total coli forms (MPN/100ml)	≤7500		$38x10^4$	-	$26x10^4$	$23x10^5$	-	-

Note: DI31: sample taken at the inlet of Dan Phuong water gate.
- DD9: sample taken at the drainage canal to the pump station in Dong Ba
- TD24: sample taken at the Tolich river
- TD22, TD31, TD32: samples taken at the Ba Xa drainage canals

- (1) applied for agriculture land with irrigation system
- (2) applied for agriculture soil with pH≤6.5
- (3) applied for agriculture soil with pH>6.5
- (4) applied for restricted crops (vegetables and crops that eaten raw)

(See Annex 2-8, Figure 15; 16)

Figure 34. Chemical Oxygen demand ($KMnO_4$) level variation of water sample along channels

Table 6. Evaluation for the suitability of irrigation water in study area

Parameter	Recom ended	Dong Ba		Thanh Liet			
Sample ID		DI31	DD9	TD22	TD24	TD31	TD32
Conductivity (dS/m)		N	N	N	N	S-M	S-M
Total Dissolved Solid (mg/l)		N	N	N	N	S-M	S-M
Total Iron (mg/l)	<5.0	<0.3	<0.3	0.4	0.8	0.5	0.5
Copper Cu(mg/l)	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc Zn (mg/l)	<2.0	0.2	0	0.5	0.5	0.5	0.2
Lead Pb (mg/l)	<5.0	-	-	0.2	0.5	0.5	0.5

Note: N= no problem, S-M= slight to moderate problem

Data on nutrient constituents are roughly counted from
Table 5. The N and P concentrations are based on an average of 50 millimetres of water (500 kilolitres/ hectare) applied per week over 32 weeks /year

Table 7. Nutrient concentration in irrigated water

Nutrient application rate	Nitrogen ($N\text{-}NH_4 + N\text{-}NO_3$)		Phosphorus (PO_4 –P)	
	mg/l	(kg/ha/year)	mg/l	(kg/ha/year)
Thanh Liet	>12	>192	2	32
Dong Ba	3-7	48-112	0.2	3.2

In comparison to recommended fertilizer use of farmers who plants 2 season of rice per year in the study area, i.e., 200-240 kgN/ha/year and 100-120 kgP/ha/season with normal irrigation water, the result shows that farmer in Thanh Liet should add half of the required Nitrate fertilizer. With the average market price of Nitrate fertilizer of VND 8000/kg, theoretical saying that reduce of fertilizer use in farming would give significant economical benefits to farmers in Thanh Liet by reducing cost of chemical fertilizer about VND 1.5 mil/ha/year.

However, nutrient level measured in the field increased due to use of fertilizer, the nutrient were more than 20mgN/l – 320kgN/ha/year and 5mgP/l – 80kgP/ha/year (Thanh Liet), which might cause high risks to crops and environment due to over load of nutrient.

Pathogen contamination is also taken into account. Maximum E.coli counted number in

100ml of wastewater is 1400MPN (TL24) equivalent to 14MPN/ml. The author estimated the risk of diarrheal disease associated with consuming salad crop through applying QMRA method (WHO, 2006). Assuming that irrigating salad crop with mean volume of wastewater remaining on 100 g of lettuce after irrigation was 10.8 ml, and a person eats 100 g of wastewater-irrigated lettuce every second day; there is one rota-virus per 10^5 E coli; and a 3-log pathogen die-off occurs between harvest and consumption. The number of rota-virus in 100g of lettuce at harvest is $10.8 \times 14 \times 10^{-5} = 2 \times 10^{-3}$ and at consumption is reduced by the 3-log die-off (i.e., 2×10^{-6}). This is the single dose d to which an individual is exposed every second day – that is on 365/2 days per year. Theoretically, risk of rota-virus infection could be counted by equations below:

$$P_I(d) = 1 - [1 + (d/N_{50})(2^{1/\alpha} - 1)]^{-\alpha}$$

$$P_{I(A)}(d) = 1 - [1 - P_I(d)]^n$$

with: N: the median infectious dose

α: a dimensionless pathogen infectivity constant

$P_I(d)$: the risk of infection from a single exposure to the pathogen dose d

n: the number of days in a year when a person is exposed to this single dose d

For rotavirus infection equations $N_{50} = 6.2$ and $\alpha = 0.253$ (Haas, Rose, & Gerba, 1999), yield:

$$P_I(d) = 1 - [1 + (2 \times 10^{-6}/6.2)(2^{1/0.253} - 1)]^{-0.253} = 1.18 \times 10^{-5}$$

$$P_{I(A)}(d) = 1 - [1 - (1.18 \times 10^{-5})]^{365/2} = 2 \times 10^{-3}$$

This is 2 times higher than WHO's tolerable risk of infection of 10^{-3} per person per year, but lower than the estimated incidents of diarrheal disease in Western Pacific region, i.e.,0.72 pppy(including Vietnam, Cambodia, China, Japan…) (WHO, 2009).

Table 8. Incident of diarrheal disease estimates for 2004

	World	Africa	The Americas	Eastern Mediterranean	Europe	South-East Asia	Western Pacific
Pop (10^6)	6436	737	874	519	883	1672	1738
ppy (10^6)	4620	912	539	421	207	1276	1255
pppy	0.72	1.24	0.62	0.81	0.23	0.76	0.72

*Source: WHO (2009); ppy- people per year; pppy: per person per year

*The regions above is according to WHO's categories of member countries of WHO

Due to limitation of water sampling analysis, many of wastewater parameters such as heavy metals or compound organics matters, pesticides residues, etc… that might exist in irrigation water.

From preliminary assessment of water quality, it can be seen that wastewater irrigation has some potential to be reused for farmers in terms of nutrient recovery and income generation as well as bring s high risk for human health relating to pathogen and other hazardous substances.

5.1.2. Socio-demographic characteristics of the surveyed sample

Total 29 farmers were interviewed in both Thanh Liet and Dong Ba areas. The number of female participated was outnumbered male (18 female - 62% /11 male-38% farmers). Notably in Thanh Liet 85% of respondents were female. The reason for difference number of male/female participants was that women were more engaged in agriculture practices than men, and at the time of interview they were working on field. While in Dong Ba, men are eager to participate in interviews that were conducted at their houses. Dong Ba men answered that they had their wives or mothers to do the farming.

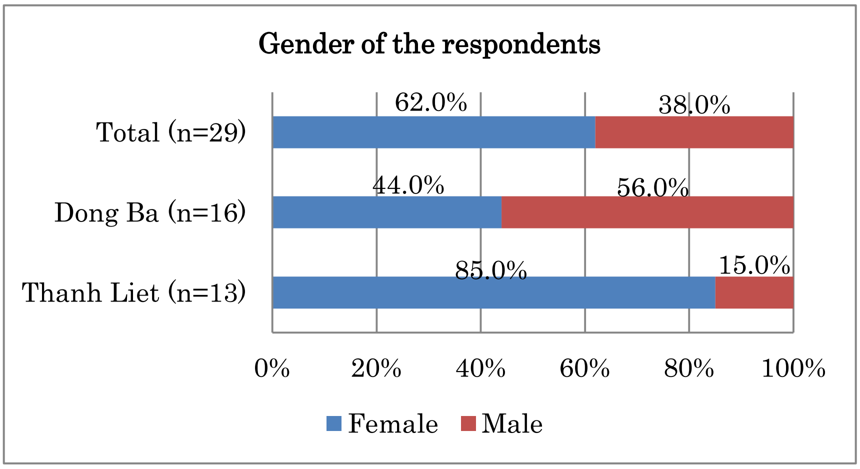


Figure 35. Gender of the respondents

(Source: questionnaire result)

Age of respondents is categorized into 4 groups. The majority of farmers are of 40 to 60 years of age (72.4%).This indicates the farming and fishing activities involved more mature and older people while younger HHs member are drawn to other non-farming works with better income. This also answered to the reason that main HHs income sources are from non-agriculture: earning as a hired labour (41.1%) or trading/services (20.7%) while only 31% said agriculture brings main income for their family (Figure 38).

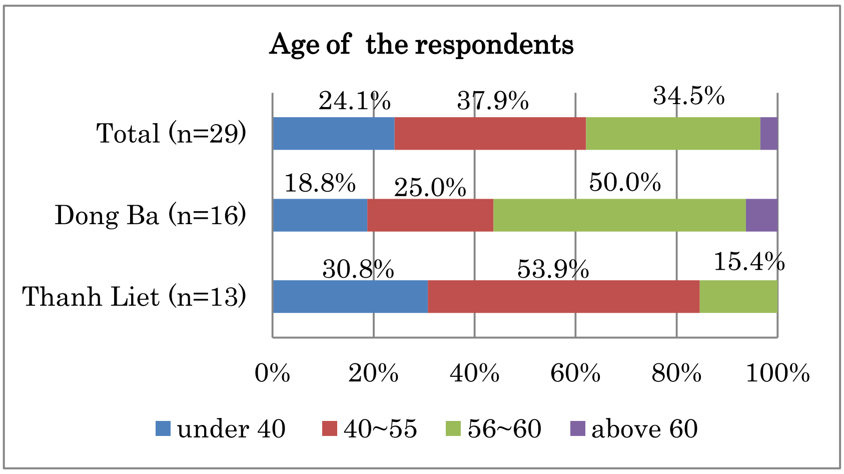


Figure 36. Age of the respondents
(Source: questionnaire result)

In terms of education, all respondents finished primary education, 10.3% finished high school and 3.4% finished college/upper education. This might be the effect of urbanization in this area, where formal education is very much concerned by the city's authorities and local government. More reference of Education status of Thanh Tri (a district that Thanh Liet commune belongs to) in Hanoi Statistic Book 2010 also indicated that 98% of population above age of 5 knows to read and write.

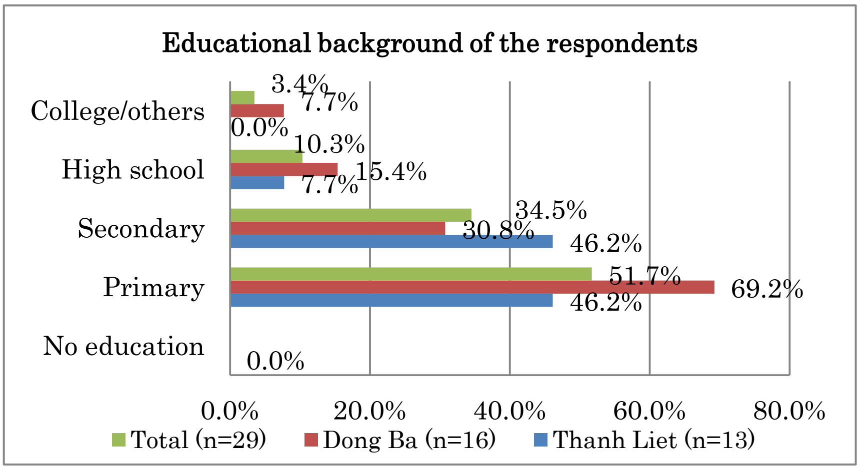


Figure 37. Educational background of the respondents
(Source: questionnaire result)

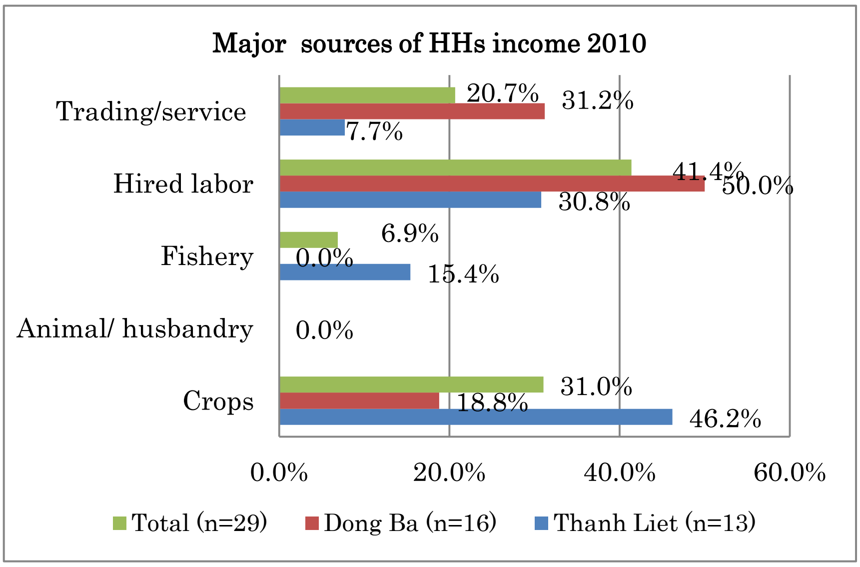


Figure 38. Major sources of HHs income 2010
(Source: questionnaire result)

Referring to migration status, most of farmers said they were born, grown up, got married and do farming in the village. There is only 1 women in Thanh Liet (Mrs. Tuoi) said she migrated 10 years ago with her husband, her family came from Dong My commune in the same district which were known for intensive fish ponds using diluted wastewater from Kim Nguu river (Phuong et al., 2005). According to Mrs.Tuoi, most of the fishermen migrated from Dong My commune. On the other hand, in Dong Ba, 2 of the respondents who engaged in flower farming migrated from Tay Tuu village, different commune but same district. The Tay Tuu villagers are famous of all flower farmers in Hanoi, and they also have experiences of irrigation with diluted wastewater from the Nhue River.

This survey found that fish and flower farmers in general use more credit than aquatic plant and vegetables growers because to produce aquatic plants or vegetables is relatively cheap in Hanoi and requires low inputs such as seed, fertilizers and pesticides whereas fish farmers need to invest in inputs for each day, labour costs, fish feed, and flower farmers need to invest either labour cost, money to buy seedlings and chemicals.

Table 9 shows credit used of Mrs. Tuoi's family (TL04). They have 5ha of fish pond. In 2010 they got the credit from the commercial bank with the interest rate of 15%/year to invest in fish farming. The credit used listed is not including fish seed and fish food.

Fish production is about 15 ton/year and selling with the market price is 1.5-2 US$/kg. This year due to abnormal weather phenomena (long cold winter), income from fish was

10,000 US$, lower than last year production

Table 9. Credit used of Mrs.Tuoi's family

Item	Amount	
	Mil.VND	US$
Credit	300	15,000
Purpose of credit used		
Land	97.5	4,875
Labor	36	1,800
Electricity	6	300

*Source: questionnaire result

Figure 39 shows some HHs property indicator of the respondents. Almost all HHs have TV (96.6%) and motorbikes (96.6%), 72.4% HHs purchased refrigerator. These numbers are slightly higher than the average of the city (HSO, 2010). Number of HHs respondents could access to tap water varies from 53% in Thanh Liet and 18.8% in Dong Ba. Farmers extract ground water for their washing and use tap water for drinking and cooking.

The proportion of toilet connected to septic tank is high because this area is closed to city centre where disposal of wastes is more regulated and the people themselves follow the norm of their neighbors in having a cleaner, more hygienic and self-contained septic tank (Phuong, et al., 2005).

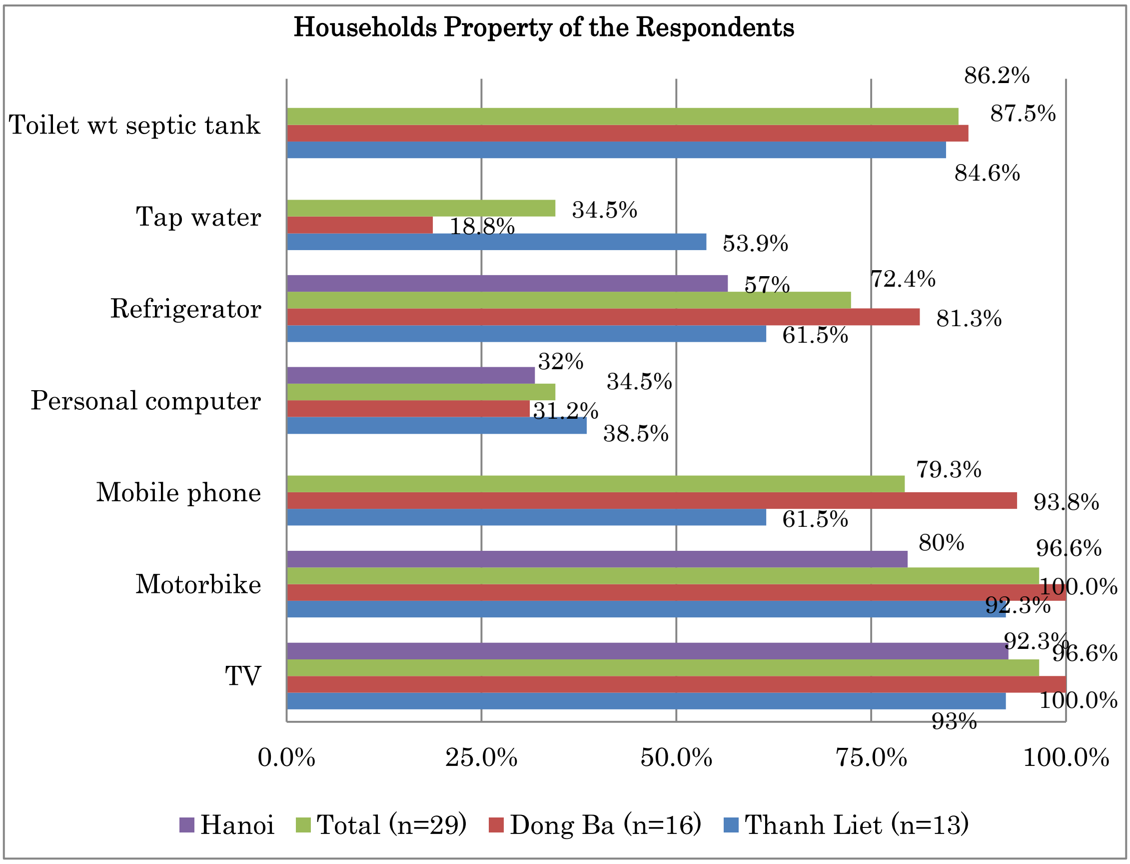


Figure 39. Households Property of the Respondents
(Source: questionnaire result and GSO)

5.2. Behaviour outcome

5.2.1. Management of cropping area

Results from questionnaire interviews shows that farmers in both Thanh Liet and Dong Ba are mostly engaged in the cultivation of aquatic plants including rice, i.e., 68% and 57% of interviewed FHHs in Thanh Liet and Dong Ba respectively (Figure 40).

Figure 41 shows the consumption pattern of crops and fish, almost all farmer respondents inform that they consume and sell their products. All of farmer respondent plant rice for their family consumption while gain revenues from selling aquatic plant vegetables (76.9 in Thanh Liet), flowers (100% in Dong Ba) and fish (100% in Thanh Liet).

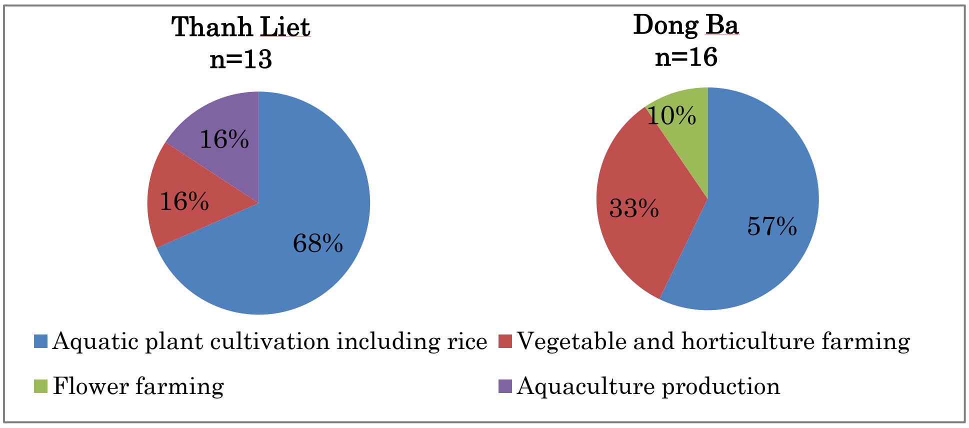


Figure 40. Proportion of FHHs involved in different farming activities
(Source: questionnaire result)

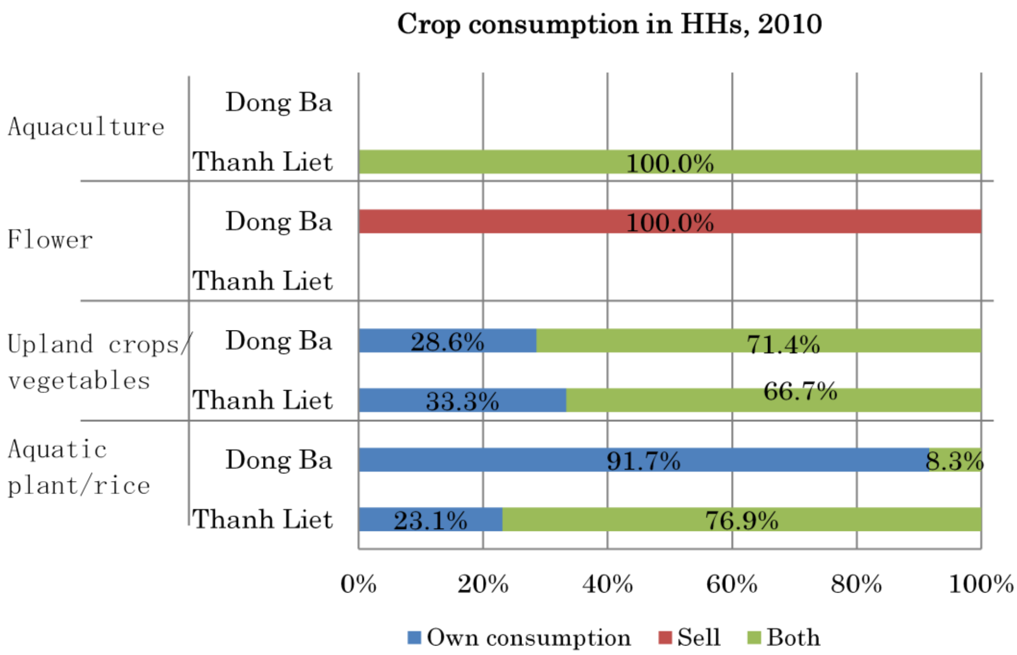


Figure 41. Crop consumption of the respondents HHs in 2010
(Source: questionnaire result)

In Thanh Liet, locations of cropping areas (lowland paddies/ upland plots) and fish ponds seems to be affected by irrigation conditions (i.e. location to the irrigation/drainage canla, wastewater quality, distribution of irrigation water). Most of the cropping areas are surrounded by fish ponds (Figure 42). Since rice are less torerant with contanminated water than other aquatic plant (e.g. water morning glory, water droport, water crest …), rice paddy are located more inner from the main drainage canals. These locations some how reduce the affect of contaminated water to the rice field. This can be seen through the improvement quality of irrigation water when entering the rice field(see more in anex 2).

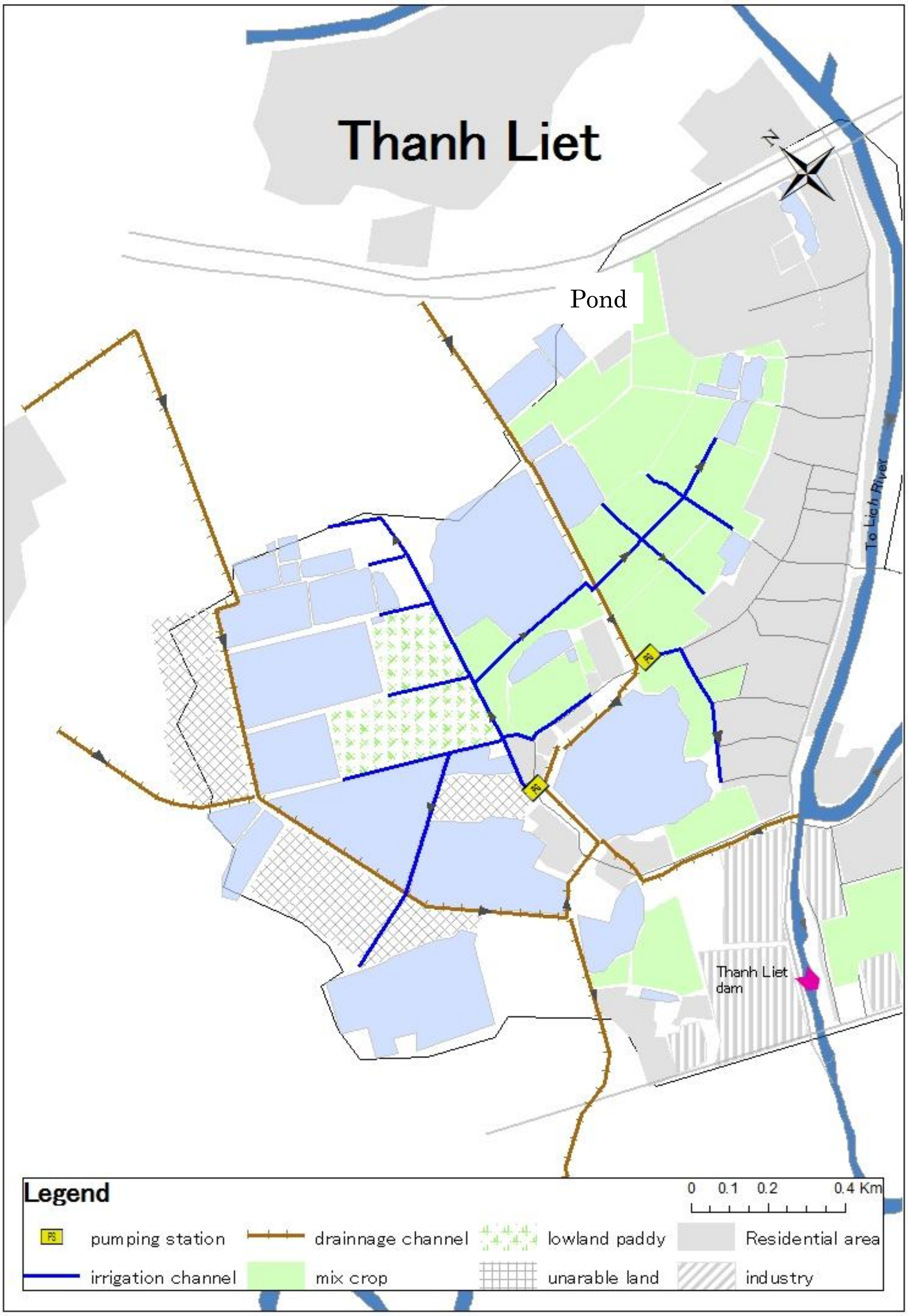


Figure 42. Agricultural Land use map of Thanh Liet (Western Tolich river part)

5.2.2. Transition to aquaculture or non-food crop

Thanh Liet saw the significant increase of fish pond area. For over 10 years, it is estimated about more than 60 ha of total 85 ha of fish ponds area in 2011 were converted from lowland paddy with less productive and unarable land(Figure 43). There are some reasons for the transition of cropping land to fish ponds:

- *Firstly, according to Thanh Liet People's Committee (PC), it encourages farmers to convert lowland paddy to integrated fish-rice system or intensive fish system by subsidizing 30-50% total construction cost. It also supports households in raising particular aquaculture species, e.g., first time raising Macrobrachium Rosenbergii by subsidizing the cost of seed/juvenile prawns by up to 50% of the price; Taiwan tilapia will be supported with US$100/ha; Pangassius catfish trials up to US$.500*
- *Secondly, income from fish production (including production of feed seed and fish) were much higher than from crops. The value of aquatic vegetables and fish production is approximately VND120 mil to VND150 mil/ha/ year (US$6000-7500) over and above the value of rice production (about VND 50 million/ha/year).For the case of Mrs.Tuoi (TL4), her family gained VND 200mil/ha (US$10000) in year 2010 with the total fish production area of 5ha.*
- *Fishermen are more favourable to wastewater feeding fishpond because they could reduce the investment in fish food for the rich nutrition of wastewater and at same time they could get subsidized by the local PC. Moreover, according to Phuong, et al.(2005), yield of fish production with wastewater is much higher than the one without wastewater. This study noted that fish polyculture systems in Dong My (wastewater based fishponds) had an average yield in 2003 of 6.66 ton/ha per year compared to Tran Phu (non-wastewater) was 4.63 ton/ha per year.*

Dong Ba on the other hand has significant increasing of flower cropped area. In the period of 10 years, the area of flower field has replaced rice paddies roughly 9 ha. For the case of Mr. Nhuong (DB19), he has total 20 sao (0.72 ha) of greenhouse for Lilies, Roses and Daisies. Year 2009, he gain VND500 mil (US$25000) (noted that Lilies has very high economical value, one bucket of 3 lilies would cost about US$ 2 to 5 depending on the time of year). Another flower farmer, Mrs.Tho (DB18) has 3 sao (0.1 ha) of Daisies for sale at price of VND 2-3 mil/month (US$ 100-150).

- *Locations of flower plots are usually at higher land. In spite of limit access to irrigation water, farmers could make used of the drainage water for irrigating flowers by installing motor pumps to take up wastewater from the canals.*

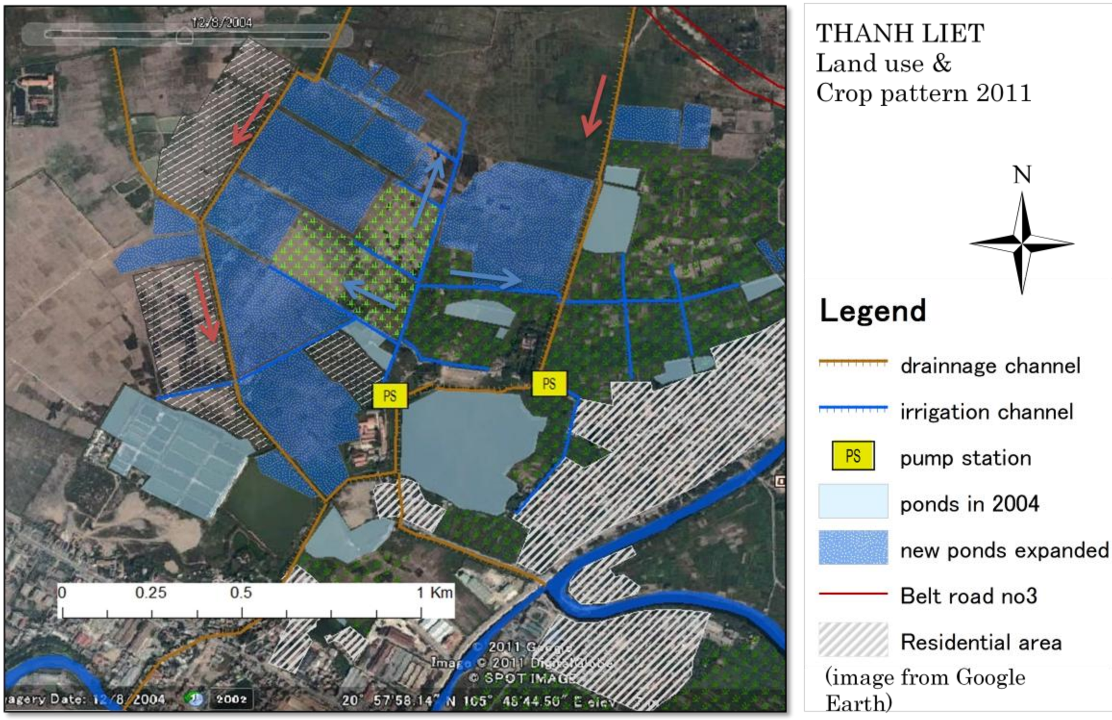


Figure 43. Expanded fish ponds in Thanh Liet

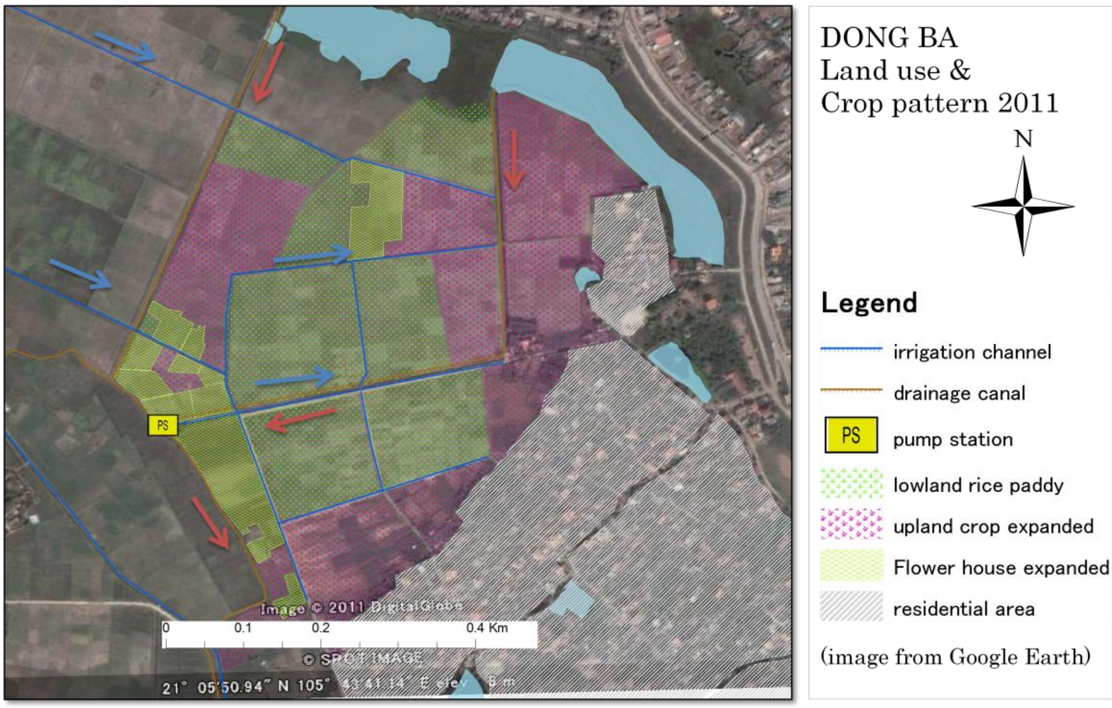


Figure 44. Expanded flower planting area in Dong Ba

Figure 45. Mr. Nhuong's (DB 19) Lily plots
(Photo taken in March, 2011)

Figure 46. Mrs.Tho's (DB18) Daisy plots
(Photo taken in March, 2011)

5.2.3. Wastewater as alternative irrigation source

In Dong Ba, the flower growing farmers tend to locate their plots near to the drainage canals to actively exploit the drain water because of the necessity of continuous irrigation (Figure 47). Figure 44 shows that entire flower cropped area and green houses (for flower) were located along the main drainage canals. Mrs.Tho (DB18) said that, since her plot was beside the drain stream with sufficient water, she could use the water any time and not to rely on the pumping schedule of the LC. Electricity cost for pump estimated at about VND 1mil/month (US$50). If the drain water was dirty (i.e., black color, strong odor) then they use groundwater as alternative. However farmers favor drain water since groundwater in Dong Ba contain some heavy metals (iron and arsenic) which were not suitable for flower growing.

In comparison to Dong Ba, the quality of wastewater in Thanh Liet is much worse (Table 5). Therefore fishermen limit the use of this wastewater by pumping in the wastewater for 3 hours in 3 days period and extract groundwater for the alternative water supply. By this practice, nutrients in wastewater could be utilized to feed the fish (Figure 48).

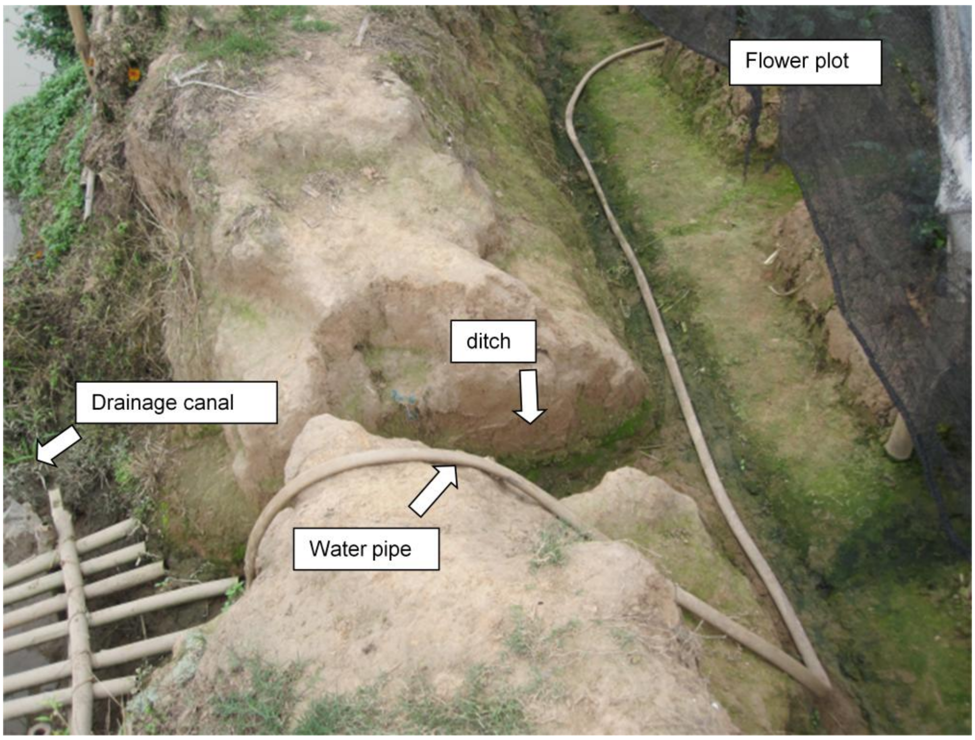


Figure 47. Intake water for flower field from drainage canal for flower plots (Photo taken in March, 2011)

Figure 48. Intake water from drainage canal for fishponds
(Photo taken in March, 2011)

5.2.4. Minimizing occupational health risks

Most of farmers in Thanh Liet make sure to wear protection gears (gloves 69%, boots 100%, full sleeves shirt 100%, full length trousers 100%, mask 46%) while working on farm to reduce occupational risks from wastewater(Figure 50). From observation of the author, both men and women in Thanh Liet were wearing gloves and boots while farming.

Farmers in Dong Ba admitted that they wear protective gears in order to prevent from chemicals (pesticides, herbicides) and sun burnt. They said wearing gloves or boots while farming is unnecessary and uncomfortable. Only 19% and 6.5% of respondents wear boots and gloves respectively while farming (Figure 50).

Figure 49. Mrs. Mo (left) and Mr. Tam (right) in Thanh Liet
(Photo taken in March, 2011)

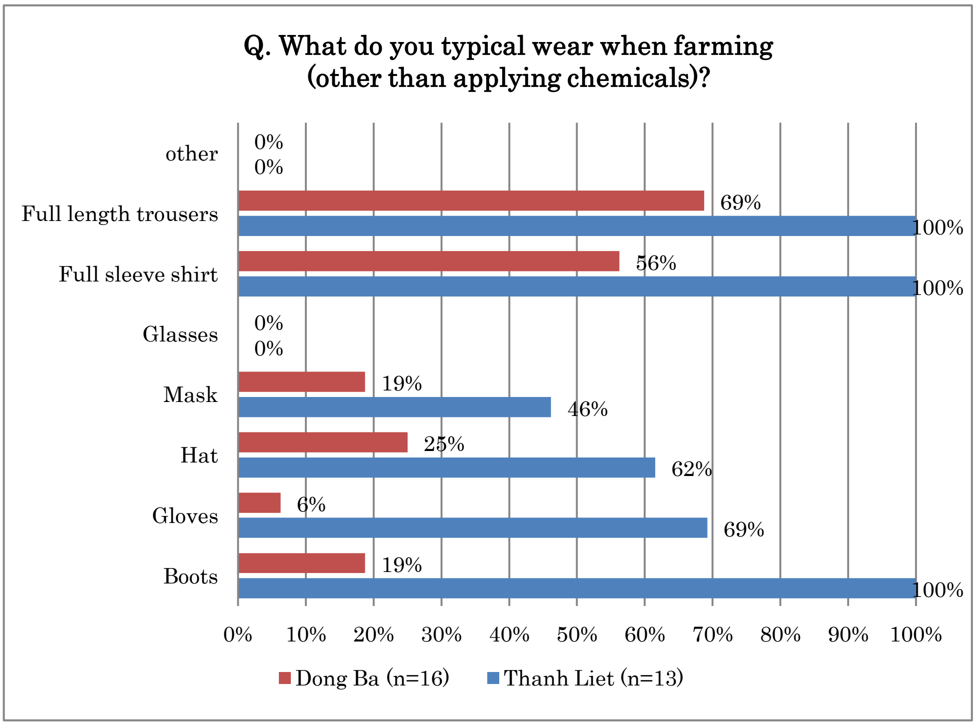


Figure 50. Habit of wearing protection gears when farming
(Source: questionnaire result)

Figure 51. Farmers in Dong Ba
(Photo taken in March, 2011)

5.3. Perceptions

5.5.1 Farmers' perception on wastewater irrigation

Farmers have different response to source of wastewater irrigation. For rice paddy and aquatic plant, all farmers in both Thanh Liet and Dong Ba use the water provided by the cooperatives, and they do not need to pay for the water fee except the service fee (including the operation cost of pumping water and maintenance of the irrigation facilities) which according to them is *cheap* or *affordable*. These farmers complain about the amount of irrigation water because the water only reaches their field 2-3 times per week. 4 farmers in Dong Ba use groundwater for their vegetable fields and 2 fishermen in Thanh Liet use groundwater for fishponds because these field either separated and not served by the irrigation facilities of the LC.

When asking about the use of wastewater for irrigation, only few farmers in Thanh Liet admitted that they acknowledged the irrigation water is contaminated because the Tolich River is receiving wastewater from city. But they emphasized that the water is cleaner in the field compared to the river. Other farmer just say that they use water provided by the cooperatives and that means the cooperatives are responsible for the quality of water.

All Dong Ba farmer state the irrigation water comes from Red River, therefore it is clean. But a man who's in charge of operating the pump station in Dong Ba said that since there is a shortage of water comes from the upper level of irrigation channel (Dan Hoai pumping station) the cooperative is utilizing the water from the drainage canals (that drains water from the field and surrounding ponds). The water in these canals is also pumped up for the flower field through numbers of pumps installed by the individual farmers (Figure 47).

5.5.2 Perception on invisible and visible risks

Farmers are sensitive for visible contaminations, such as dirt, colour or odour. Many farmers were observed to wash their feet and hands after working at the drainage canals or ponds that appeared to be clean.

In addition, they made statement on water quality based on their own the information source. According to Thanh Liet farmer, if the water comes from the Tolich River, they called it urban wastewater, or from Tan Trieu- a craft village nearby, they called it craft village wastewater. Farmers are much aware with industrial and craft village wastewater because they said it is very toxic and would kill fish and crops. Some statement of farmers related to pollutant sources are given below:

- *One female farmer in Thanh Liet stated that the cooperative pump water from Tolich River, it is polluted and dirty. She pointed out that the pollutants are harmful such as detergent from toilet effluents, industrial effluents.*

- *Mrs. Mo (TL06) said, the household wastewater comes from septic tank is harmful but it also good for crops so she let the water flowing bypass her vegetable field.*

- *Fishermen – Mr.Tam (TL10) added: the most harmful source is wastewater from Trieu Khuc crafts village where villagers earn money from recycle plastic, paper or metal. The water discharge from these activities is bad odor, black, and toxic. If the water is pumped into fishponds or field, the fish will be "floated" [1] and the crops will be destroyed.*

[1] The fishermen use the term of cá nổi = floated fish means dead fishes

- *The man in charge of operating the pump in Dong Ba mentioned the water comes from the drainage canal is polluted by various sources: over use of pesticides and chemical fertilizer from flower cultivation, wastewater comes from livestock and living activities of nearby residents.*

Farmers' perception on possible risks posed by wastewater varies between Thanh Liet and Dong Ba (Figure 52).

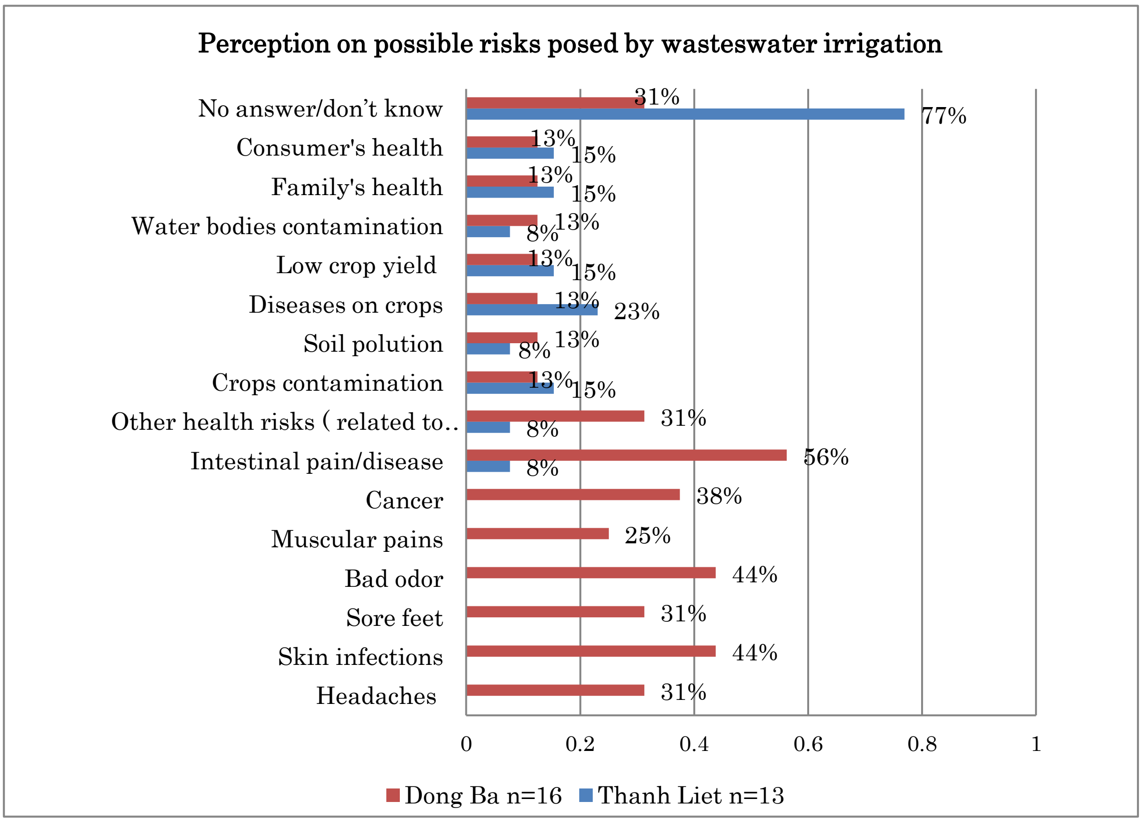


Figure 52. Farmers' response on possible risks posed by wastewater irrigation (Source: questionnaire result)

When asked: "What do you think are possible health risks of wastewater irrigation?", most farmers showed hesitation to answer: 77% farmers in Thanh Liet and 31% in Dong Ba had no answer. Some farmers gave very general answer such as wastewater irrigation has bad effect on farmers' families health (Thanh Liet 15%, Dong Ba 13%), consumer's health but they do not have specific explanation to which type of diseases might caused by wastewater irrigation. Some farmers mentioned about environmental risks such as contamination of water bodies (Thanh Liet 8%, Dong Ba 13%) or soil pollution (Thanh Liet 8%, Dong Ba 13%). Some said wastewater contaminated crops (Thanh Liet 15%, Dong Ba 13%) and resulted in low yield (Thanh Liet 15%, Dong Ba

13%) and disease on crops (Thanh Liet 23%, Dong Ba 13%).

Dong Ba farmers seems more concerned about health risks posed by wastewater irrigation. Highest risks are intestinal diseases (56%) and skin infection (44%). 38% anxious of chemical remain in crops irrigated by wastewater would pose cancer. Other health risks related to wastewater irrigation mentioned was headache (31%), sore feet (31%) and muscular pain (25%).

Apart from risk posed by wastewater irrigation, farmers also concerned of health risks posed by over use of chemicals such as pesticides, herbicides (Thanh Liet 8%, Dong Ba 31%).

5.4. Motivation

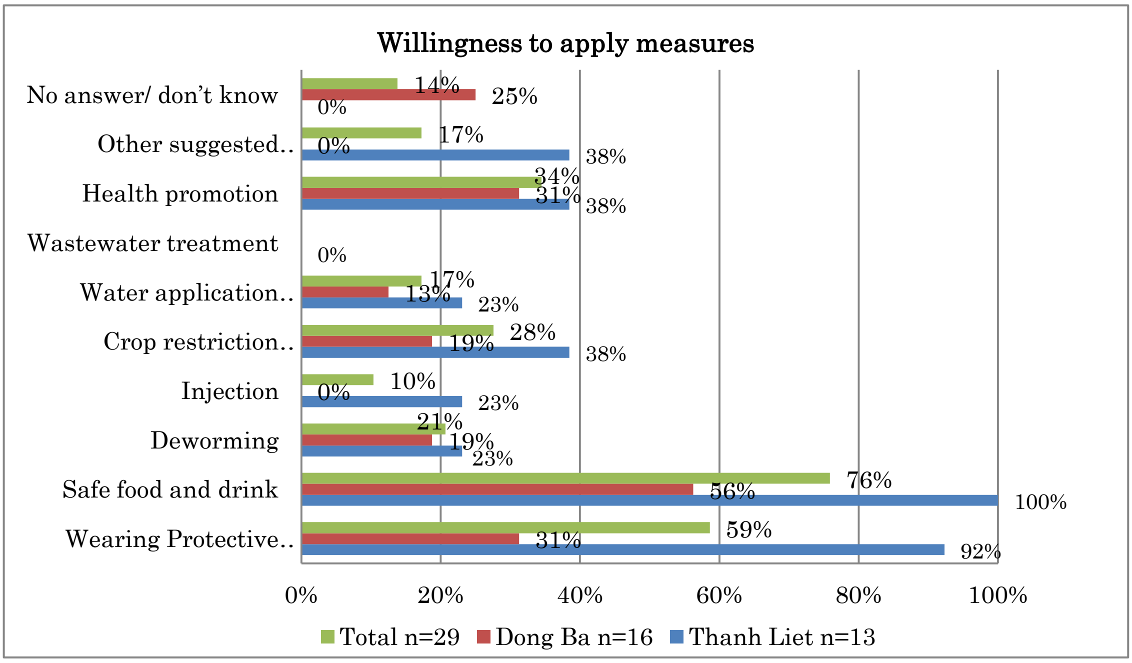


Figure 53. Willingness to apply measures for mitigating wastewater irrigation risks (Source: questionnaire result)

Figure 53 shows that most farmers in Thanh Liet agree that wearing protective cloth (92%); keep hygienic of food and drinks (100%) are effective to protect their physical health. On the other hand, Dong Ba farmers are less concerned about these protective habits: 31% agree to wearing protective gears and only 56% agree to keep clean of food. The remaining farmers do not give specific answers or do not know (25%).

- *Mrs. Chinh (TL02) explained that although wastewater is dirty but the contaminants will decrease after entering the crops. If people eat the vegetables or rice, only small hazardous substances will enter the body and almost no impact to health if the food is washed and cooked.*

Farmers believe the contaminants won't enter their body though skin contact but only through eating and breathing. By wearing protective clothes they can keep their skin clean and resists from skin diseases.

Both farmers in Thanh Liet and Dong Ba said De-worming and Injections are not feasible and not suitable for them. They said that those measurements only work for children.

Wastewater treatment, localized irrigation and stops of irrigation before harvesting are time consuming and require more investment costs.

Washing vegetables with tap water before selling is costly and unnecessary, so farmers usually utilize the water in ponds or channels to wash the crops. Many female farmers growing vegetable were seen to wash their crops in the drainage channel which appeared to be *clean.*

Figure 55. Mrs. Chinh & her mother in-law

Figure 54. Washing crops before selling

(Photo taken in March, 2011)

- *Mrs. Thuy (TL07,* figure 54*) explained that she has to wash the crops from dirt because the consumers only chose the green and fresh ones. And she said the buyer could wash again with clean water before cooking, but for local food shop it is not necessary to wash because she already washed them clean.*

5.5. Discussions

From the result of the case study conducted, the author give explanation of farmers' capacity to govern wastewater irrigation by taking the systemic and non-equilibrium approach, that is to view farmer wastewater management practice in the environment which change over time, unpredictable due to uncertainties and risks. Individual aspect of farmers' wastewater irrigation management capacities are divided into: (1) drives and motivations; (2) background and experiences; and (3) knowledge and skills. Farmers perform their tasks in the environment that is influenced by various factors, distinguished into 4 main dimensions: (1) institutional environment; (2) social environment; (3) physical environment; and (4) economic environment. The result of interaction within the system is then clarified in corresponding to the behaviour outcome of farmers.

The interrelations of each factor was visualised by employing causal loop diagram method. The map contains the following three types of items: (1) non-highlighted items, which represent causal factors influencing other factors and/or result factors influenced by other factors; (2) items in square boxes represent the main factors either characteristics of farmers or exogenous factors. The arc connecting the items denotes a causal flow, which begins from a causal factor and terminates at its result factor. The (+) or (-) denotes the relation between 2 factors positive or negative. Positive means the causal factor decrease would lead to increase of result factor (+) and negative is decline of the result factor (-). The causal effect between these factors forms a positive reinforcing loop, represented rounded arrow denoted with the (+) or balancing loop denoted with the (-).

5.5.1 Personal aspects of farmers

Drives and motivation for wastewater governance are described as willingness to improve wastewater irrigation by reducing occupational health risks. Measures that are affordable and simple and have short term effect such as wearing protective gears or to have positive effect on farmers' own health such as keep safe of food and drink (Figure 56).

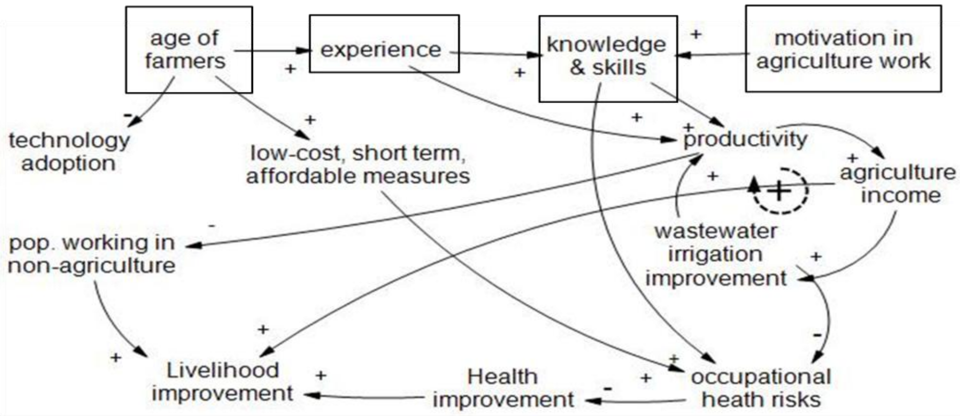


Figure 56. Personal characteristics of farmers affecting management of wastewater

In addition, health and livelihood improvement are the most important to farmers, i.e., most farmers considered agriculture work is hard and do not bring much income. They have to farming because there are no other choices.

- *Mrs. Mo (TL6) said that due to lack of working skill and age (she is in her 40s), no employers hire her, and so she has to do farming instead. This work does not bring much income but rather than do nothing.*

Working as hired labour, or services/trading bring much income for farmers' families and more over, this could help to change their lifestyle to be nearer to city people with better living condition. A baseline survey conducted by Phuong, et al.,(2005) give some explanations: As the master plan of Hanoi city dictates, the economy should move toward industry, service and modernize agriculture respectively. Almost all young people who are working within agriculture have a strong perception of escaping from agriculture activities, moving to the city to get married with a person who does not work in agriculture.

Farmers have less motivation on farming because of low income, working in the hazardous environment (chemicals, wastewater). Therefore they would rather to escape from the agriculture activities than to work out to improve the working conditions (i.e., improving water quality)

In case of flower farmers and fisherman, agriculture brings substantial economical benefits: income from selling flower and fish are much higher than rice or vegetables. Hence, they have more motivation to invest money and labour to improve irrigation condition, i.e. making settling ponds or pumping oxygen to boost wastewater treatment processing in the pond in the case of Mrs.Tho (DB18); Mr Nhuong (DB19); Mrs.Tuoi (TL04) and Mr.Tam (TL10)

Farmers' background and experience seems to affect their perception and behaviour toward wastewater irrigation management. Thanh Liet farmers have more experience on wastewater use compared to Dong Ba farmers. Through their experiences, they developed skills and knowledge such as to decide when to provide wastewater to fishponds, or wearing protective cloth while farming. Farmers in Thanh Liet are able to identify the pollutants in wastewater when asked.

However, most farmer respondents were aged above 40, this make barrier for farmers to carry out experiments or apply innovative technologies to improve wastewater irrigation (i.e., wastewater treatment, dripping irrigation). Younger farmers are keener to new change and are willingness to take risks while older farmers are stick to their own experience. Education also has positive effect on how farmer perceive of health risks posed by wastewater irrigation. It can be seen that all farmers interviewed were completed primary education and aware about the risks. Chi, T.T.N et al., (2002) in the study of factors affecting farmers adoption of technology in farming system in the Mekong Delta of Vietnam also suggested that factors that trigger adoption of new technologies comprise of progressive, young and educated farmers. However, not all farmers adopted technologies introduced because they are new to them. They were feeling hesitated in application of new technology because they do not believe that the new technology can ensure the high yield. These farmers are usually old age and work based on their own experience.

Knowledge and skills of farmers influenced their behaviour on wastewater irrigation management. Fisherman, flower farmers and some Thanh Liet farmers had more knowledge about wastewater in the invisible risks by providing information about source of pollutants; name some of some contaminated substances such as heavy metals or nutrients, etc,. As a result they decide to take over and minimizing the risks of wastewater irrigation.

5.5.2 Exogenous factors

Institutional environment such as regulation on wastewater use in agriculture, decentralised/centralised wastewater management, spatial separation on governance responsibilities of different department, state of participatory irrigation management seems to influence farmers' management capacities (Figure 57).

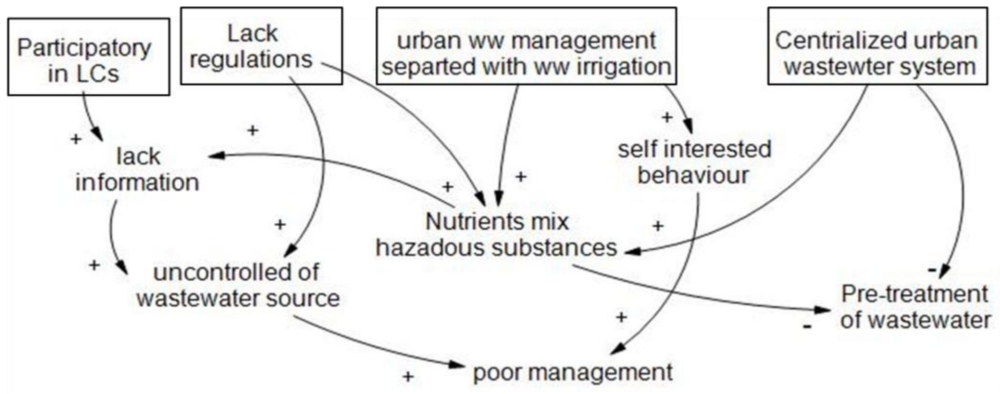


Figure 57. Institutional environment affecting farmers' management of wastewater

For instant, lack of regulation on wastewater irrigation makes difficulties for farmers to control the inflow of wastewater source. In centralised management, urban wastewater is usually a combination of domestic and industrial wastewater that contains not only nutrients but also hazardous such as pathogens or chemical that poses high risks for reuse. When the wastewater is diverted to irrigation channels, farmers were not acknowledged, and if the wastewater contain high amount of toxicities, farmers could loss there production (dying of fish or low yield crops).

Decentralised wastewater management encourages farmers to have better management of wastewater irrigation since the wastewater is separated and pre-treatment at source. Farmers also have much knowledge about the wastewater produced and could make better decision to reuse of wastewater (in the case of some farmers utilised wastewater from HHs septic tanks). This study supports Huibers's explanation (Huibers, et al., 2010) that optimum use of irrigable area would lead to the decision to site decentralized systems. This would also allow selection of locations best suited to control the wastewater inflow qualities and to exclude toxic-waste streams in the sewerage.

Spatial separation on government responsibilities of different department in the urban districts and the peri-urban districts of Hanoi municipality, in addition, responsibilities concerning the water and food chains are divided among different departments result in separation of wastewater farmers in the wastewater chain. The research found that in the Thanh Liet, wastewater collected was discharged to an upper level of canals is due to a centralized wastewater system in Hanoi. The water from these canals is then diverted to a local irrigation system without proper treatment. Farmers were not acknowledged of the discharge of wastewater from cities, they blame for city people and authorities for not having responsibility to treat wastewater. According to Evers et al., (2010) separation of urban wastewater and peri-urban irrigation system would lead to self-interested behaviour of farmers, which according to Jon E.(2007) if the subject were rational and self interested, nobody would contribute anything, in this case to contribute to the safety of wastewater irrigated agriculture products. Or Evers (2010) identified farmers behaviour as "spot-market" behaviour results in a behaviour pattern in which the excessive use of fertilizers results in short-term benefits of high crop yields, but leads to long-term uncertainties of soil and crop quality. It can also lead to short-term costs of water pollution in the form of eutrophication, which directly relates to a decline in fish production.

Local participation is considered as a primary basis for success in many rural development projects including irrigation management projects (Narayan, 1995; K.V. Raju & Brewer, 2001; K.V. Raju, Dayal, & Chatterji., 2008); In Participatory Irrigation Management, participation is considered a key factor contributing to the long-term sustainability of WUAs. This study confirms that the status of participatory irrigation management of farmers is also influence factor. Participatory status is referred to 3 modes: through financial contribution, through direct involvement in the operation and maintenance of irrigation schemes, and through involvement in decision making regarding the operation and maintenance of the schemes. This study clarified that in terms of participation in financial contribution to LCs under irrigation service fee, farmers who are member of the LCs, usually got access to the LCs irrigation facilities, thus they got dependent on the LCs irrigation management. According to them, LCs is the providers of irrigation facilities and they should take responsibilities of the irrigation services. But due to abolishment of irrigation fee, farmers pay only small money for irrigation services, then they must accept that they could only get low quality of irrigation water but they do not make any effort to improve the condition. In contrast, fishermen and flower farmers are more active to irrigation management, they act independently from LCs thus do not rely on water provided by LCs.

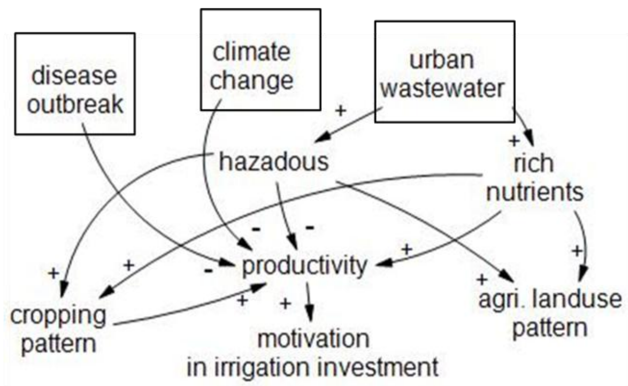


Figure 58. Physical environment affecting farmers' management of wastewater

Physical environment could bring both negative and positive influences on farmers managerial capacity, i.e., negative effect such as negative weather phenomenon (climate change), scarcity of water in dry season or large volume of water in rain season, outbreaks of pests diseases result in low yield or loss of production discourage farmers to invest effort to irrigation management. In addition to this, summer rice season 2010 in Thanh Liet, many farmers lost their crop due to diseases and rats. Positive effect is of the rich nutrient in wastewater could bring substantial benefits for farmers in reducing amount of fertilizer or fish food, however, only few farmers recognized this point. Irrigation condition also affects farmer management on cropping pattern such as transition to non-food crop or fish, managing location of agriculture production land.

Considering social environment (Figure 59) peri-urban farmers live separated with others farmers, some living in different village, thus social connection between peers are week. As result, farmers do not share their experiences or skills to others or learning from others. They do not form groups to better management of wastewater irrigation at local scale and lager scale. They prefer to act independently among peers. As for consumers, they do not care much about the safety of product irrigated with wastewater but only care about its appearance so that consumer would buy with better price. These weaken their motivation to apply risk mitigation measures for wastewater irrigated crops.

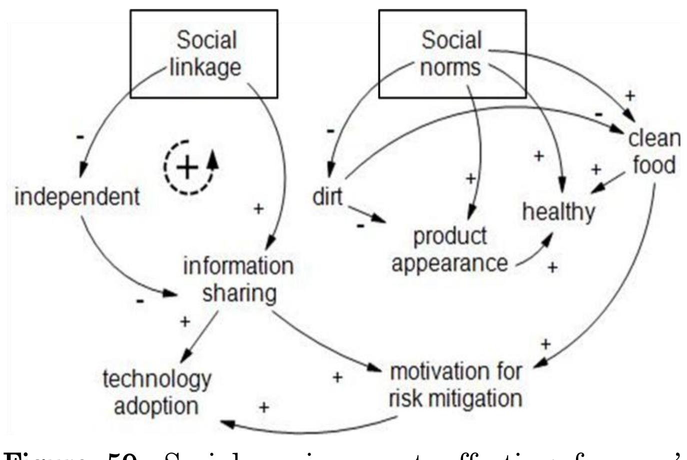


Figure 59. Social environment affecting farmers' management of wastewater

Social norms also affect farmers' perceptions on visible risks and behaviour of wearing protective clothes and have kept hygienic of food and drinks. Farmers, especially for female farmers, keeping clean of the outside, getting rid of dirt before returning home and cleaning of food is most important. In the study about farmers perceptions of wastewater use in agriculture by Knudsen, et al. (2008), the authors give explanation that in Vietnam, concept of beauty an appearance involve more than aesthetics in a strict sense. Aesthetics is part of the Vietnamese understanding of health, which includes social, moral, aesthetic and physical concerns. The presentation of nice and pleasant appearance is indicative to society of a socially, morally and physically healthy family. Vietnamese women are typically responsible for the inner function of the family and home and are supposed to invest their energy in the health of the family.

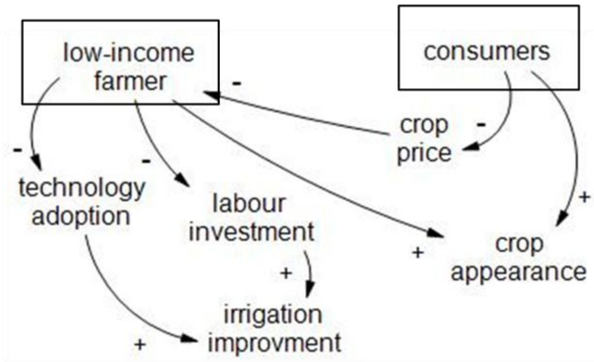


Figure 60. Economic environment affecting farmers' management of wastewater

Economic environment are determinant factor for farmers' wastewater irrigation management (Figure 60). Income from rice or vegetables irrigated with wastewater is low compare to fish or flower farming, so low-income farmers are more hesitate to invest new technology (that is costly) or labour that has small return of money. Besides, consumers in Hanoi are used to buying food and vegetables at local market, with almost no guarantee of certification of the quality of food, they only know through sellers or farmers who sell to them. Consumers tend to choose foods that look fresh or green and cheap but not asking about the origin. Thus farmers make more effort on making their products appeared to be clean and fresh but not to improve quality of water that according to them might not affect much on the look of the crops.

"This page is intentionally left blank"

Chapter 6

Conclusions

6.1. Significance of the study

This research found that wastewater irrigation in Hanoi peri-urban agriculture and urban wastewater management were integrated system. In this system, wastewater was produced in the urban area and used for irrigation and aquaculture purposes in the peri-urban area with almost no treatment or very little treated. Crops that produced by using wastewater were then provided to the urban and nearby market and generated substantial income for wastewater farmers. Urban wastewater has some potential to peri-urban farmers in terms of nutrients and water resource recovery as well as threats for health, agriculture productivity and the environment.

Despite of being linked in urban wastewater and urban food chain, wastewater farmers behaved independent and self interested among peers and others (i.e. consumers, authorities) which results in some short terms measures such as generate income from wastewater fed fish ponds, aquatic plants or non-food crops, reduce occupational health risks or keep cleanliness of food and drinks to improve health.

The study found out that there is a significant increasing of fish pond, wastewater tolerant crops and non-food crop cultivated land which indicates farmers' interests of economic aspects of wastewater agriculture i.e. nutrient and abundant wastewater sources utilization. At the same time they minimize health risks by wearing protective clothing, keep cleanliness of food and drinks such as only eat cooked vegetables and drink boiled water.

Management of wastewater agriculture taken by farmers would minimize wastewater impact on health and environment in some extends. However, according to WHO (2006) guidelines, it is recommended to have a combination of measures not only wearing protective gears or preparing food but also restriction of grown crops, irrigation technique, or some construction of simple wastewater treatment facilities (i.e. anaerobic or facultative ponds, constructed wetlands).

Many farmers were observed to not having protective clothes when exposing to wastewater irrigation, using excessive amount of fertilizer, washing vegetables in wastewater canal. Still 70% farmers in Thanh Liet and 13% farmers in Dong Ba do not acknowledged or do not know of the risks posed by wastewater irrigation reflect the poor management capacity of farmers.

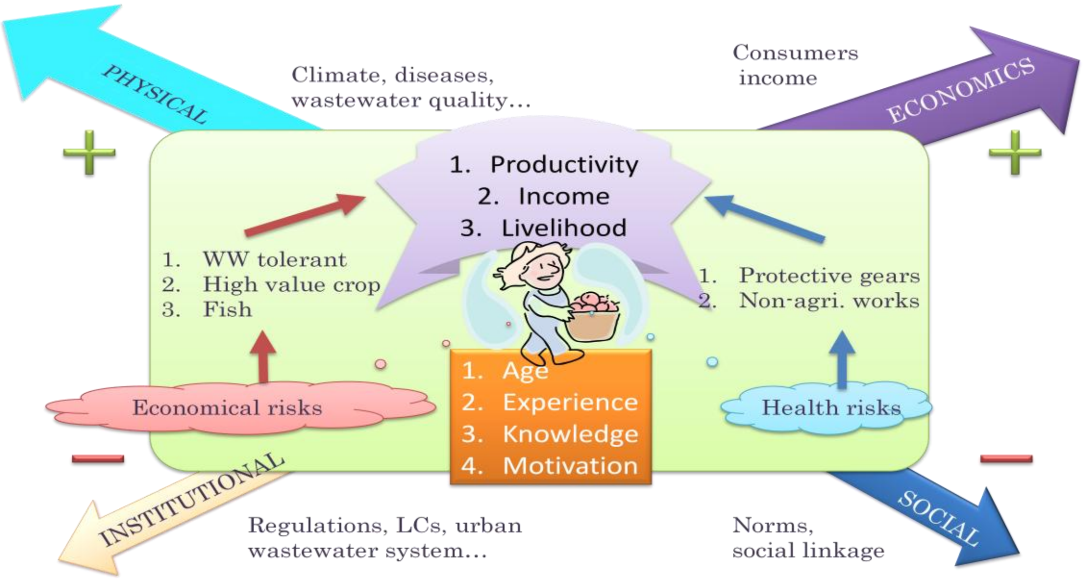


Figure 61. Internal and external factors that influenced farmer's capacities

The study highlighted the factors that influenced farmer's capacities of wastewater irrigation governance. These factors included:

- Internal factors such as personal characteristics of farmers refer to (1) age of farmers, (2) experience in wastewater irrigation, (3) knowledge and skill in wastewater irrigation, (4) motivation in wastewater agriculture.
- External factors were divided in 4 dimensions: (1) institutional environment includes regulation on wastewater use in agriculture, decentralised/centralised wastewater management, spatial separation on governance responsibilities of different department, state of participatory in local cooperatives; (2) physical environment such as climate change, diseases outbreak, constituent in wastewater; (3) social environment consists of social linkage and norms; (4) economic environment comprise of 2 aspects: consumer buying behaviour and income from wastewater agriculture.

Following the examination of relationship between those internal and external factors, this research found that farmers' managerial capacity reflects in age and experience of farmers. Older farmers often gain more experience in managing farm including irrigation to increase productivity. Through practicing wastewater agriculture they receive more knowledge and develop management skill to minimize wastewater risks on crops and health. But on the other hand, old farmers more hesitate to new technology adoption or carry out new experiments on crops; they prefer to their own way of farming resulted in many years of experience or learnt from parents.

Motivation in farming also affects farmer's managerial behaviour by encouraging them to develop knowledge and skill, invest labour and money in wastewater irrigation technique to increase productivity.

Wastewater irrigation management by farmers were recognized as informal, short-term and self-interested due to separating farmers from urban wastewater management, ignorance of wastewater irrigation agriculture in the urban food supply chain and lack of regulation relating wastewater reuse and food safety for wastewater irrigated crops. In addition, centralized urban wastewater system makes barriers for farmers in utilizing nutrients in wastewater without bearing the risks of hazardous constituents.

Participation in wastewater irrigation is fundamental concern for wastewater governance at local level. However, farmers are less motivated to participate, while get more dependent on LCs management scheme. They only need to pay for irrigation service fee and leave the rest responsible to the LCs.

Physical environment included weather, diseases on crops and state of wastewater influences productivity, cropping pattern and agricultural land use. These physical factors could either encourage or discourage farmers' motivation to improve irrigation condition.

Weak social linkage among peer farmers and farmers-local authorities, farmers-consumers influences information sharing, which prevent them from applying innovation in farming. Moreover, the contamination of irrigation water seems invisible and were not considering as important compared to the norm of understanding dirt. This results in low motivation to improve irrigation quality, while more efforts making product look fresh and clean.

Economic environment play important role in controlling farmers behaviour toward economic benefits and consumer buying habit. Most of wastewater crops and fish were to provide to urban or nearby market. However, consumers are not aware about the irrigation aspect but only care of appearance and price. This made farmers to produce cheaper products with nice appearance, while investment in irrigation according to farmers does not bring much benefit from selling wastewater irrigated products.

This research concludes that result of farmers behaviour where more driven by economical and physical factors, while institutional and social factors appeared to discourage farmers to have high performance of farming.

6.2. Future research

Findings from this research was more focus on personal characteristics of farmers and the external factors that influence management capacity of farmers to wastewater irrigated agriculture. However, it is suggested that farmer's managerial capacity need to involve decision making process that try to optimize, or at least influence the technical and biological process at farm and include the assessment of farm results. Nevertheless, a farmer who has favourable characteristics would likely to have good results in management practices even if there might be some faults in his decision making process.

6.3. Recommendations

This result could be implied for Ministry of Natural Resource and Environment, Ministry of Agriculture and Rural Development, Hanoi People's Committee, Hanoi Urban Planning Department, the local authorities, NGOs, donors, local leaders, local cooperatives, and local farmers.

From the dynamics of internal and external factors, this research suggest that more efforts should been made in institution and social aspect of urban wastewater management relating to reuse of wastewater taken by farmers. The resilience transition of the system could be enhanced by empowering farmers' managerial capacity toward institutional and social environment.

This research proposes two mechanisms for strengthening farmers' managerial capacity on wastewater governance via wastewater irrigation, i.e. strengthening social participation and institutional involvement of farmers.

6.3.1. Participatory wastewater irrigation management

This research strongly suggests that farmers should be more involved in the management of wastewater irrigation practice. The participation of farmers is including mobilizing wastewater resources, contribution on cost of wastewater treatment and irrigation facilities, minimizing health risks and other environmental risks posed by wastewater irrigation.

There is a need for farmer organization which acts as wastewater user association. This organization should be given full authorities including planning, design, operation, maintenance, rehabilitation, resource mobilization and conflict resolution.

Based on current status of decentralized irrigation service provision by the LCs, this research suggests that Wastewater User Associations (WWUAs) could negotiate with Irrigation and Drainage Management Companies (IDMCs) about supplementary water sources.

WUAs could also make contract to the fishermen or other Participatory Irrigation Management (PIM) institutions, local irrigation and drainage companies to supply water to the field. The fee for water services collected from participant's farmers could be higher than the present's fee and should based on farmers willingness to pay and the willingness to sell of the water sellers.

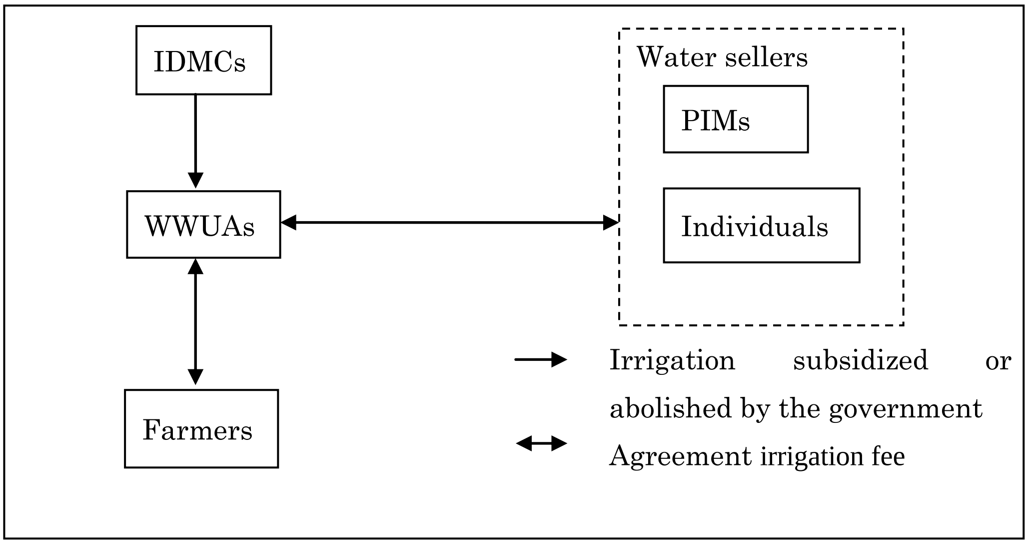


Figure 62. Mechanism for irrigation at local scale

6.3.2. Integrated urban wastewater management and wastewater irrigation

There is a need for cooperation of different governmental bodies and stakeholders along the urban wastewater chain and food chain. Each stakeholder has to recognize the common goal of safe wastewater irrigated products. Farmers should be recognized as the stakeholder in the management of urban wastewater systems. In this manner, farmers could have access to information to get control over risks and optimizing benefit from wastewater reuse and as the same time have responsibility over the products. This could therefore prevent farmers to behave like self interested or *spot-market,* which would lead to more sustainable and long-term management.

This research strongly suggest that the government, donors, NGOs should provide support to local farmers in terms of capacity building, financial resources, rule enforcement, consultation, assistance over resource utilization and conflict resolution. For capacity building, it is necessary to develop managerial skills as well as leadership capacities of farmers' leader.

Agriculture extension services and NGOs should provide farmers with technology transfer focusing on irrigation technology, wastewater treatment, crop management and guidelines for safe practice of wastewater irrigation.

Trust should be built up between farmers and those stakeholders so that the message of safe production of food could be widespread. Scientists should have multidimensional knowledge and working closer with farmers to build up trusts and develop effective and suitable measures.

This research suggested that the authorities, NGOs, and donors should consider managerial capacity characteristics of farmers within wastewater farming. Farmers are more likely to participate in irrigation management if they have more motivation in wastewater agriculture and they could account for wastewater irrigation as the provision of their livelihood.

References

Andersen, L. S. (2005). Urban water supply and sanitation *Wastewater management in the tropics* (pp. 203-305). London: IWA.

Boehlje, M. D., & Eidman, V. R. (1984). *Farm Management*. New York: John Wiley & Sons.

Bos, R., Carr, R., & Keraita, B. (2010). Assessing and Mitigating Wastewater-Related Health Risks in Low-Income Countries: An Introduction. In P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (Eds.), *Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries* (pp. 29-50). London: EarthScan.

Bouwer, H. (1994). Irrigation and global water outlook. *Agricultural Water Management, 25*(3), 221-231.

Brody Lee, T. B. a. A. B. D. (2010). The Dynamics of Urban Agriculture in Hanoi, Vietnam. *Urban Agriculture, The Journal of Field actions*.

CarinW.Rougoor, GerTrip, RuudB.M.Huirne, & JanA.Renkema. (1998). How todefine and study farmers' management capacity: theory and use in agricultural economics. *Agricultural Economics, 18*, 261-272.

Chi, T. T. N., & Ryuichi, Y. (2002). Factors affecting farmer's adoption of technologies in farming system: A case study in OMon district, Can Tho province, Mekong delta. *Omonrice 10*, 94-100.

Clark, W. C. (2007). Sustainability Science: A room of its own. *PNAS Proceedings of the National Academy of Science of The United States of America*, 1737-1738.

Clark, W. C., & Dickson, N. M. (2003). Sustainability science: The emerging research program. *PNAS Proceedings of the National Academy of Science of The United States of America, 100,* 8059–8061.

Do, T. T., Hoek, W., Vinh, K., Phung, C. D., Nguyen, H. V., & Dalsgaard, A. (2006). Low risk for helminth infection in wastewater-fed rice cultivation in Vietnam. *Journal of Water and Health,* 321-331.

Eisenhardt, K. M. (1989). Building theories from case study research. *The Academy of Management Review, 14*(4).

Evers, J. G., Huibers, F. P., Van Vliet, B. J. M., Dung, N. V., & Van, D. T. H. (2006). *Nutrient management and institutional cooperation as conditions for environmentally safe wastewater irrigation: the case of Hanoi, Vietnam.* Paper presented at the International Workshop on Environmental Consequences of Irrigation with Poor Quality Waters, New Delhi.

Evers, J. G., Huibers, F. P., & Vliet, B. J. M. V. (2010). Institiutional aspect of integrating irrigation into urban wastewater management: the case of Hanoi, Vietnam. *Irrigation and drainage, 59*, 336-344.

FAO. (2000). *Small ponds make a big difference - Integrating fish with crop and livestock farming*. Rome: FAO.

Gunn, I., Ferguson, G., & Dakers, A. J. (2003). *Sustainable Wastewater Management: A Handbook for Smaller Communities*: Ministry for the Environment- New Zealand.

Haas, C. N., Rose, J. B., & Gerba, C. P. (1999). *Quantitative Microbial Risk Analysis*. New York: John Wiley & Sons.

Haruvy, N. (1997). Agricultural reuse of wastewater: nation-wide cost-benefit analysis. *Agriculture Ecosystems and Environment, 66*(2), 113-119.

Ho, T. L. T. (2001). *Status of Heavy Metal Pollution of Agricultural Soils and River Sediments in Central Hanoi.* Paper presented at the Wastewater Reuse in Agriculture in Vietnam: Water management, Evironment and Human health aspects, Hanoi.

HSO. (2010). *Hanoi Statistical Yearbook 2009*. Hanoi.

Huibers, F., Redwood, M., & Raschid-Sally, L. (2010). Challenging Conventional Approaches to Managing Wastewater Use in Agriculture. In P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (Eds.), *Wastewater irrigation and health: Assessing and Mitigating Risk in Low-income Countries* (pp. 287-302). London: Earth Scan, IDRC, IWMI.

Jon, E. (2007). *Explaining social behavior : more nuts and bolts for the social sciences*. New York Cambridge University Press.

Karia, G. L., & Christian, R. A. (2006). *Wastewater treatment: Concepts and design approach*. New Delhi: Prentic-Hall of India Private Limited.

Kates, R. W., Clark, W. C., Robert Corell, J., Hall, M., & Jaeger, C. C. (2001). Sustainability Science. *Science, 292*, 641-642.

Knudsen, L. G., Pham, P. D., Nguyen, T. H., Samuaelsen, H., Jensen, P. K., Dalsgaard, A., et al. (2008, 3). The Fear of Awful Smell: Risk Perceptions among Farmers in Vietnam Using Wastewater and Human Excreta in Agriculture. *Southeast Asian Journal of Tropical Medicine and Public Health Vol.39 no.2,* 341-352.

Komiyama, H., & Takeuchi, K. (2006). Sustainability science: building a new discipline. *Sustainability Science,* 1-6.

Le, T. H. (2003, 11). Programs to Improve Production and Consumption of Animal Source Foods and Malnutrition in Vietnam. *Animal Source Foods to Improve Micronutrient Nutrition in Developing Countries, The Journal of Nutrition,* 4006S-4009S.

Le, T. L. (2001). The VAC system in Northern Viet Nam. *Integrated agriculture-aquaculture A Primer,FAO/IIRR/WorldFish Center*.

Lee, B., Binns, T., & Dixon, A. (2010). The Dynamics of Urban Agriculture in Hanoi, Vietnam. *Urban Agriculture, The Journal of Field actions*.

Minhas, P. S., & Samra, J. S. (2003). Quality assessment of water resources in Indo-Gangetic basin part in India. Karnal, India: Central Soil Salinity Research Institute.

Narayan, D. (1995). Contribution of People's Participation: Evidence from 121 Rural Water Supply Projects (pp. 116): The International Bank for Reconstruction and Development/THE WORLD BANK.

Nguyen, N. N., Hoang, T. N., Nguyen, Q. Q., & Tran, Q. T. (2001). *Water Quality in Drilled Wells in Hanoi.* Paper presented at the Wastewater Reuse in Agriculture in Vietnam: Water management, Evironment and Human health aspects, Hanoi.

Pescod, M. B. W. (1992). The urban water cycle including wastewater use in agriculture. *Outlook on Agriculture, 21*(4), 263-270.

Phuong, N. T. D., Tuan, P. A., Tien, N. T. H., Bau, P., Diep, H. K., & Tan, N. T. (2005). Report on Baseline and Monitoring Survey in aquatic producer households in peri-urban Hanoi. Hanoi: Production in Aquatic Peri-urban systems in Southeast Asia.

Quadir, M., D.Wichelns, Raschid-Sally, L., MacCornick, P. G., P.Drechsel, Bahri, A., et al. (2010). The challenges of wastewater irrigation in developing countries. *Agricultural Water Management 97,* 561-568.

Raju, K. V., & Brewer, J. D. (2001). Social and Environmental Assessment of Karnataka Community-based Tank Improvement Project Bangalore: Jal Samvardhane Yojana Sangh of Government of Karnataka Bangalore: Institute for Social and Economic (draft report, July 2001).

Raju, K. V., Dayal, P., & Chatterji., J. (2008). *Irrigation management transfer: Strategies and Best Practices*. New Delhi, India: Asian Development Bank.

Raschid-Sally, L., & Jayakody, P. (2008). Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment *IWMI Research Report* (Vol. 127, pp. 35). Colombo,Sri Lanka: International Water Management Institute.

Raschid-Sally, L., Tuan, D. D., & Abayawardana, S. (2004). *National Assessments on Wastewater Use in Agriculture and an Emerging Typology: The Vietnam Case Study*: CABI, IWMI, IDRC.

Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2003). *Wastewater Engineering: Treatment and Reuse* (4 ed.). New York: McGraw-Hill.

Trinh, T. L. (2001). *Wastewater and its Treatment System in the Southern part of Vietnam.*

Paper presented at the Wastewater Reuse in Agriculture in Vietnam: Water management, Evironment and Human health aspects, Hanoi.

Ujang, Z., & Henze, M. (2006). *Municipal Wastewater Management in Developing Countries. Principles and Engineering*. London: IWA Publishing.

UN-Habitat. (2006). *Meeting Development Goals in Small Urban Centres: Water and Sanitation in the World's Cities*. Nairobi: United Nations Human Settlements Programme.

van-Lier, J. B., & Huibert, F. P. (2004). *Agricultural use of treated wastewater: the need for aparadigm shift in sanitation and treatment*. Wallingford - UK: IAHS.

Vermillion, D., & Sagardoy, J. A. (1999). Transfer of irrigation management services: guidelines. *FAO Irrigation and Dranaige, 58*.

Viet Anh, N., Barreiro, W., & Parkinson, J. (2005). Decentralised Wastewater Management in Vietnam - A Hanoi case study. Hanoi.

Viet Anh, N., Hung Long, N., Ngoc Quang, T., Thanh Son, N., Tan Sinh, B., & Lan Huong, T. (2004). Towards application of Ecosan for urban areas in Vietnam (pp. 40). Hanoi: Swedish Environment Secretariat in Asia (SENSA).

Walker, B. H., & Salt, D. (2006). Resilience Thinking: Sustaining Ecosystems and People in a Changing World. *Island Press Washington, DC.*, 174.

WHO. (2006). Volume II: Wastewater use in agriculture *The Who Guidelines for the safe use of wastewater, excreta and grey water in agriculture*. France: The WHO Press.

WHO. (2009). *Global health risks: mortality and burden of disease attributable to selected major risks.*: WHO Press, World Health Organization.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.): Thousand Oaks, Calif. : Sage.

Annex

"This page is intentionally left blank"

Annex 1. Quality of Irrigation water

"This page is intentionally left blank"

Table 1. Water quality measured in Dong Ba (March,2011)

Name	Date	Temp	pH	EC	TDS	NH4-N	NO3-N	PO4-P	DO	COD	Cu	Fe total	Zn	Pb	E.coli	Total Coliform
		oC		mS/cm	ppt	mgN/l	mgN/l	mgP/l	mgO/l	mgO/l	mg/l	mg/l	mg/l	mg/l	MPN/ 100ml	MPN/ 100ml
TCVN B1					5.5~9			0.5	10	0.3	4	30	0.5	1.5	1.5	0.05
TCVN B2					5.5~9			1	15	0.5	2	50	1	2	2	0.05
DI1	2011/03/08	18.2	7.64	0.31	150	1	1	0.1	7	20	<0.5	0.3	0	0.1	200	95210
DI2	2011/03/08	18.1	7.67	0.31	150	1	1	0.2	9	10	<0.5	0.3	0	0.1	300	179190
DD3	2011/03/08	19.5	7.52	0.36	180	1	5	0.2	7	20	<0.5	<0.3	0	0.1	300	29000
DD5	2011/03/08	18.2	7.77	0.78	390	2	0.2	2	6	20	<0.5	1	0.5	0.1	400	520230
DI6	2011/03/08	18.1	7.69	0.3	150	2	1	0.1	7	20	<0.5	0.3	0	0.05	100	83500
DI8	2011/03/08	17.9	7.64	0.34	170	2	1	0.2	7	20	<0.5	0.3	0		100	65060
DD9	2011/03/08	19	7.52	0.32	150	2	2	0.2	6	20	<0.5	<0.3	0			
DD21	2011/03/13	20.9	7.48	0.38	190	2	0.5	0.2	5	20	<0.5	1	0.5		100	204000
DI22	2011/03/13	24.9	7.72	0.39	190	2	0	0.5	7	20	<0.5	1	0.5	0.1	550	364800
DD23	2011/03/13	21.6	7.46	0.56	280	2	0.2	0.5	7	20	<0.5	2	1		115	452400
DI24	2011/03/13	22.3	9.59	0.2	100	5	0	0.5	7	13	<0.5	<0.3	0		100	337200
DI31	2011/03/21	20.2	8.56	0.27	130	5	2		10	5	<0.5	<0.3	0.2		200	382400
DD32	2011/03/21					5									233	447100

Note

DI1 D- Dong Ba 1- ID of sample

TD2 T- Thanh Liet 2- ID of sample

(red) Water quality exceed TCVN- B2

(yellow) Water quality exceed TCVN- B1

Table 2. Water quality measured in Thanh Liet (March,2011)

Name	Date	Temp	pH	EC	TDS	NH4-N	NO3-N	PO4-P	DO	COD	Cu	Fe total	Zn	Pb	E.coli	Total Coliform
		oC		mS/cm	ppt	mgN/l	mgN/l	mgP/l	mgO/l	mgO/l	mg/l	mg/l	mg/l	mg/l	MPN/ 100ml	MPN/ 100ml
TCVN B1					5.5~9			0.5	10	0.3	4	30	0.5	1.5	1.5	0.05
TCVN B2					5.5~9			1	15	0.5	2	50	1	2	2	0.05
TD1	2011/03/05	17.2	7.28	0.72	360	5	1	0.5	6	13	<0.5	<0.3	0.2	1		
TD3	2011/03/05	17.5	7.65	1.28	640	>10	0.2	5	1	60	<0.5	1	0.5		400	1250000
TI4	2011/03/09	17.9	7.67	0.84	420	>10	1	2	7		<0.5	1	0	0.05		445000
TD5	2011/03/05	17.5	7.41	0.75	370	>10	5	0.5	5	13	<0.5	<0.3	0			
TD6	2011/03/05	18.2	7.57	0.93	460	>10	1	2	4	120	<0.5	0.5	0.2	0	600	900000
TD8	2011/03/05	18.8	7.76	0.82	410	5	5	1	4	50	<0.5	<0.3	0.2		1000	850000
TD9	2011/03/05	17.9	7.38	0.72	360	>10	1	1	4	13	<0.5	<0.3	0	0.2		
TI11		18	7.21	0.67	330	2	10	1	7	20	<0.5	<0.3	0			680000
TI10	2011/03/05	18.5		0.73	360	5	10	1	10	50	<0.5	1	0.2			667000
TI13	2011/03/05	18	7.83	1.03	510	5	2	0.5	7	50	<0.5	0.5	0.5			110000
TD14	2011/03/05	17.7	7.8	0.73	360	2	1		9	20	<0.5	0.5	0.2			450000
TD15	2011/03/19	16.8	7.49	0.65	320	>10	2	0.5	3	20	<0.5	2	0.5		233	1112000
TI16	2011/03/05	18.2	7.38	0.64	320	1	10	0.2	6	100	<0.5	0.3	0		800	680000
TI17	2011/03/05	19.4	7.69	1.5	750	>10	0.2	2	1	120	<0.5	0.5	0.5		500	100000
TD22	2011/03/19	17.7	7.4	0.68	350	>10	0.5		1	20	<0.5	0.5	0.2	0.2	133	265000
TD23	2011/03/19	19.3	7.46	0.68	330	>10	1		1.3	13	<0.5	1	0.2		400	877500
TD24	2011/03/19	18.8	7.58	0.63	320	>10	0.2	2	0	30	<0.5	0.5	0.5	0.5	1400	2283000
TD31	2011/04/04	23.9	7.46	0.85	459	>10	0	2.00	0	120	<0.5	0.5	0.5	0.5		
TD32	2011/03/24	18.2	7.70	0.99	500	>10	0	2.00	0	120	<0.5	0.5	0.2	0.5		

Note

DI1 D- Dong Ba 1- ID of sample

TD2 T- Thanh Liet 2- ID of sample

(red) Water quality exceed TCVN- B2

(yellow) Water quality exceed TCVN- B1

Annex 2. Variation of Irrigation water quality at different measured points

"This page is intentionally left blank"

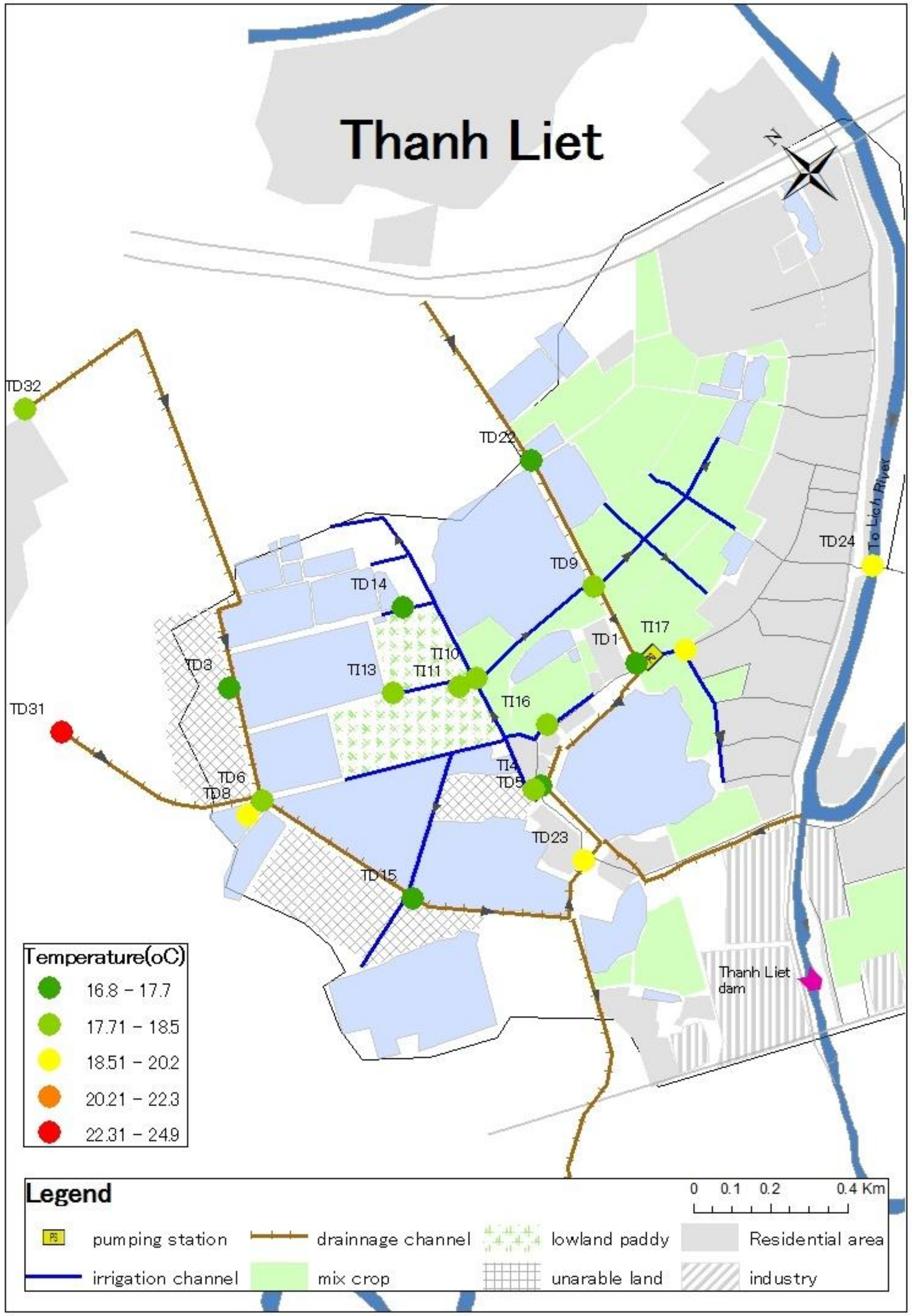


Figure 1. Temperature of water samples taken at different locations

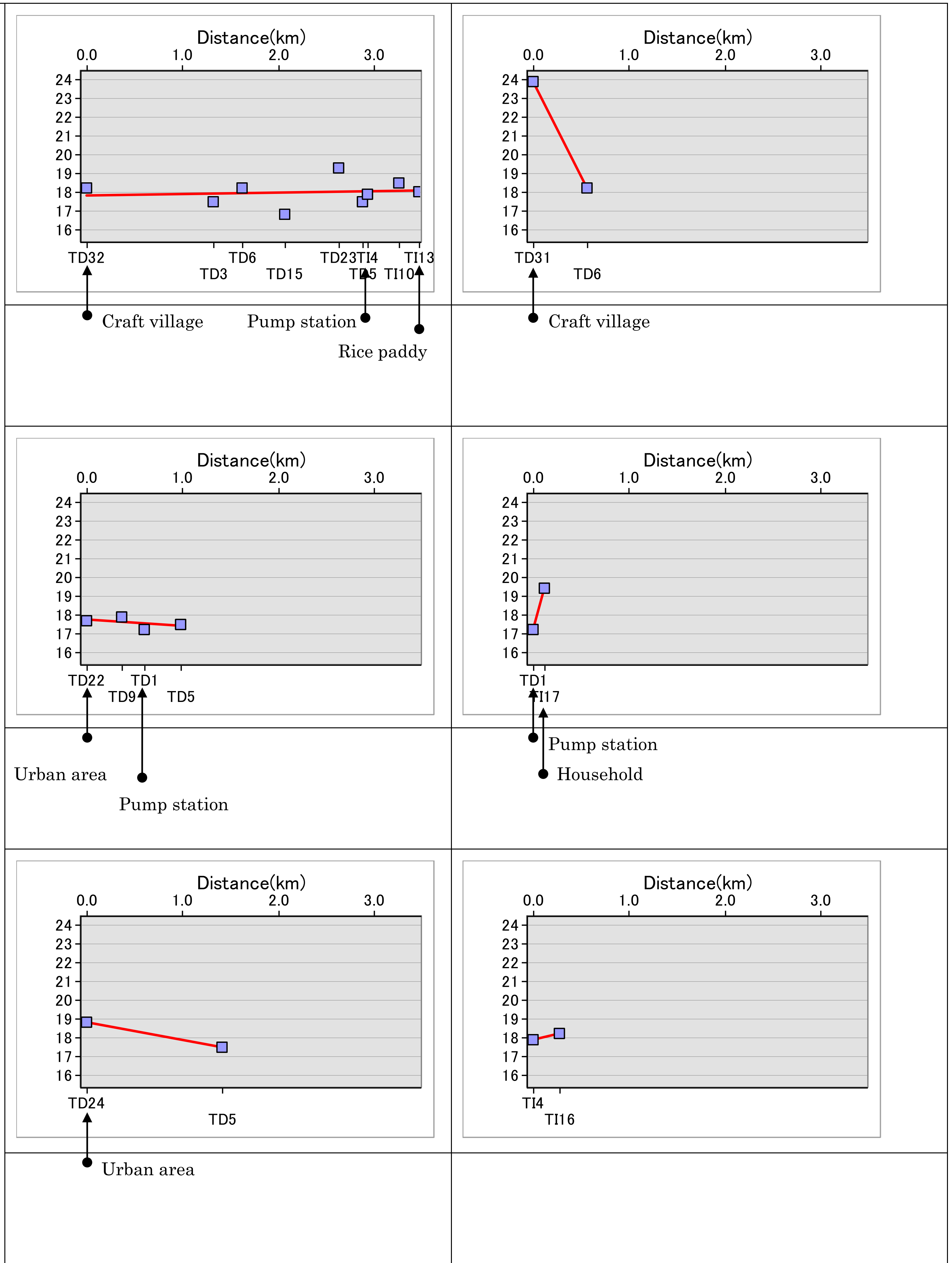


Figure 2. Temperature variation of water sample along channels

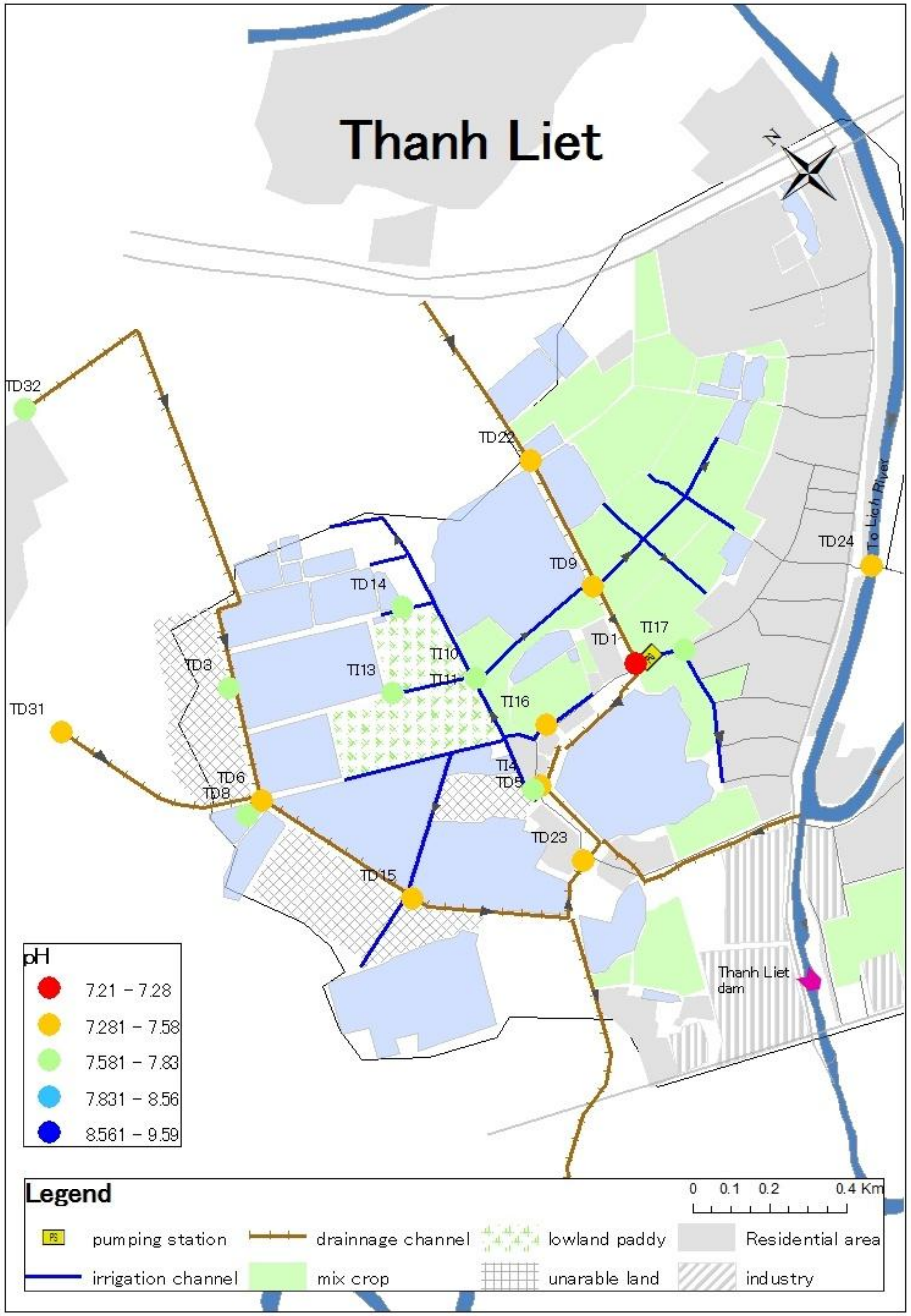


Figure 3. pH level of water samples taken at different locations

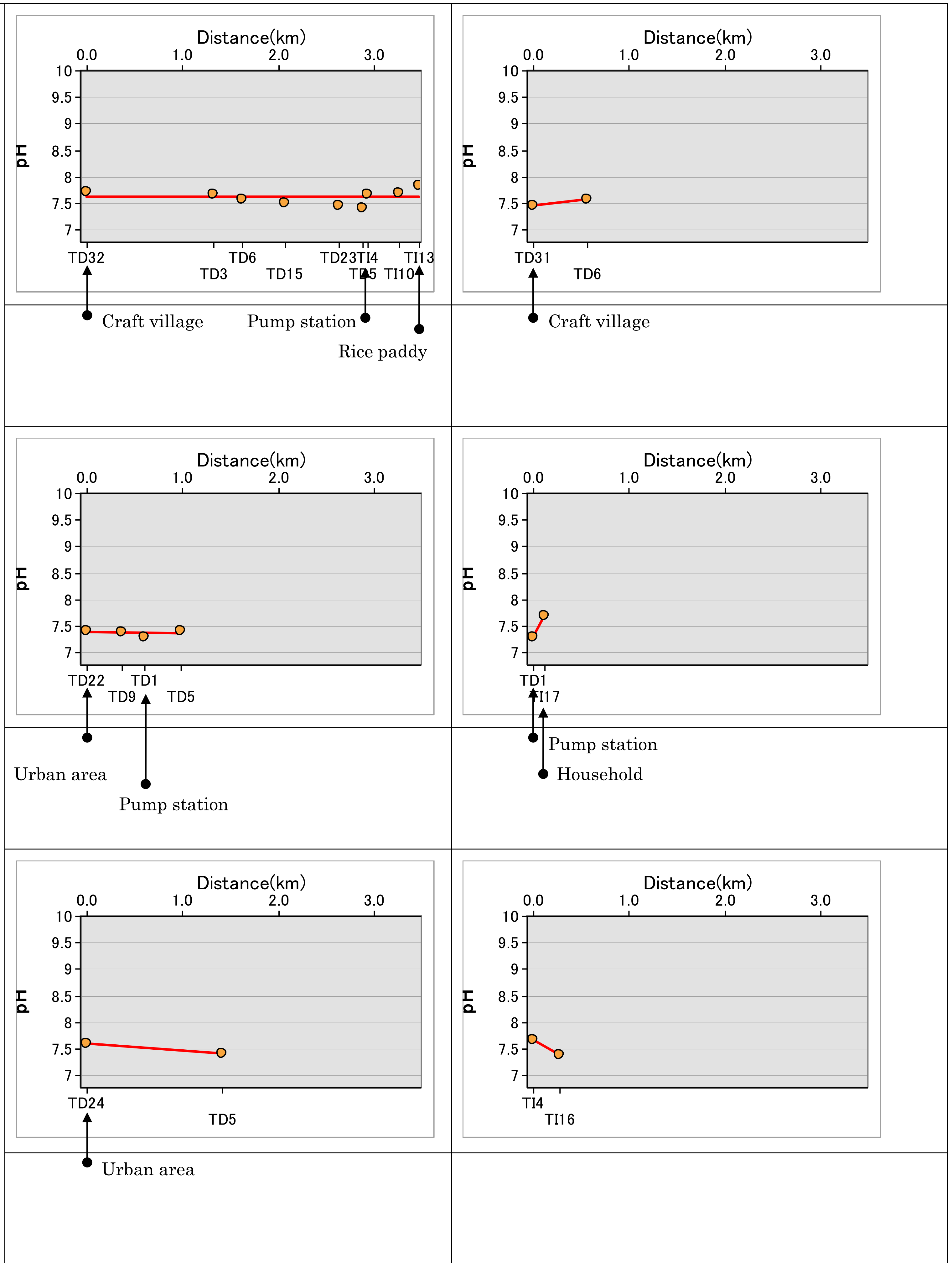


Figure 4. pH level variation of water sample along channels

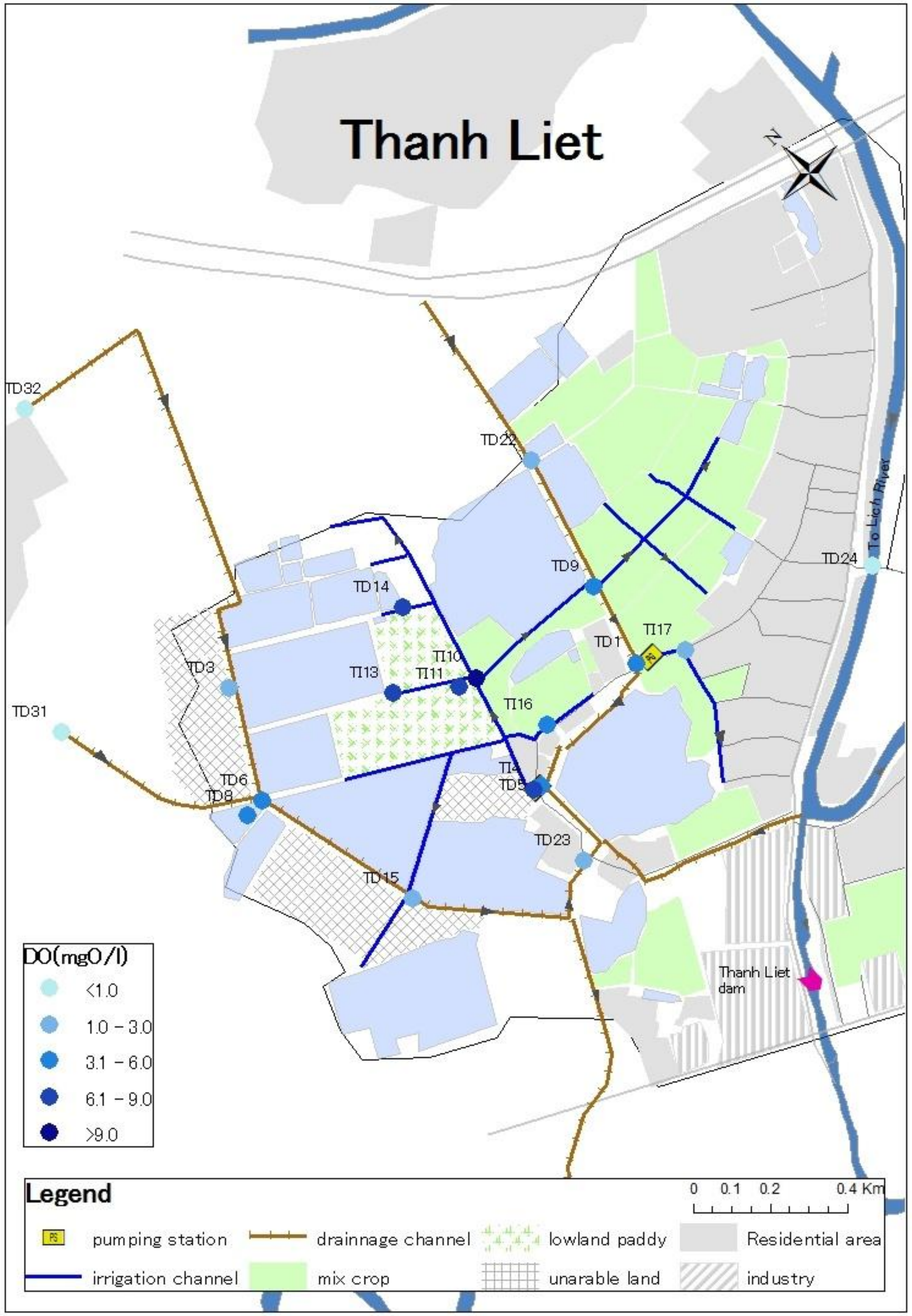


Figure 5 . Dissolved Oxygen level of water samples taken at different locations

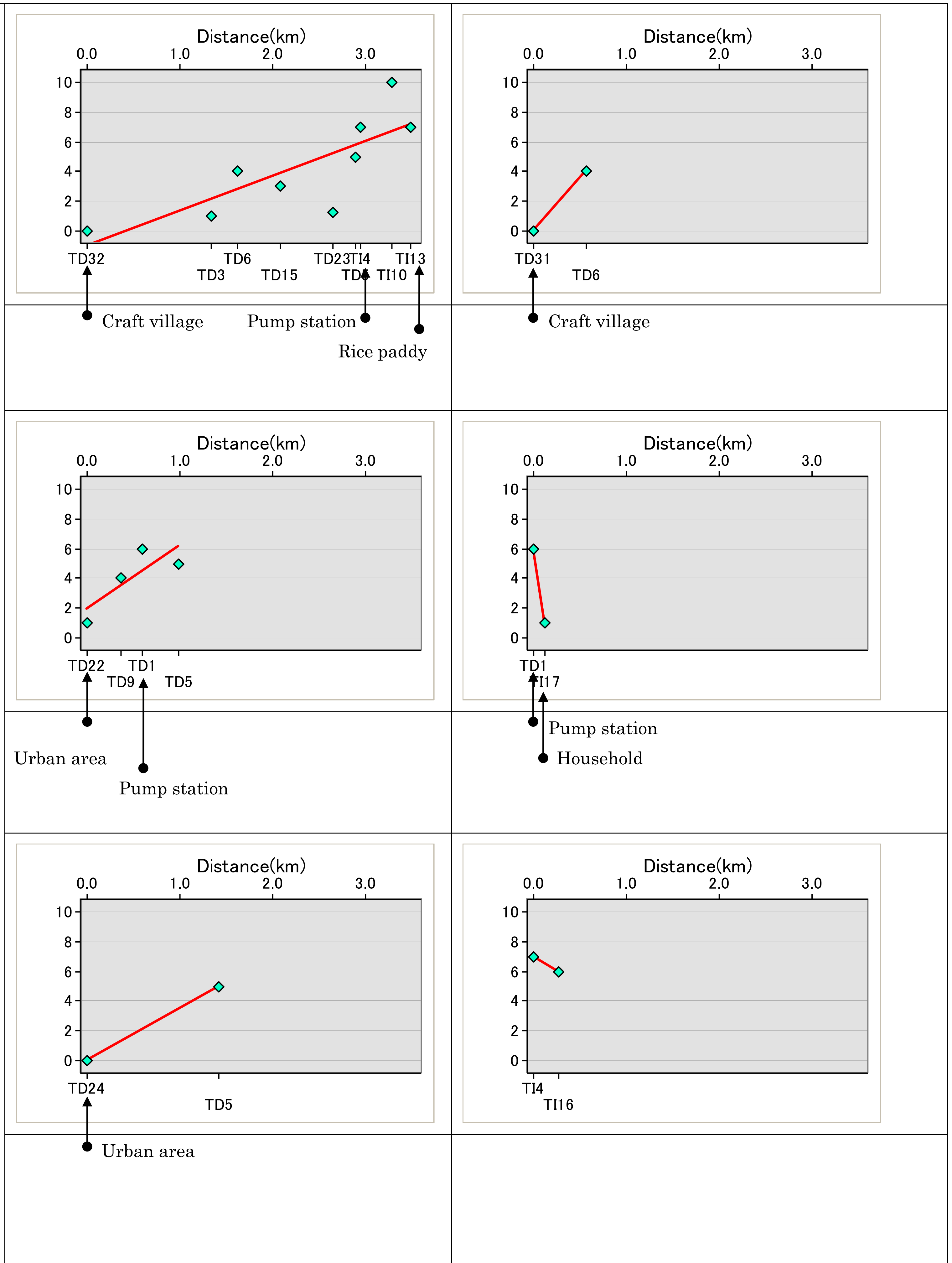


Figure 6. Dissolved Oxygen level variation of water sample along channels

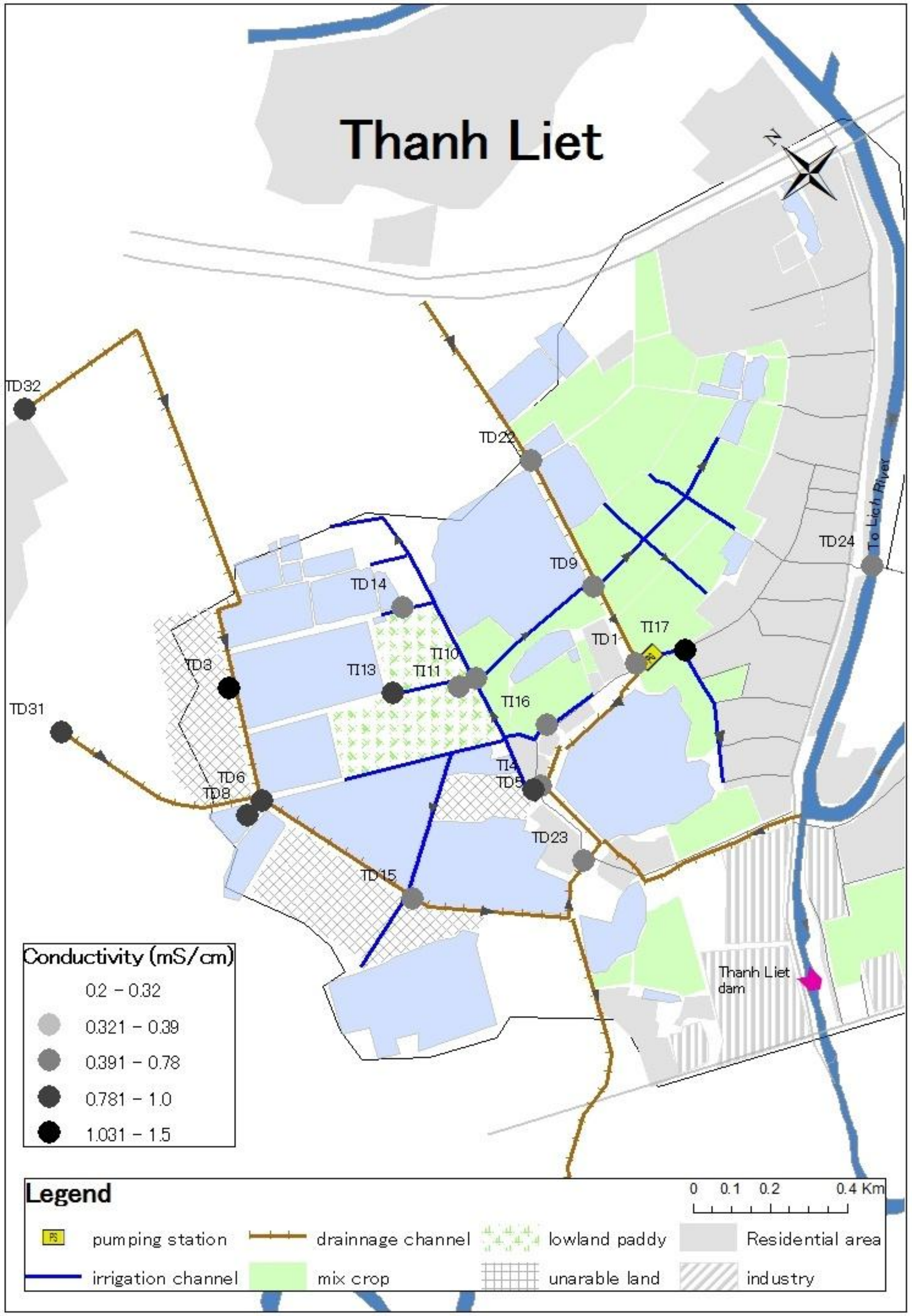


Figure 7. Conductivity of water samples taken at different locations

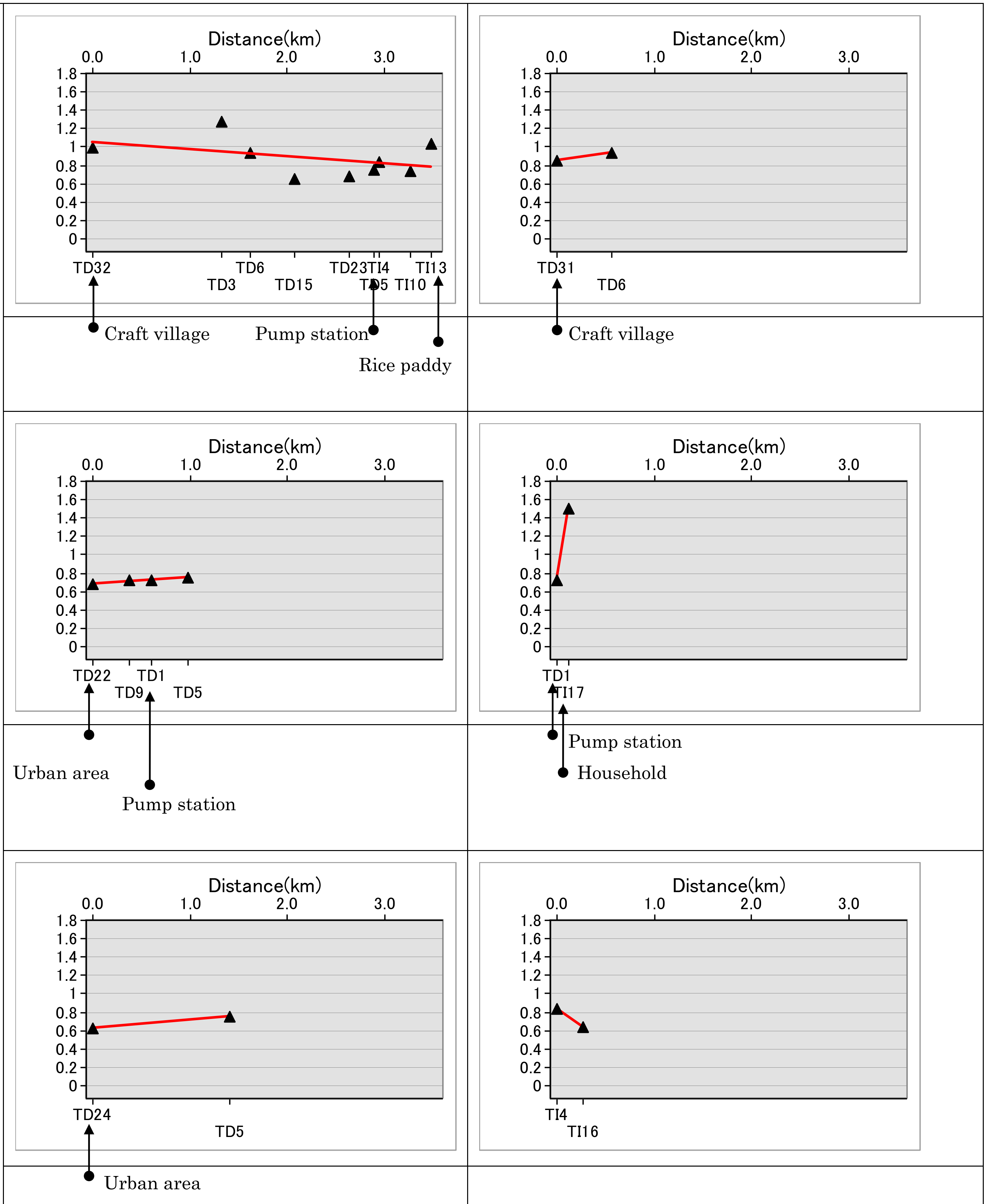


Figure 8. Conductivity variation of water sample along channels

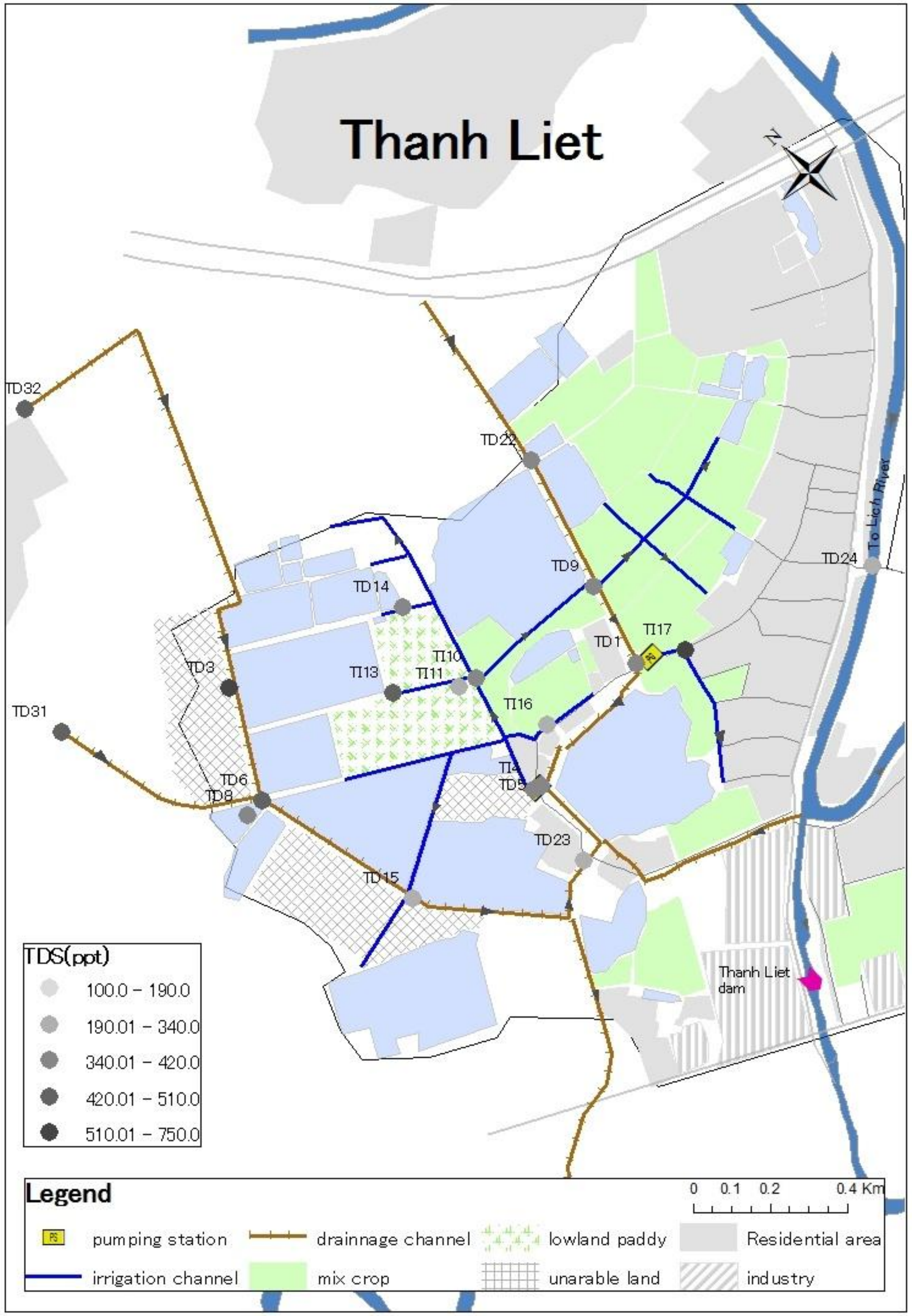


Figure 9. Total Dissolved Solid level of water samples taken at different locations

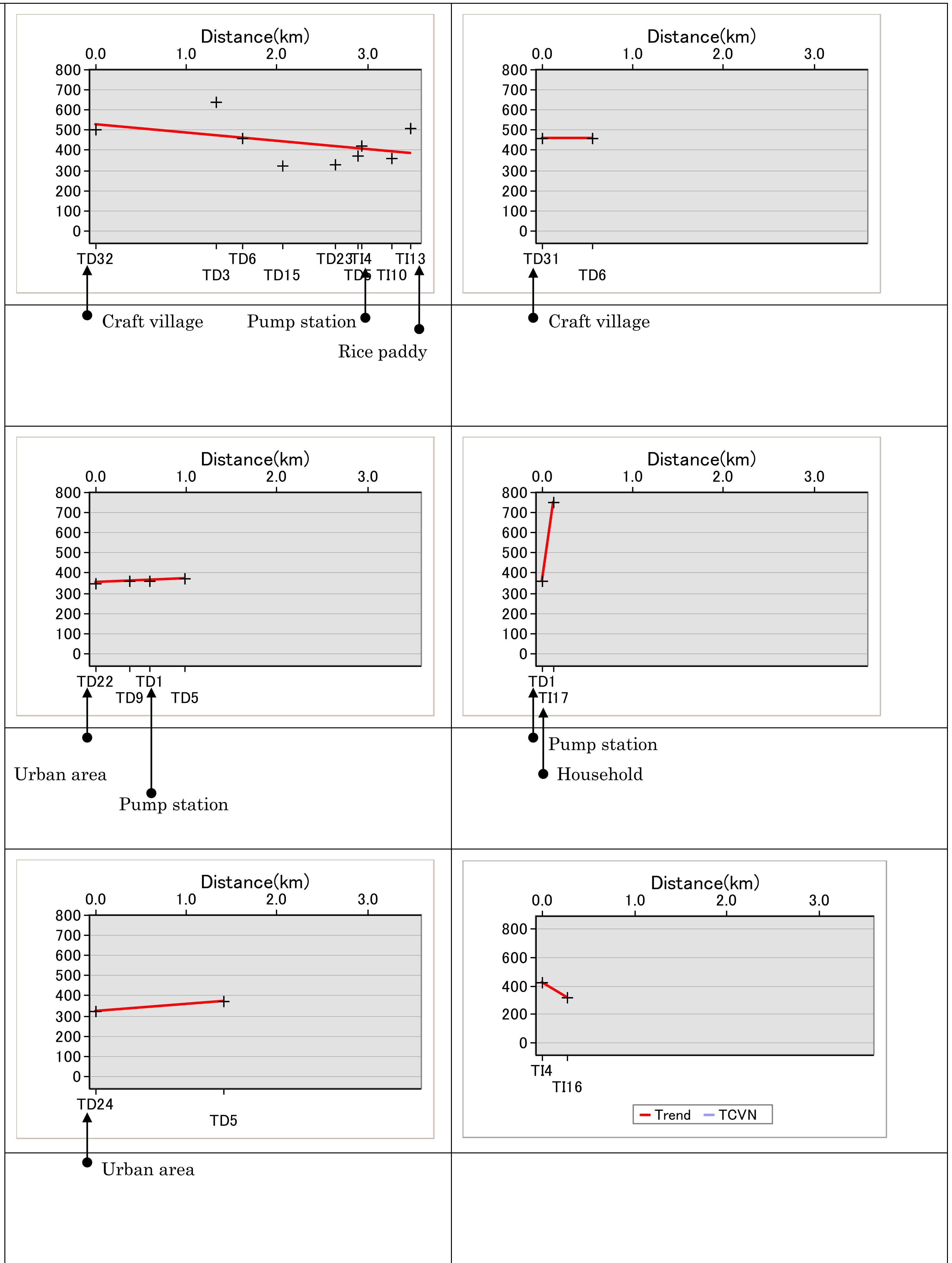


Figure 10. Total Dissolved Solid level variation of water sample along channels

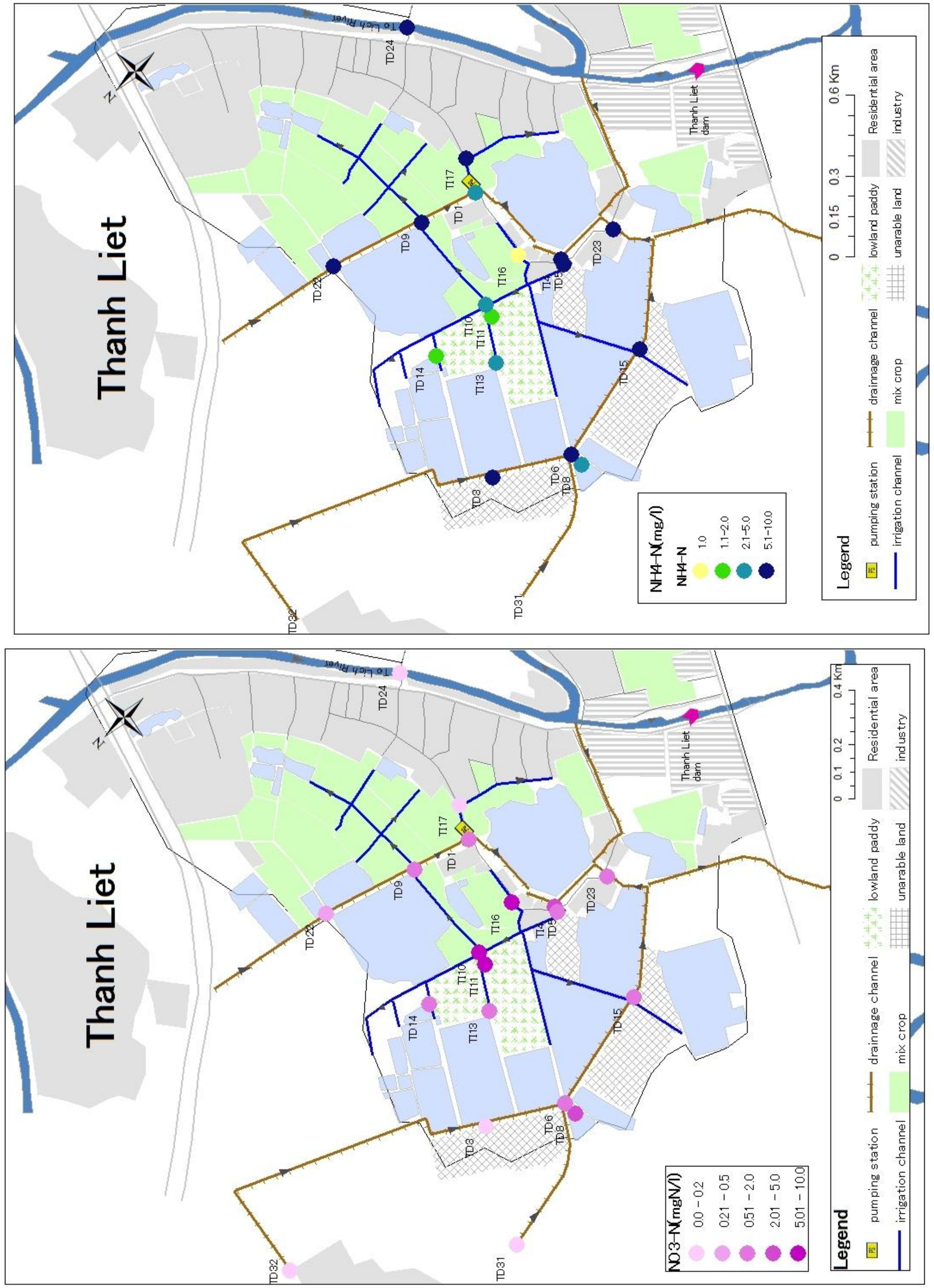


Figure 11. Ammonium and Nitrate level of water samples taken at different locations

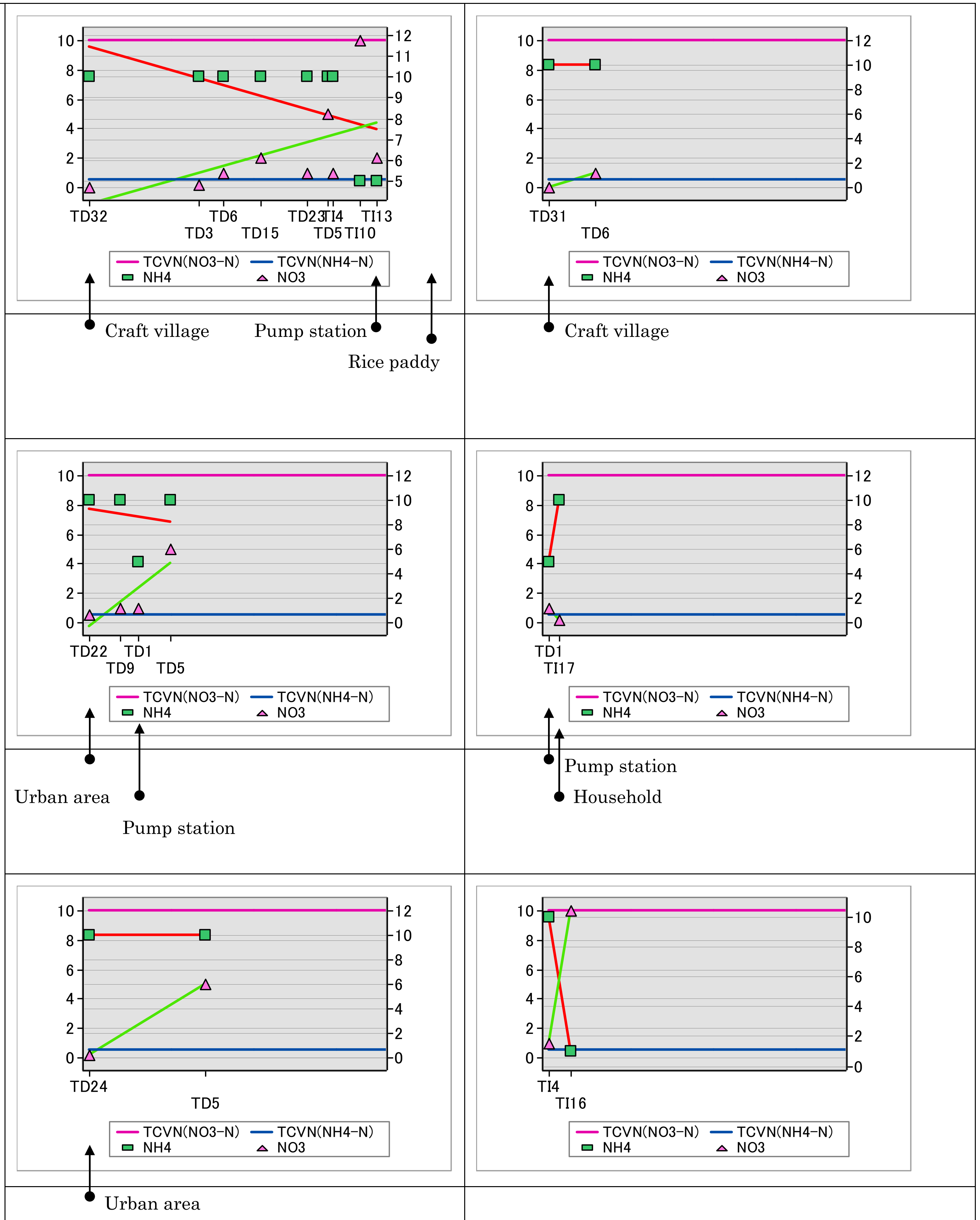


Figure 12. Ammonium and Nitrate level variation of water sample along channels

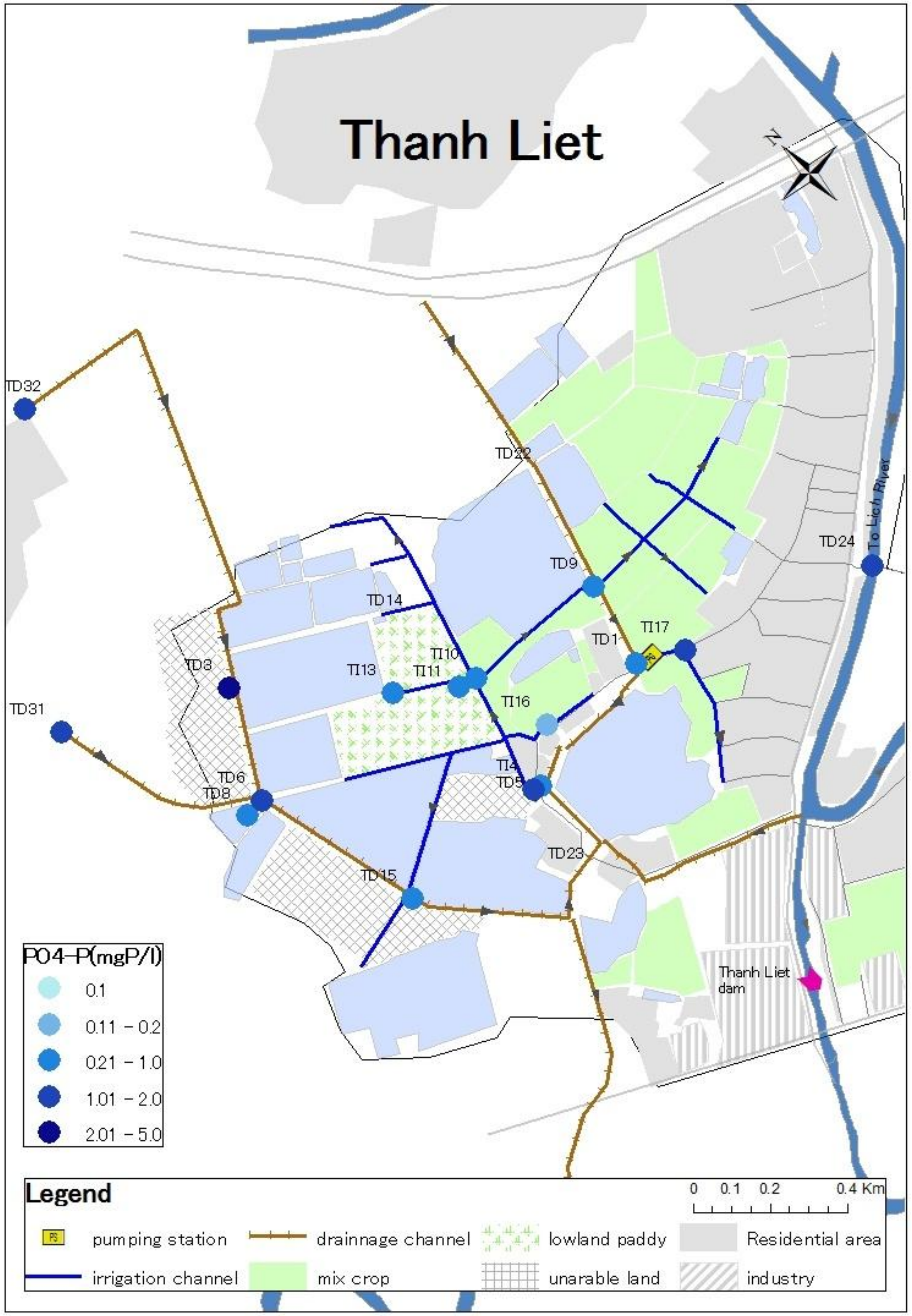


Figure 13. Phosphate level of water samples taken at different locations

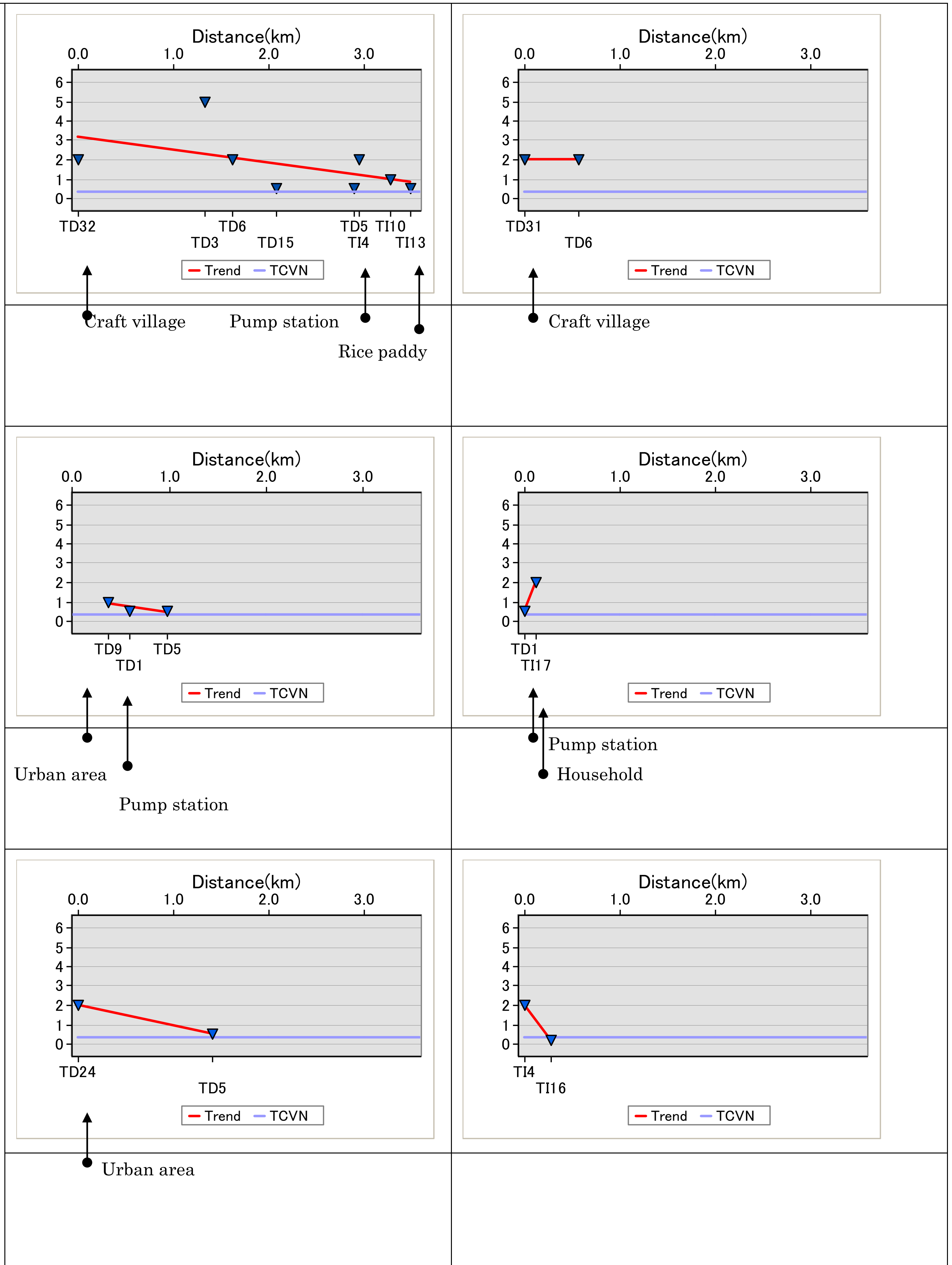


Figure 14. Phosphate level variation of water sample along channels

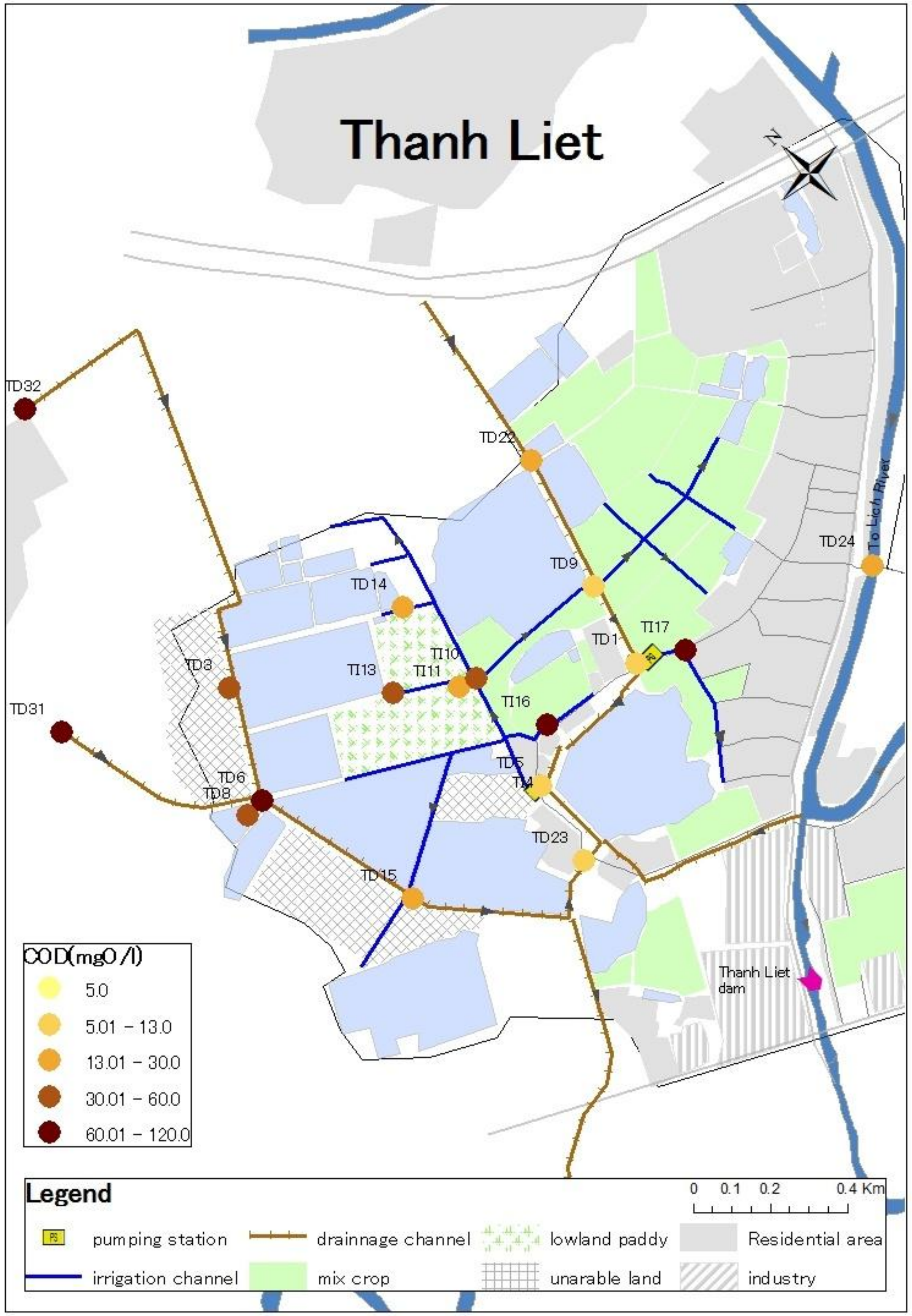


Figure 15. Chemical Oxygen demand ($KMnO_4$) level of water samples taken at different locations

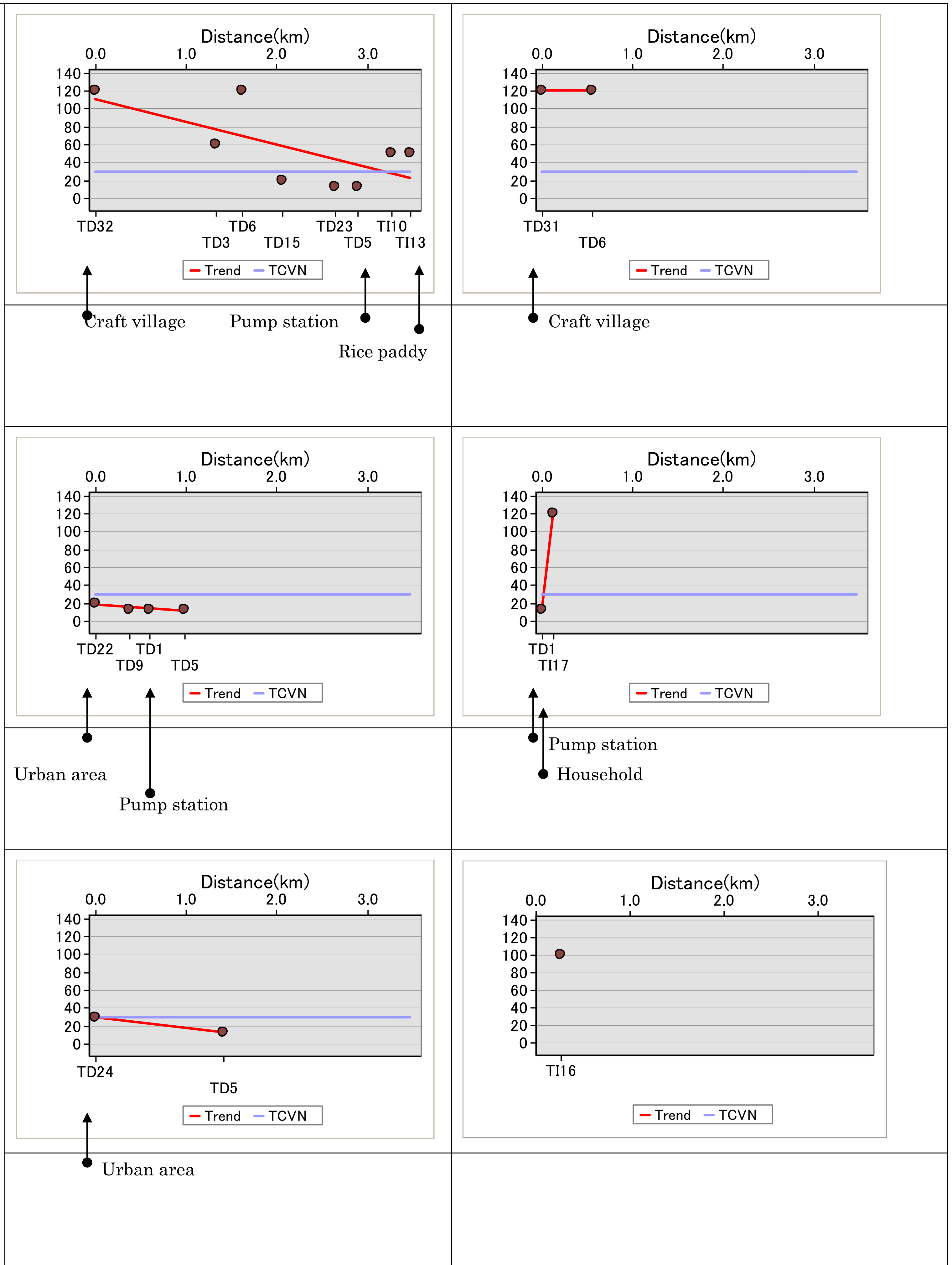


Figure 16. Chemical Oxygen demand ($KMnO_4$) level variation of water sample along channels

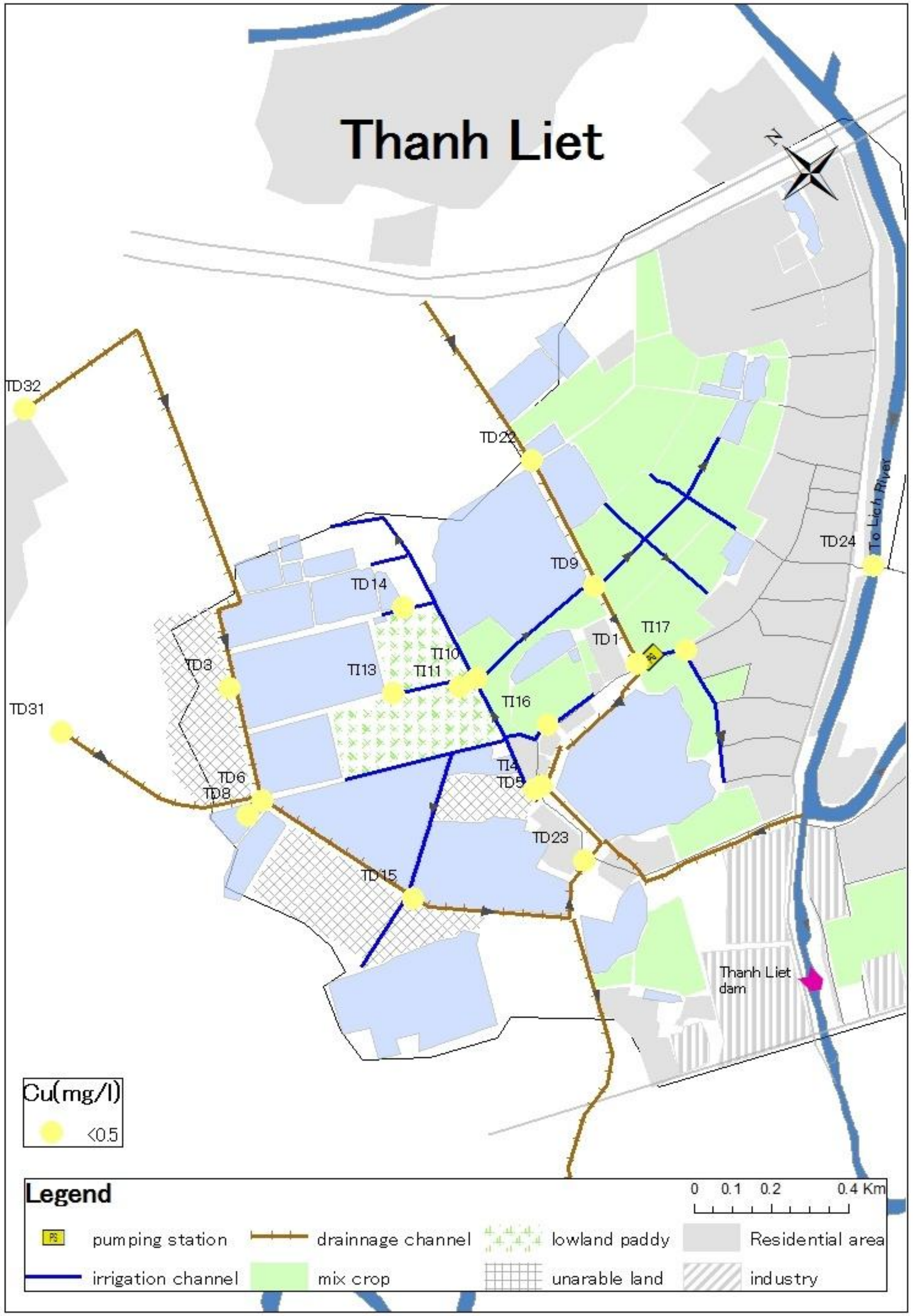


Figure 17. Copper level of water samples taken at different locations

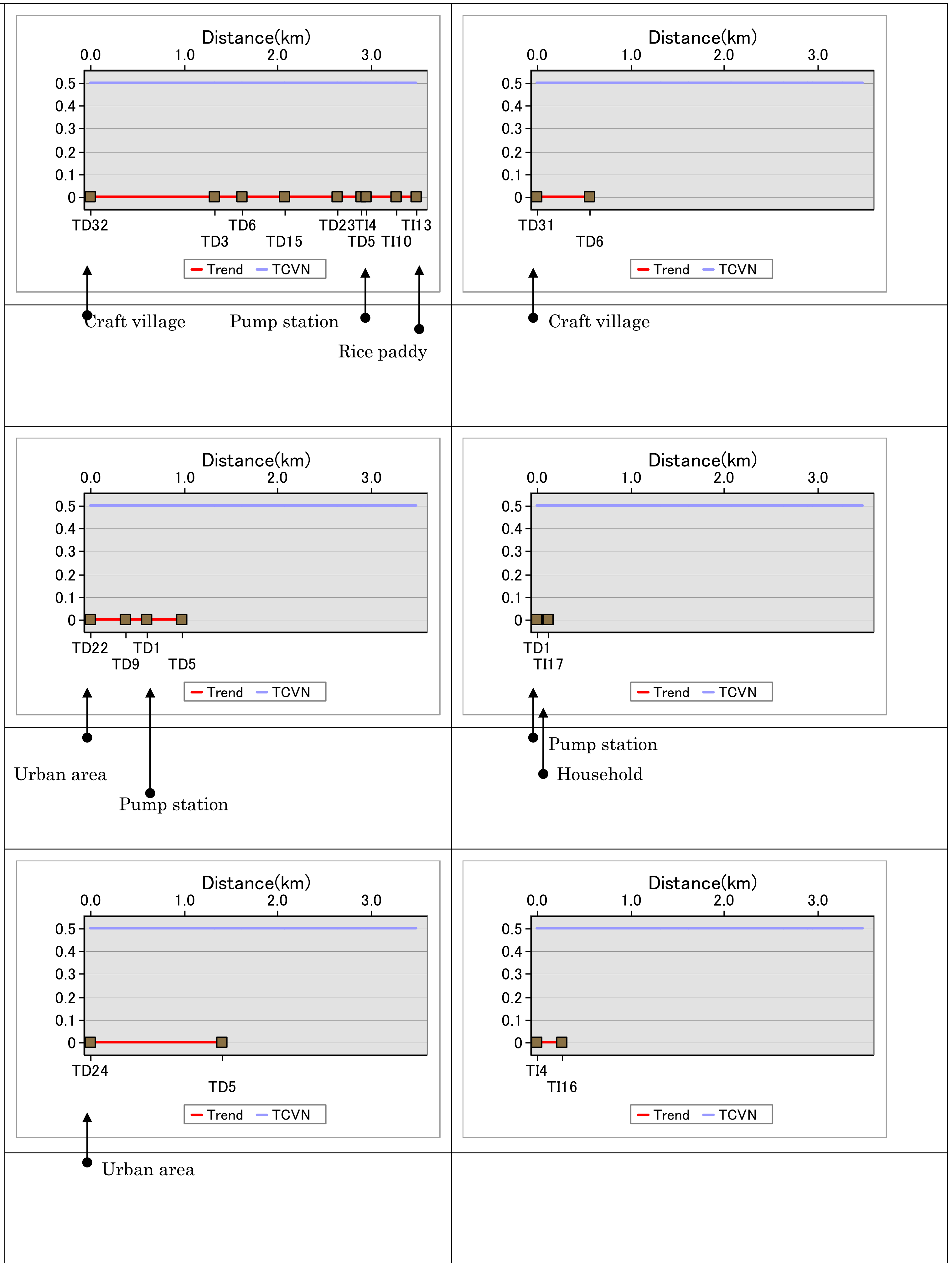


Figure 18. Copper level variation of water sample along channels

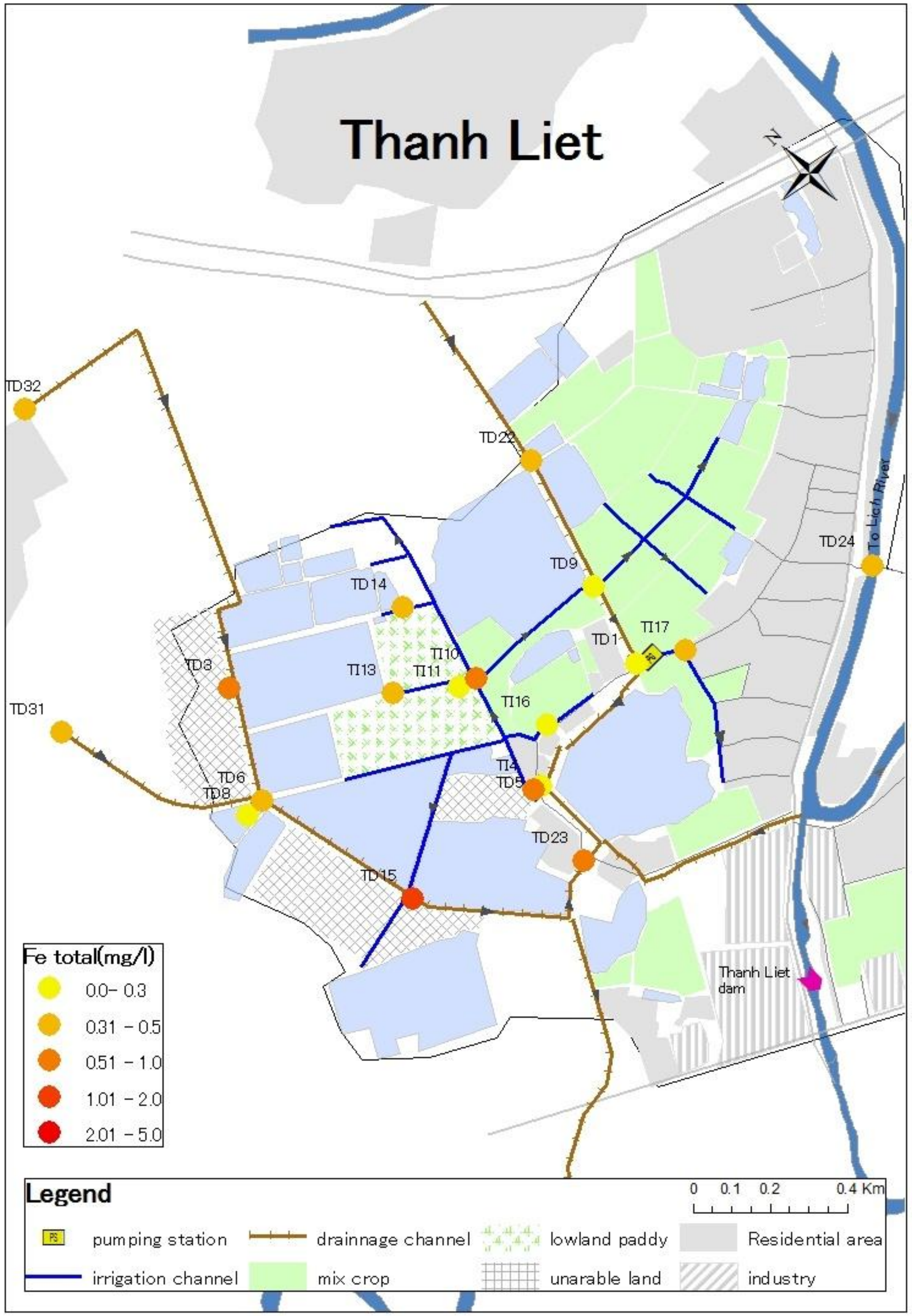


Figure 19. Total Iron(Fe^{2+} Fe^{3+}) level of water samples taken at different locations

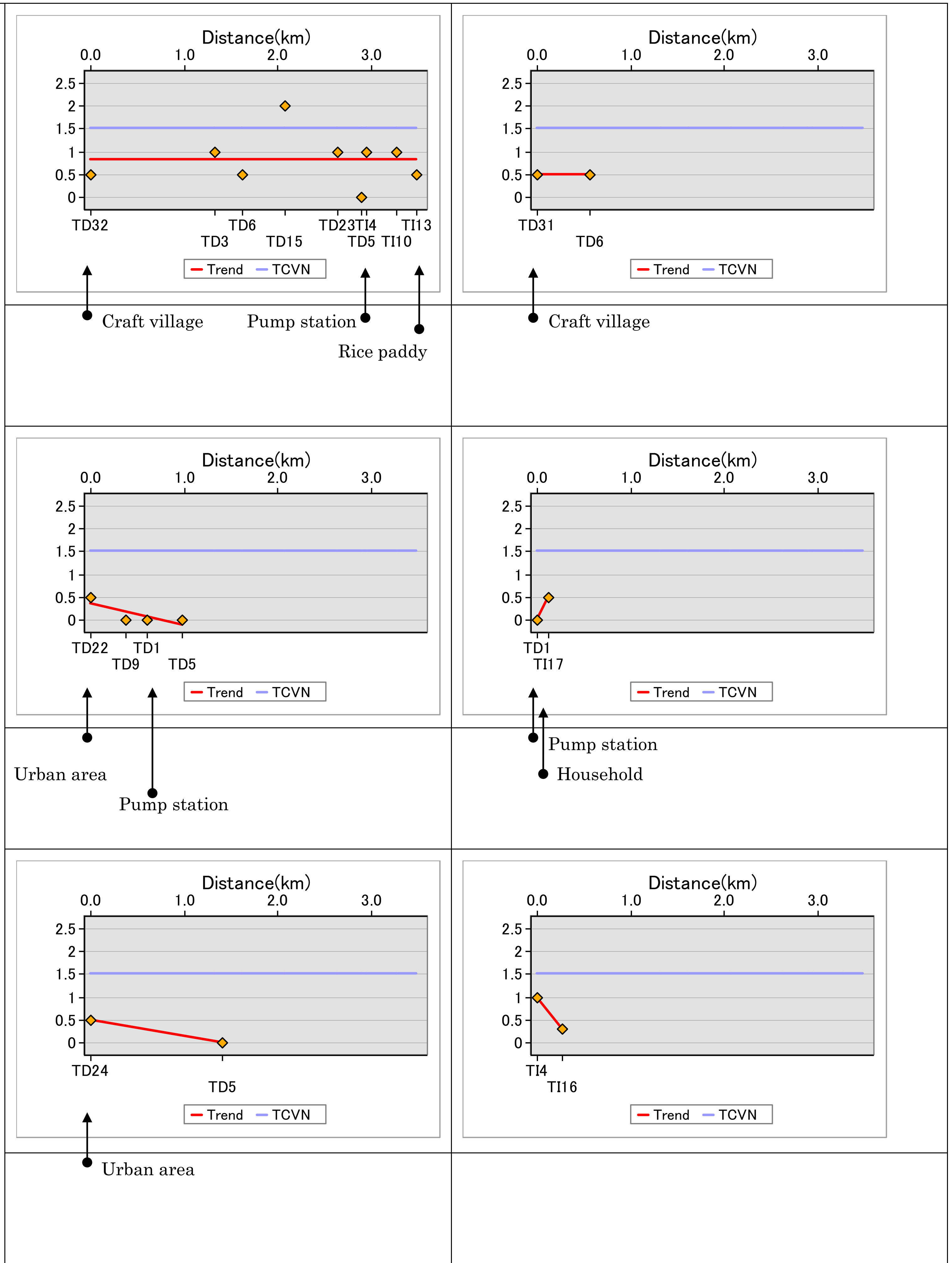


Figure 20. Total Iron level variation of water sample along channels

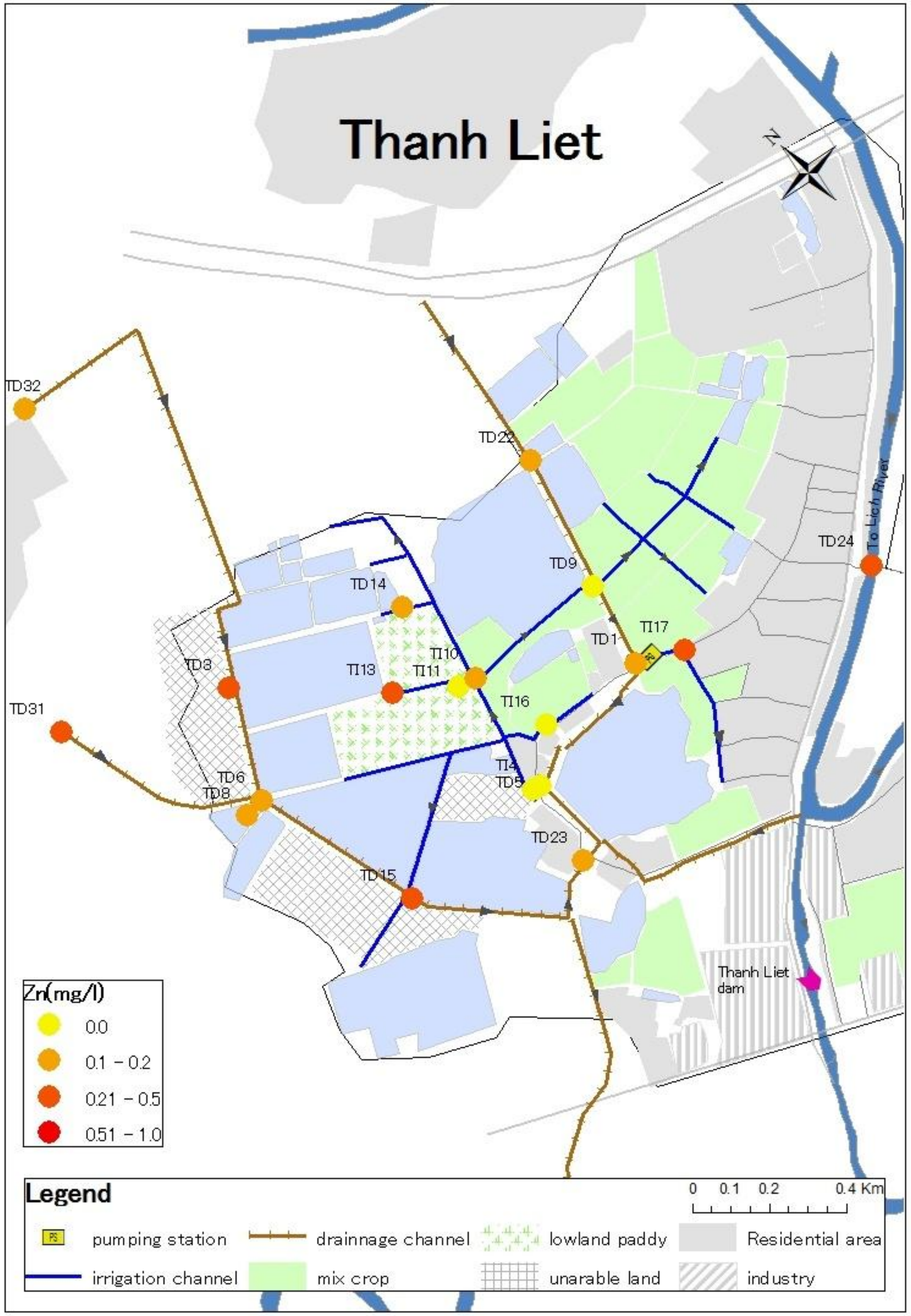


Figure 21. Zinc level of water samples taken at different locations

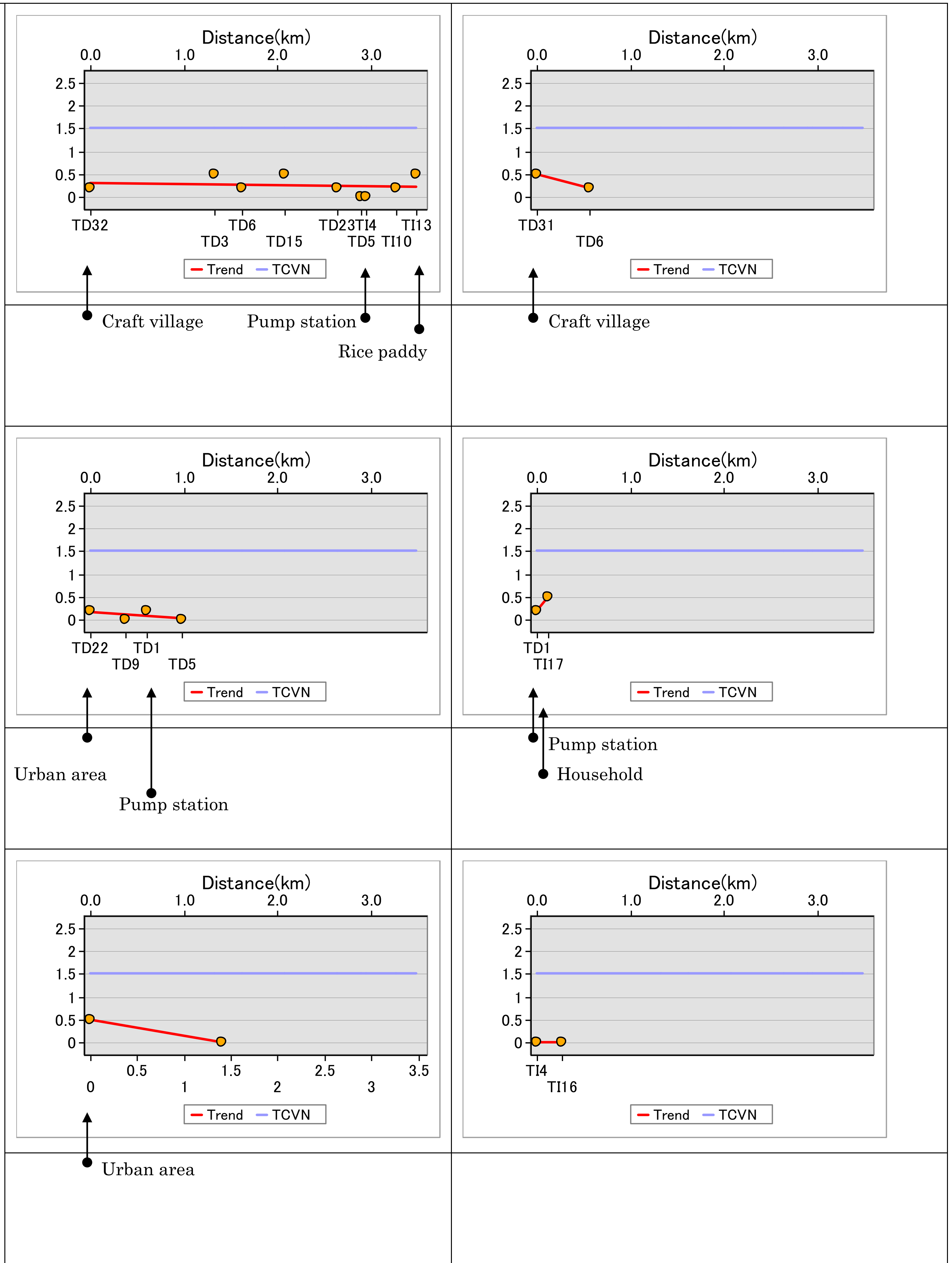


Figure 22. Zinc level variation of water sample along channels

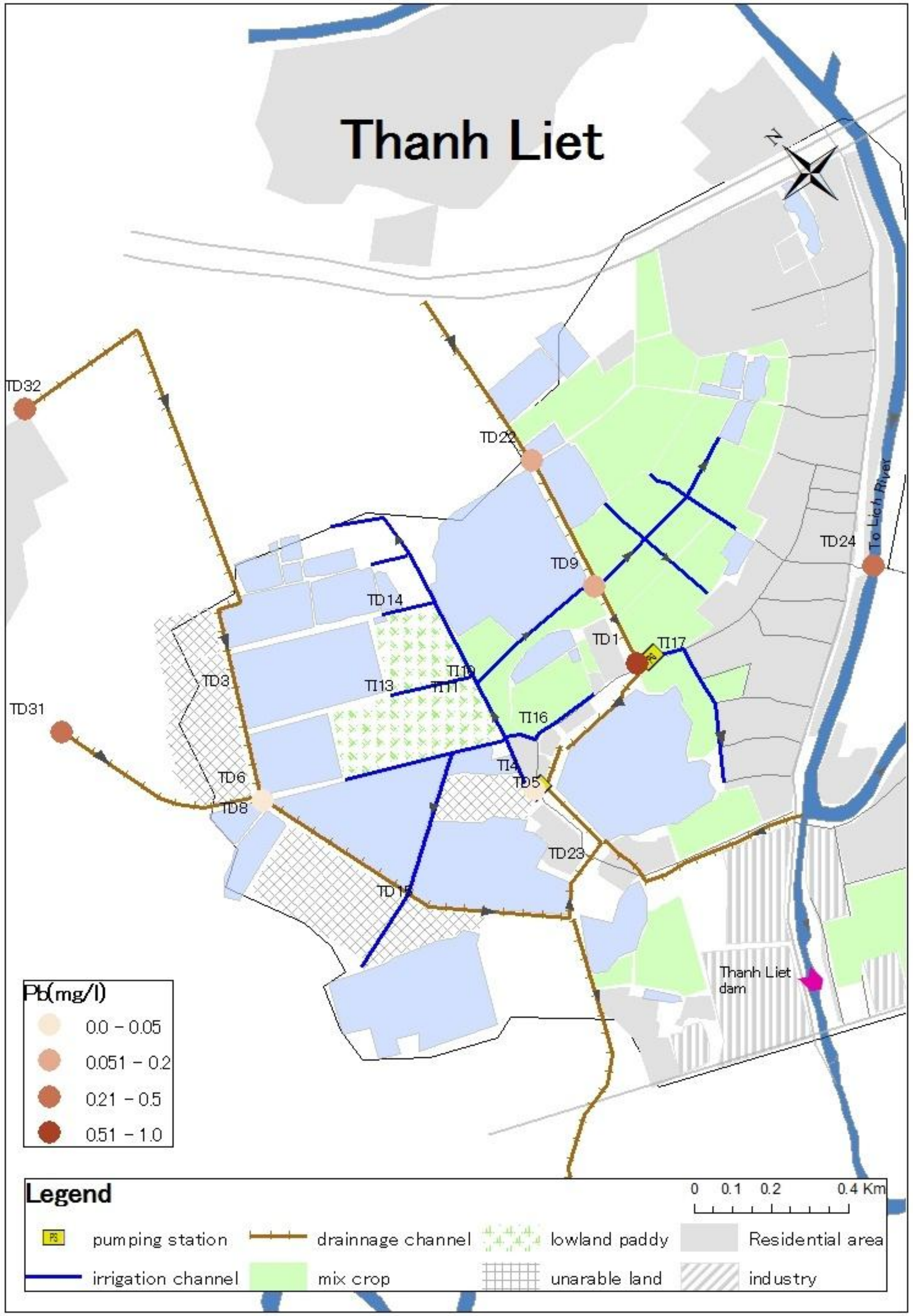


Figure 23. Lead level of water samples taken at different locations

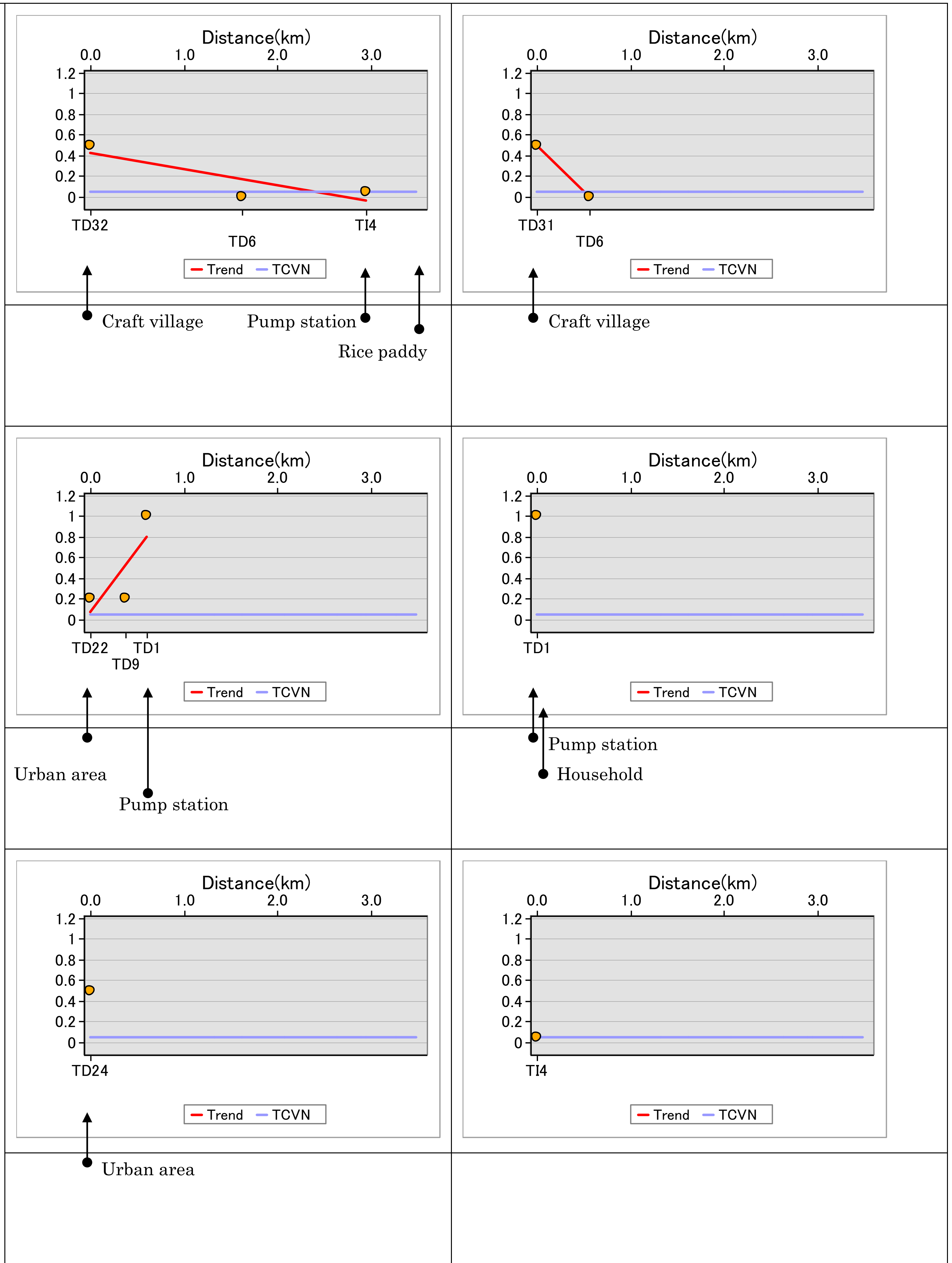


Figure 24. Lead level variation of water sample along channels

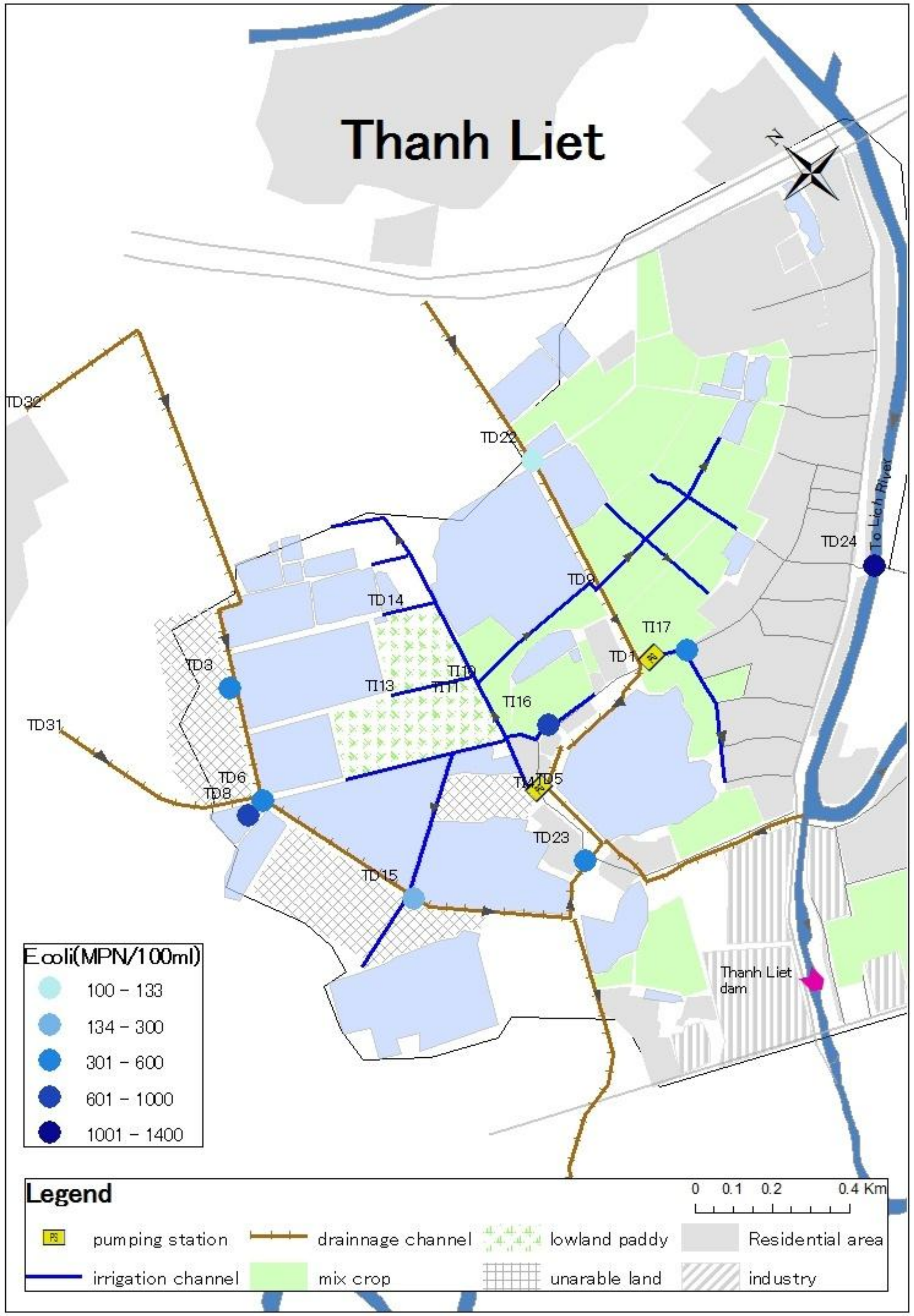


Figure 25. E.coli level of water samples taken at different locations

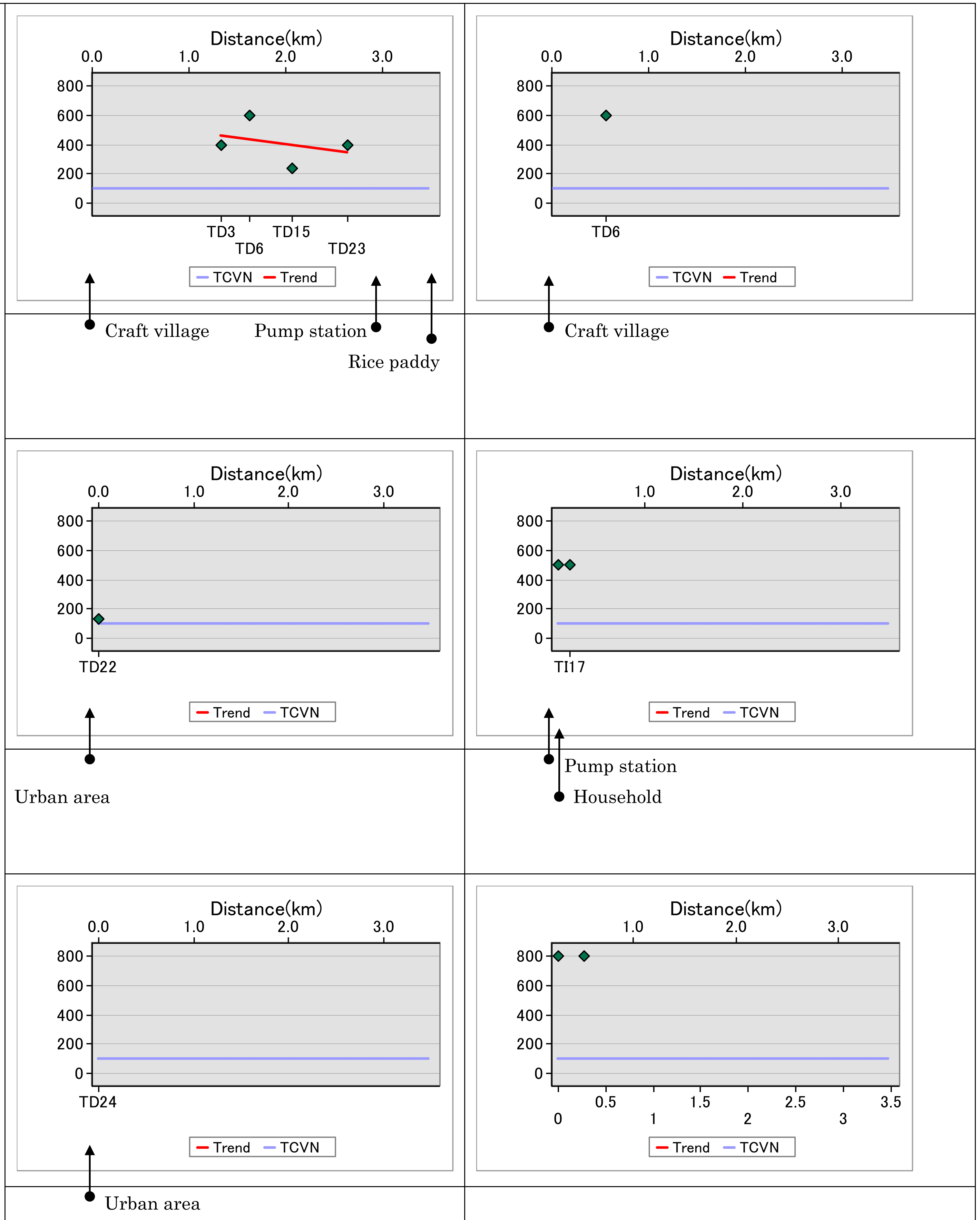


Figure 26. E.coli level variation of water sample along channels

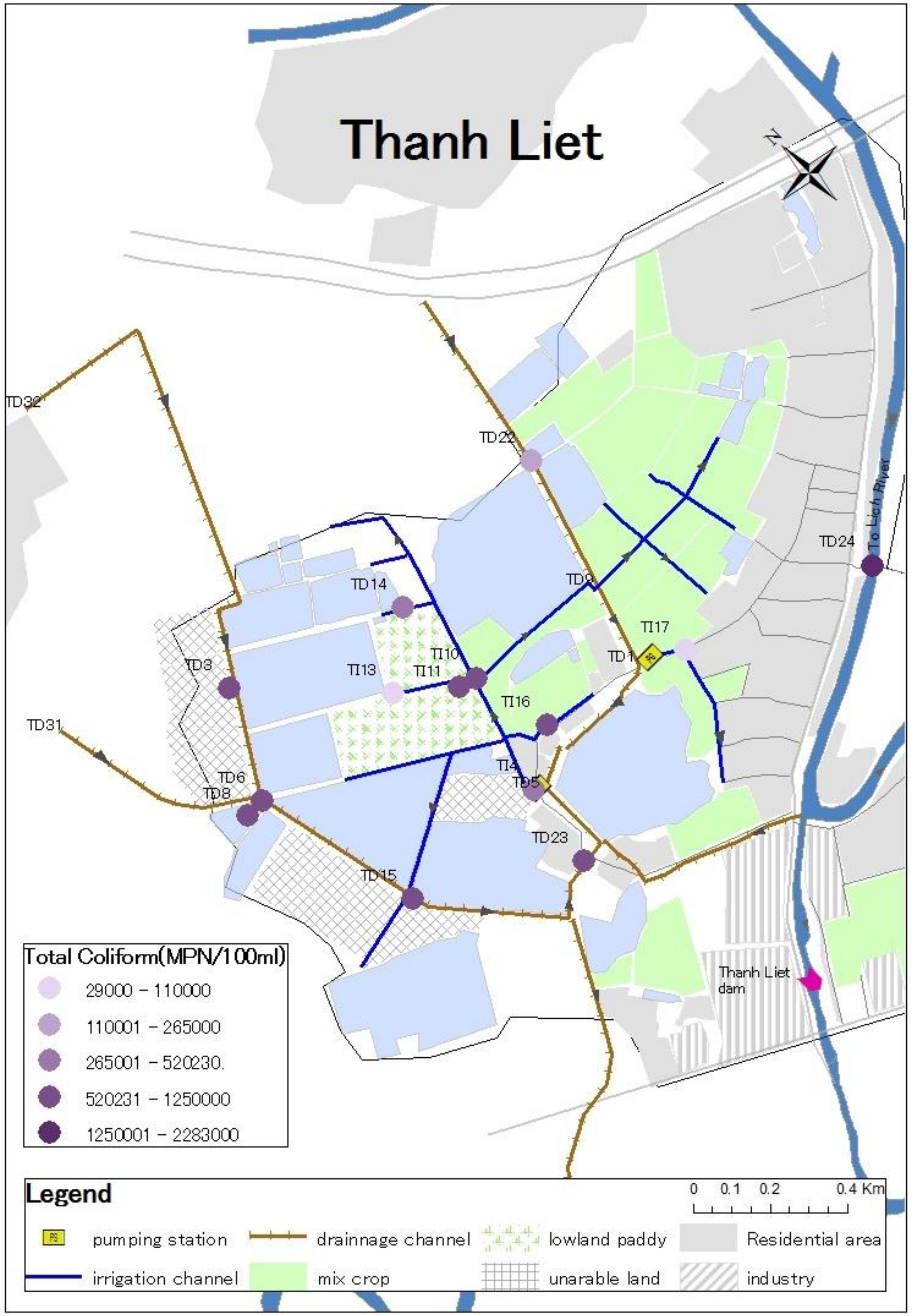


Figure 27. Total Coliform level of water samples taken at different locations

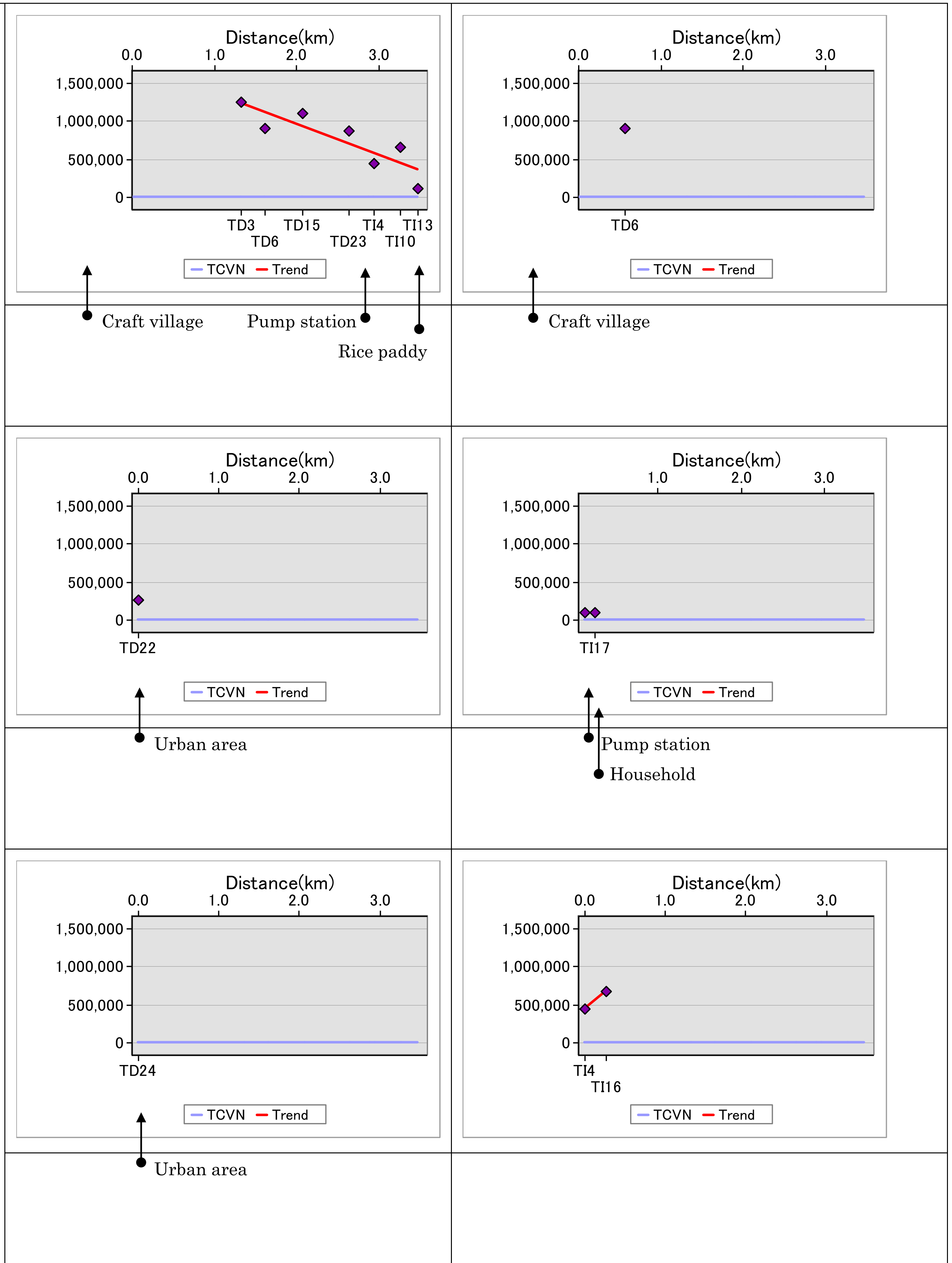


Figure 28. Total Coliform level variation of water sample along channels

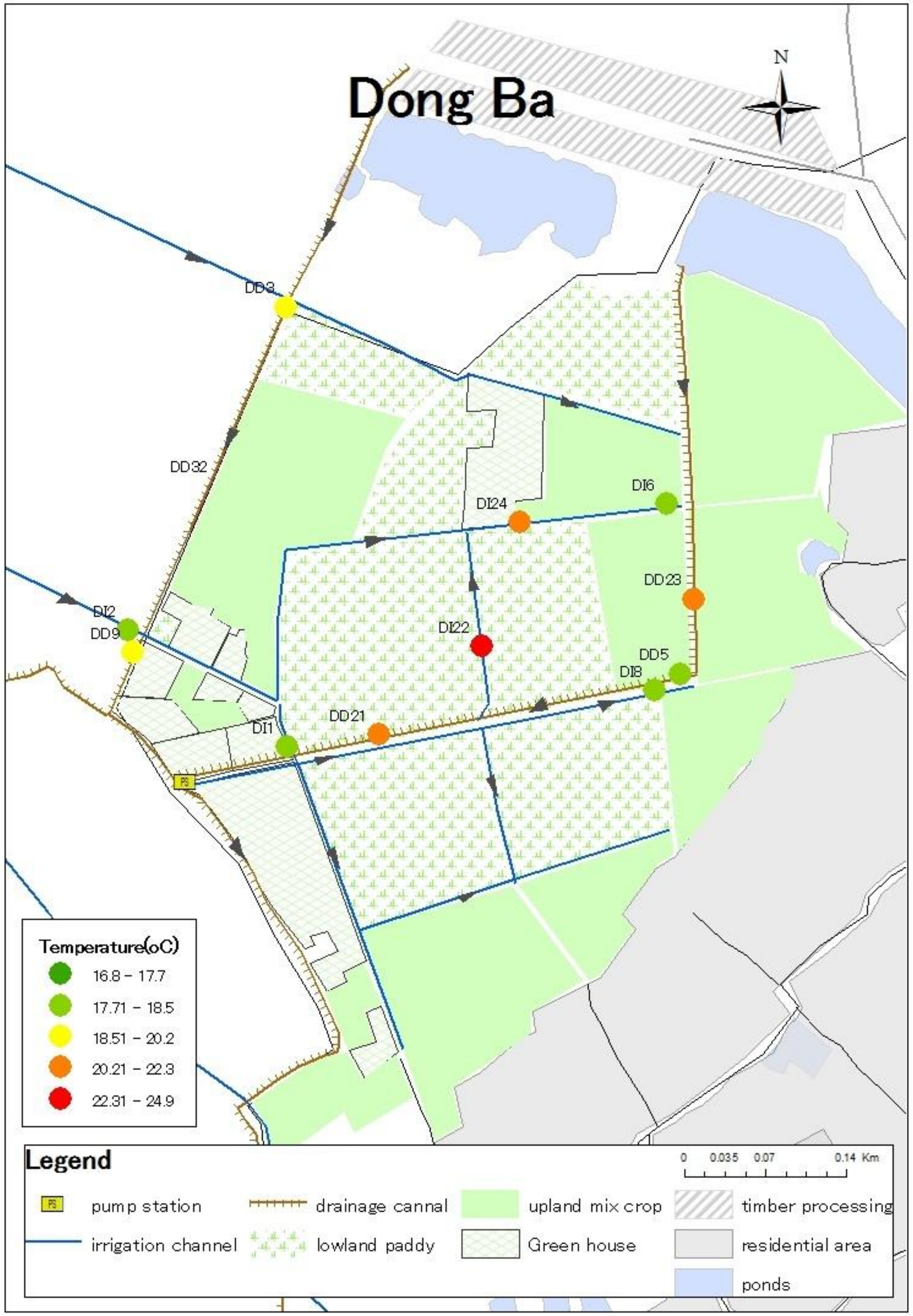


Figure 29. Temperature of water samples taken at different locations

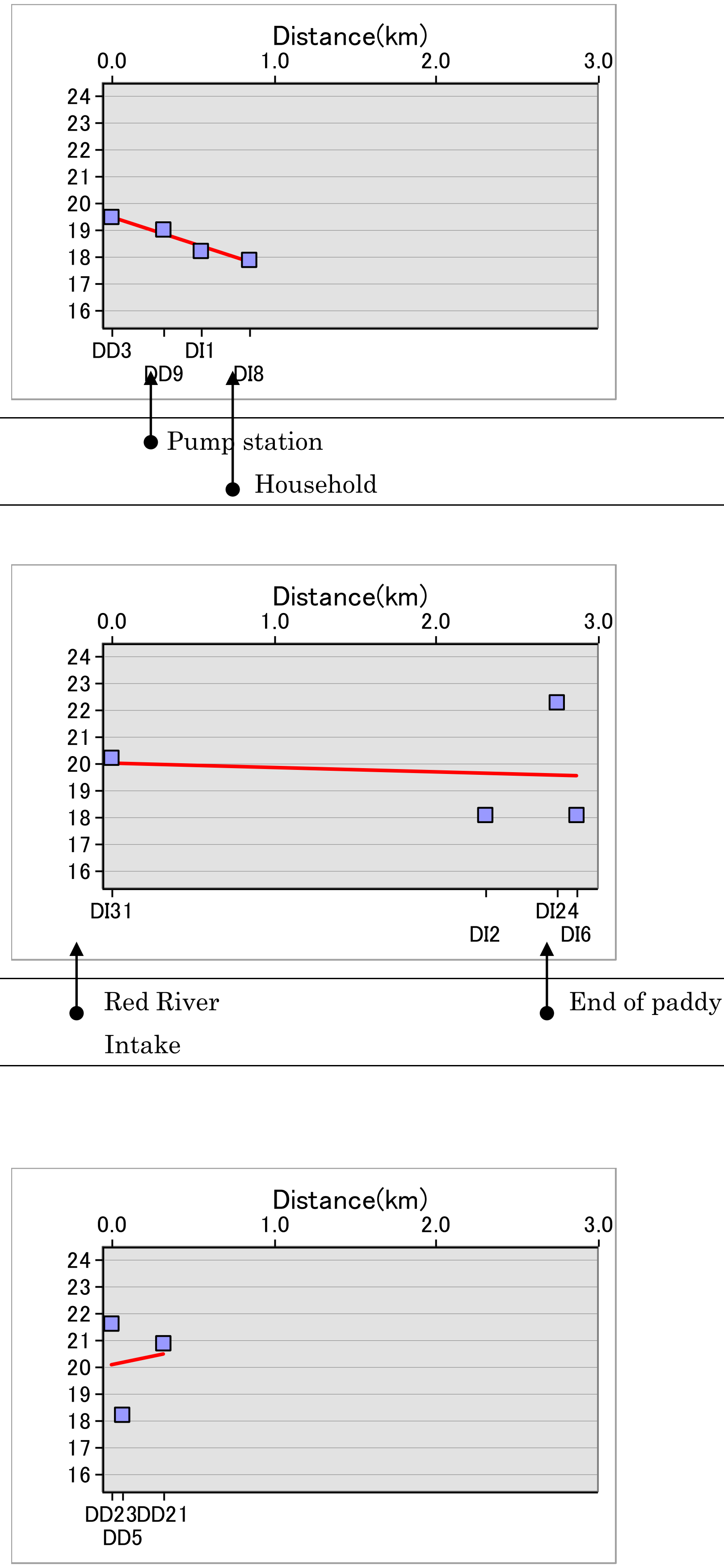


Figure 30. Temperature variation of water sample along channels

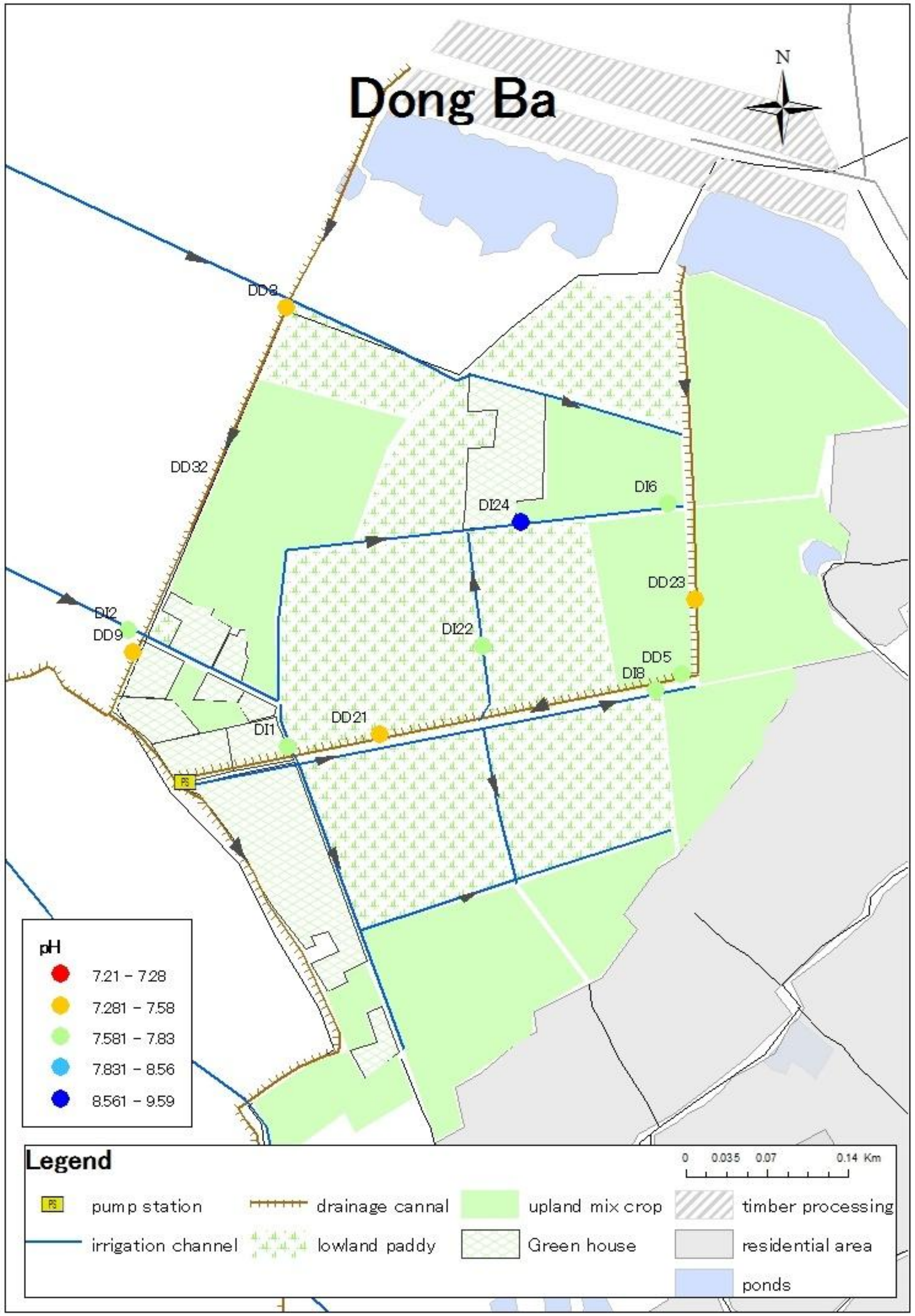


Figure 31. pH of water samples taken at different locations

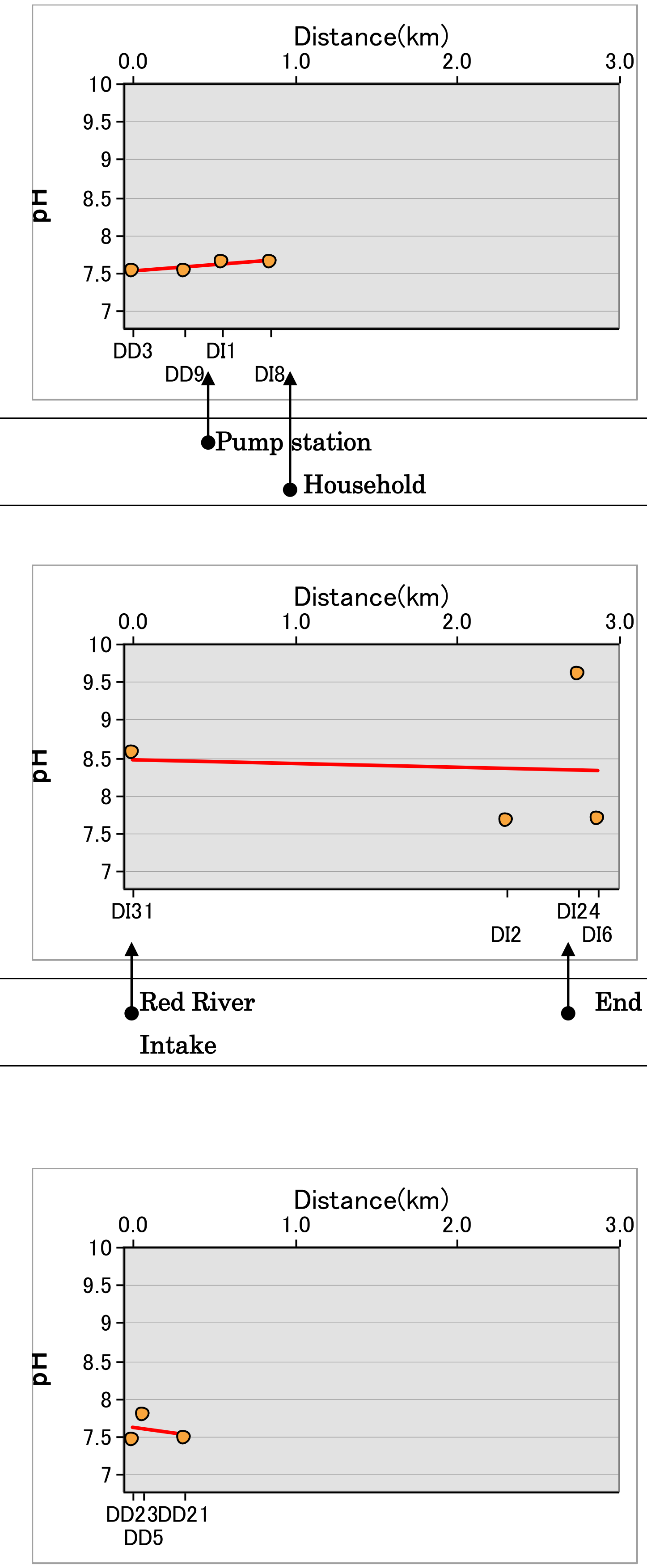


Figure 32. pH variation of water sample along channels

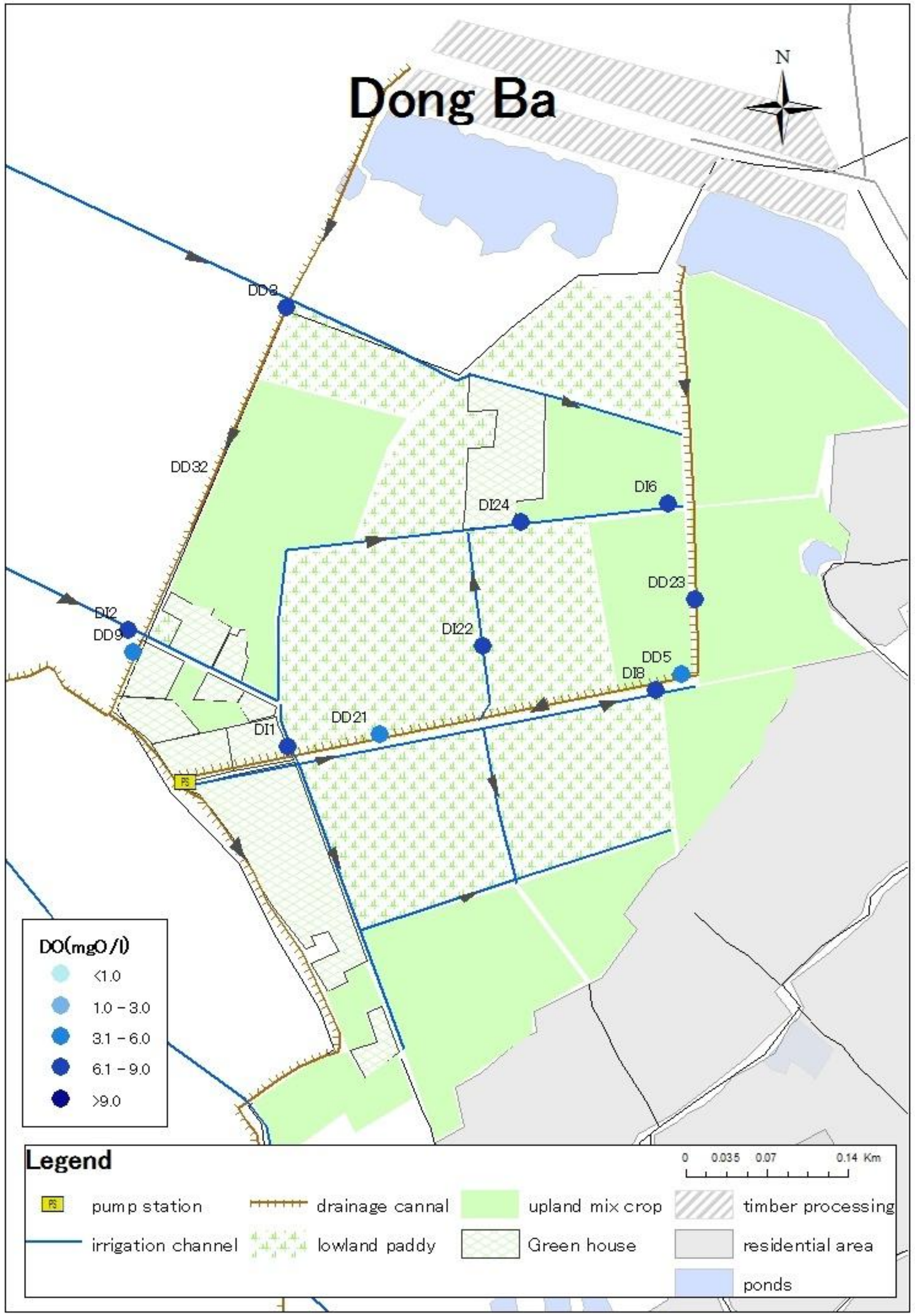


Figure 33. Dissolved Oxygen level of water samples taken at different locations

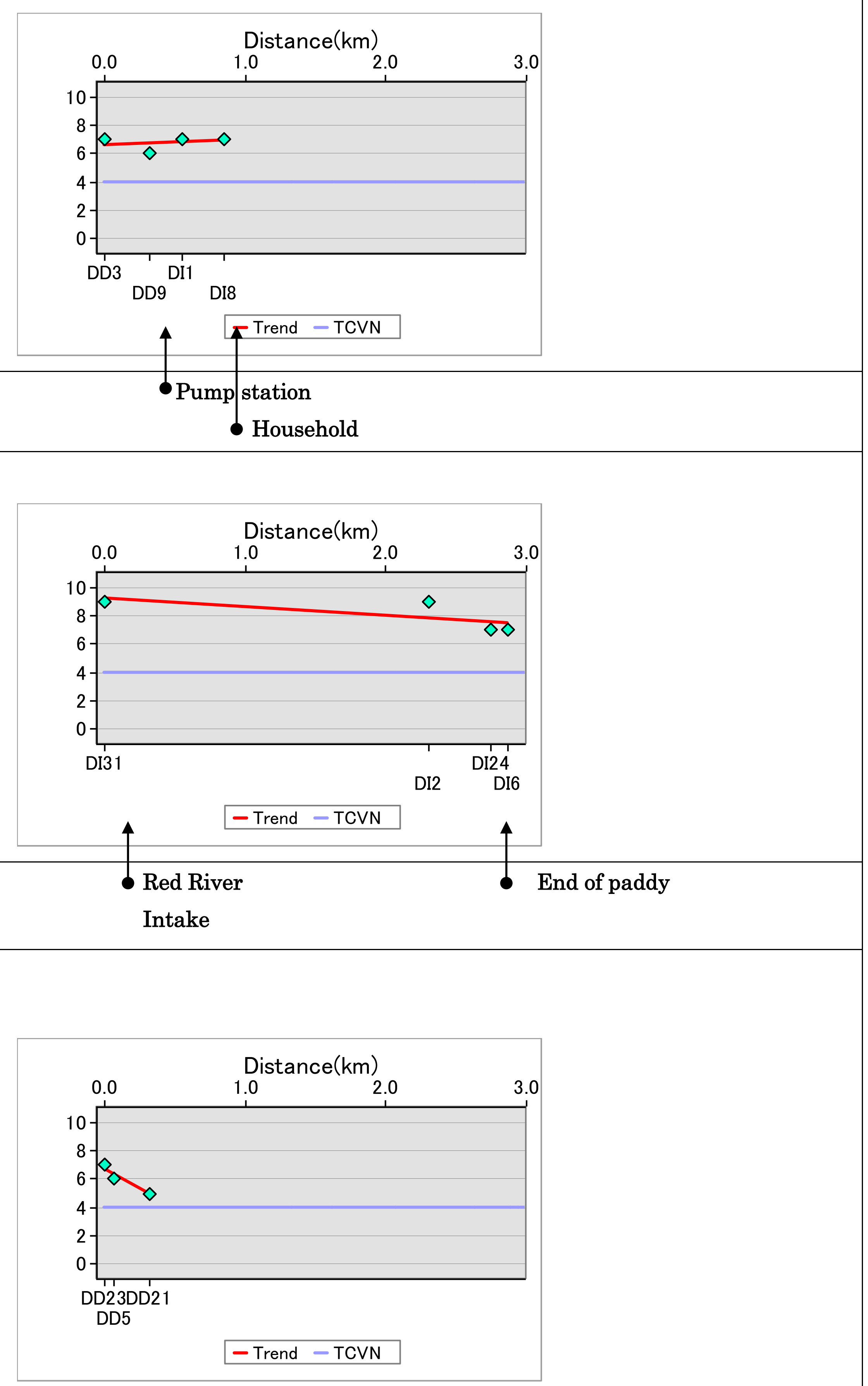


Figure 34. Dissolved Oxygen level variation of water sample along channels

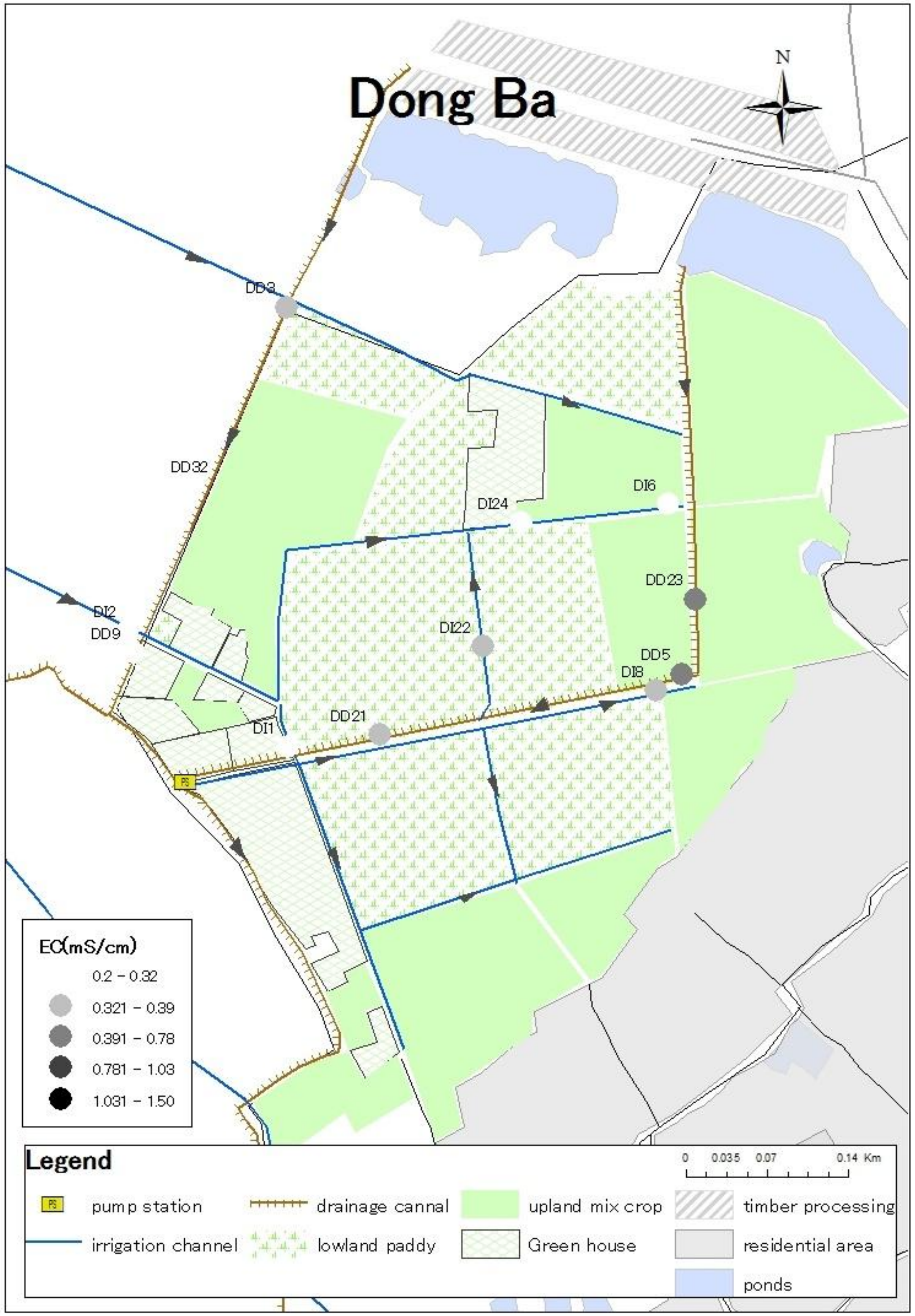
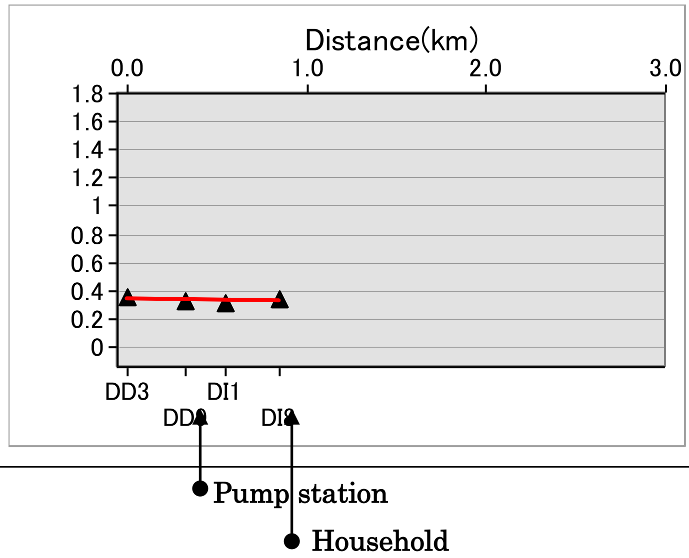
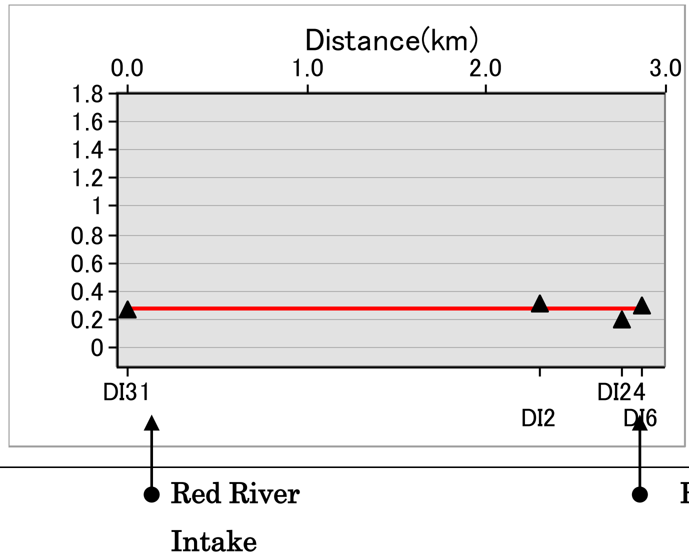


Figure 35. Conductivity of water samples taken at different locations





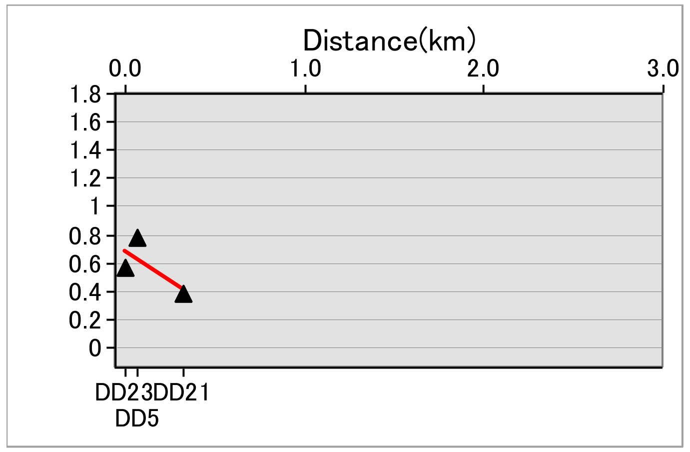


Figure 36. Conductivity variation of water sample along channels

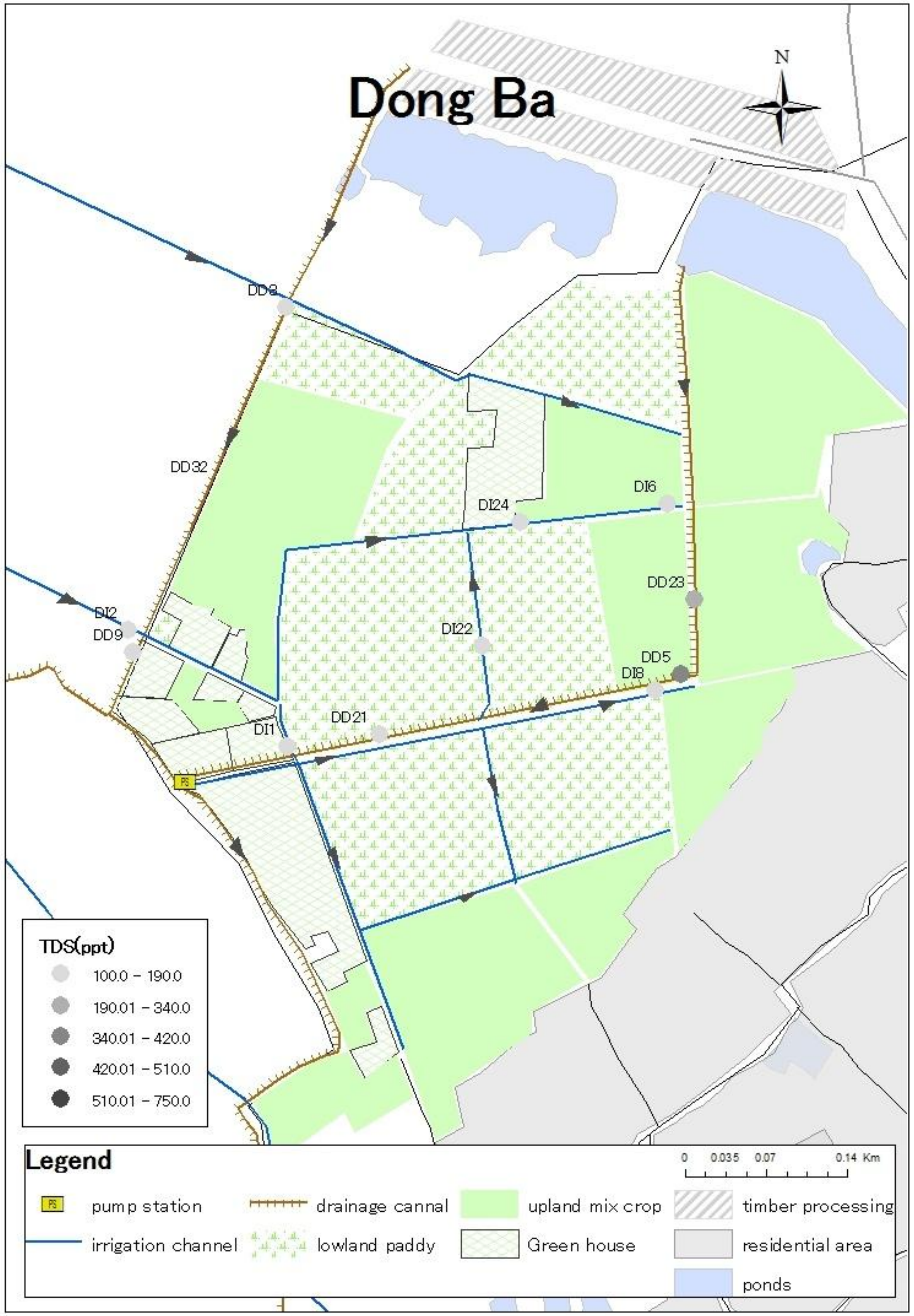


Figure 37. Total dissolved solid level of water samples taken at different locations

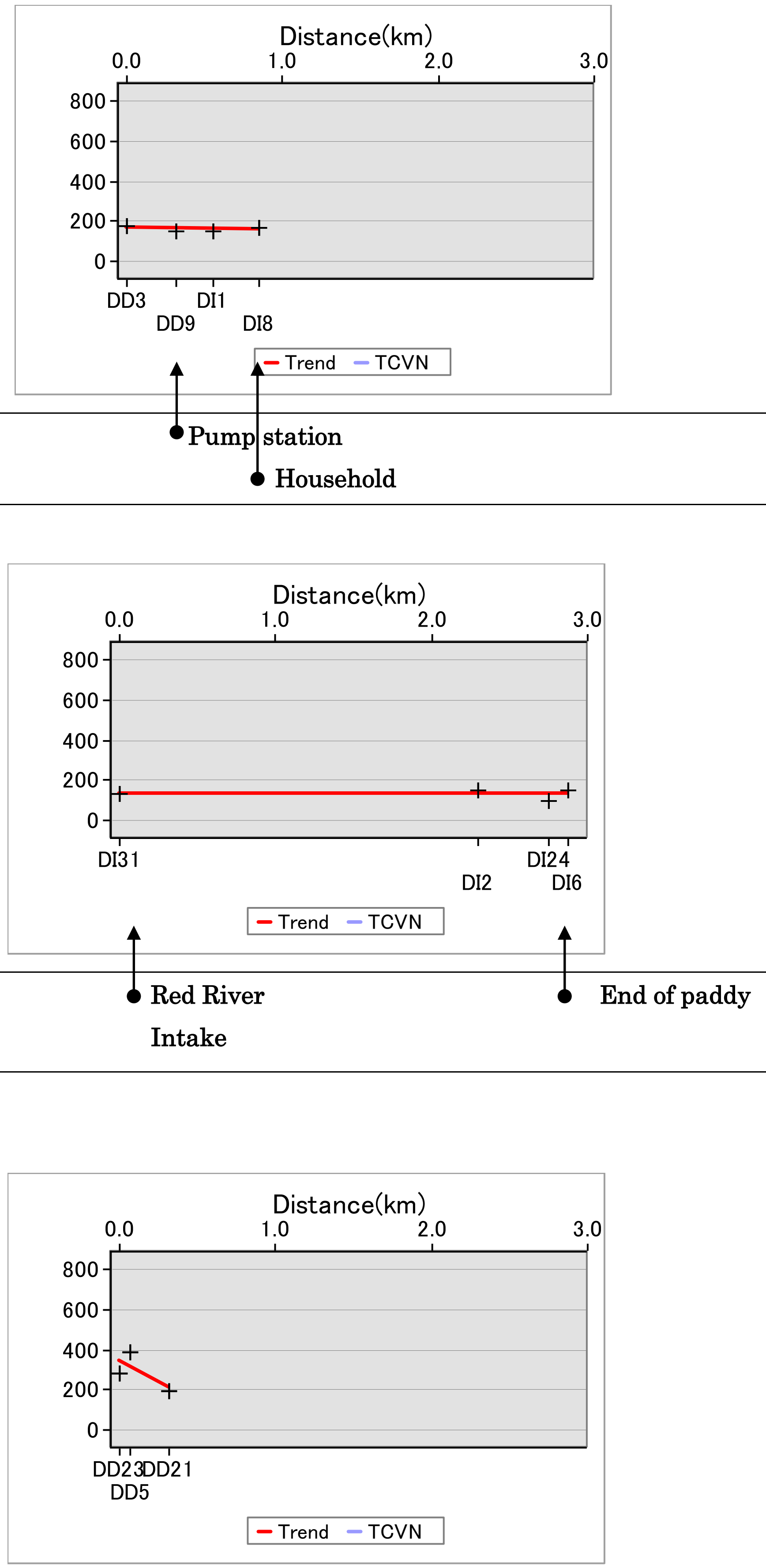


Figure 38. Total dissolved solid level variation of water sample along channels

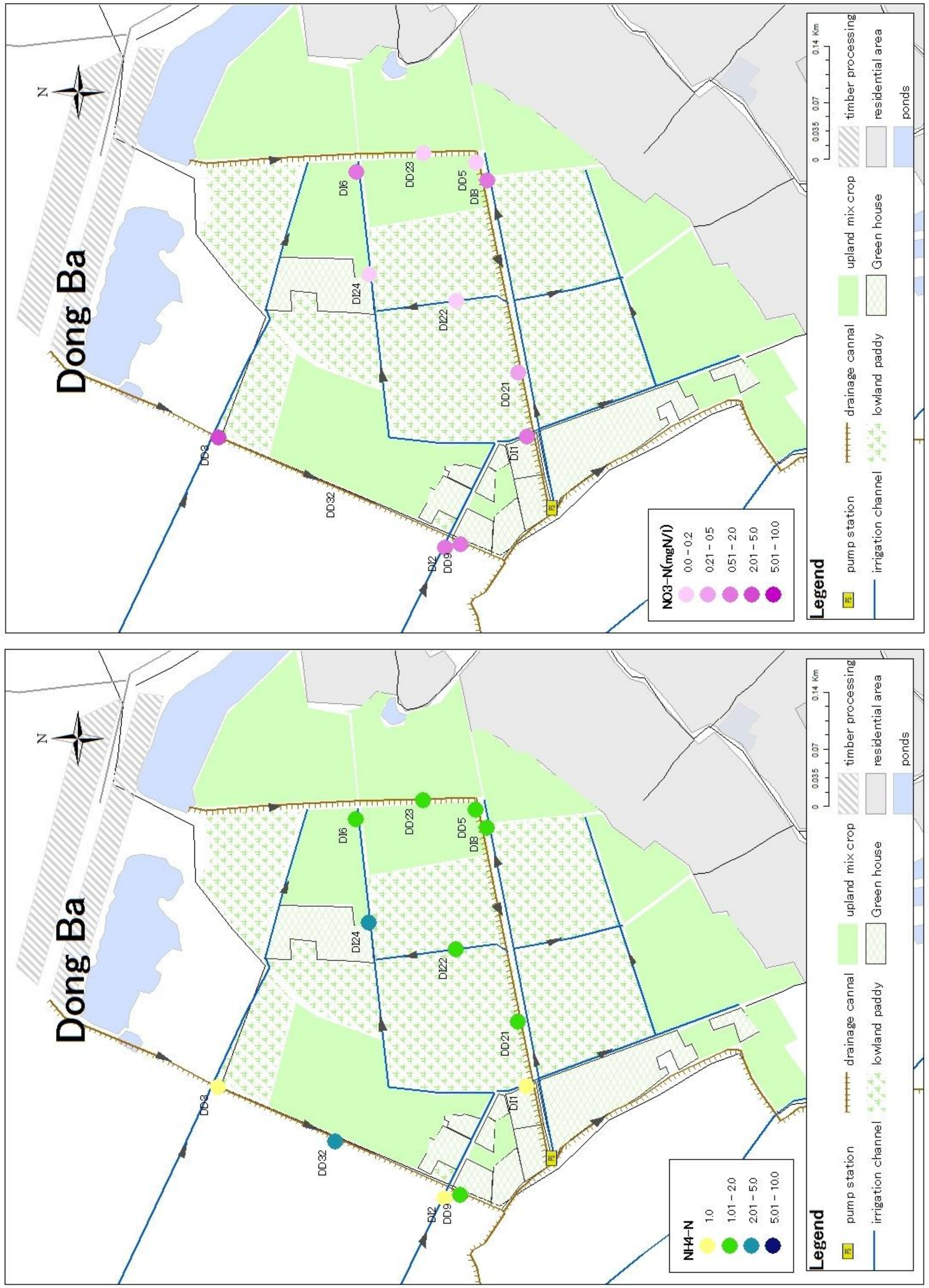


Figure 39. Ammonium and Nitrate level of water samples taken at different locations

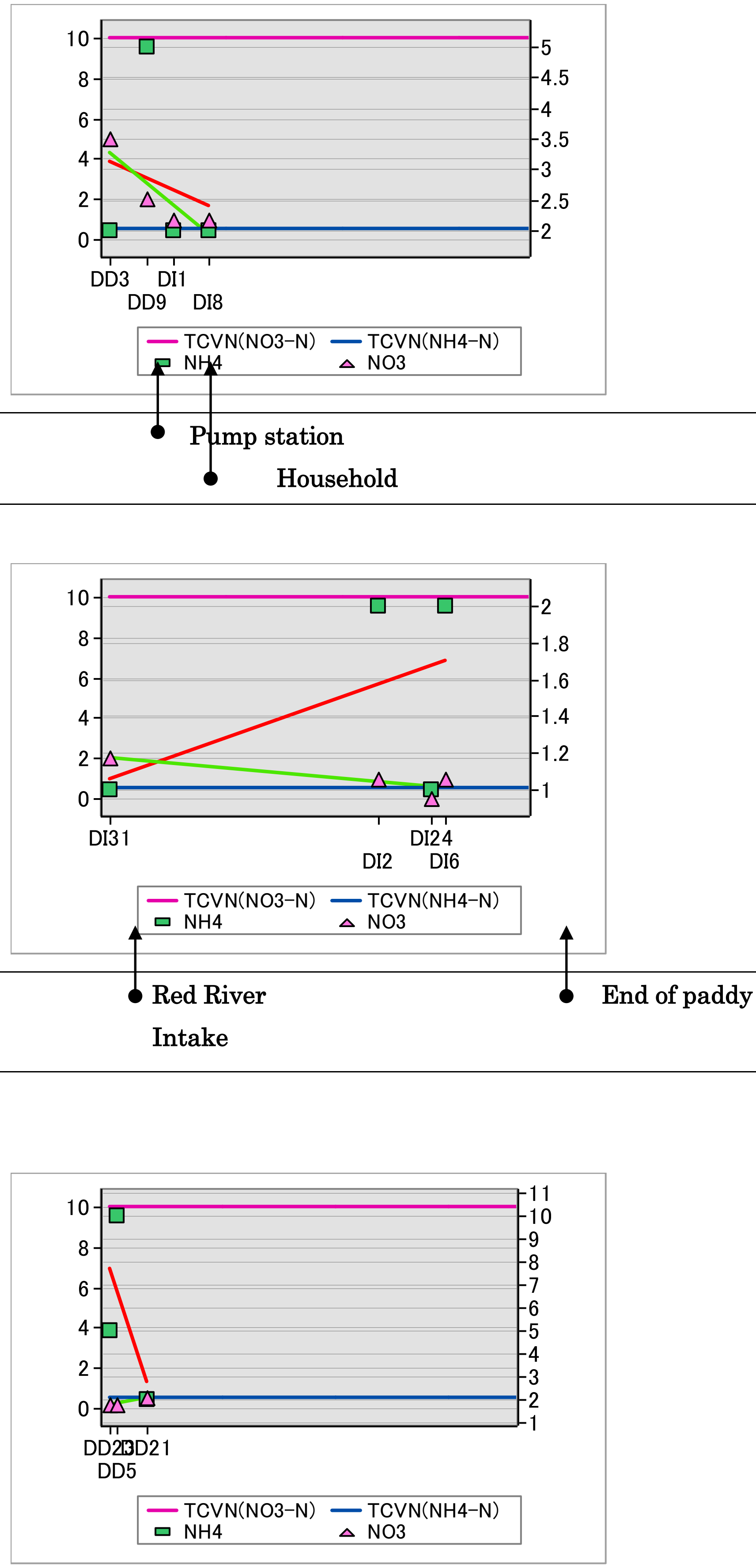


Figure 40. Ammonium and Nitrate level variation of water sample along channels

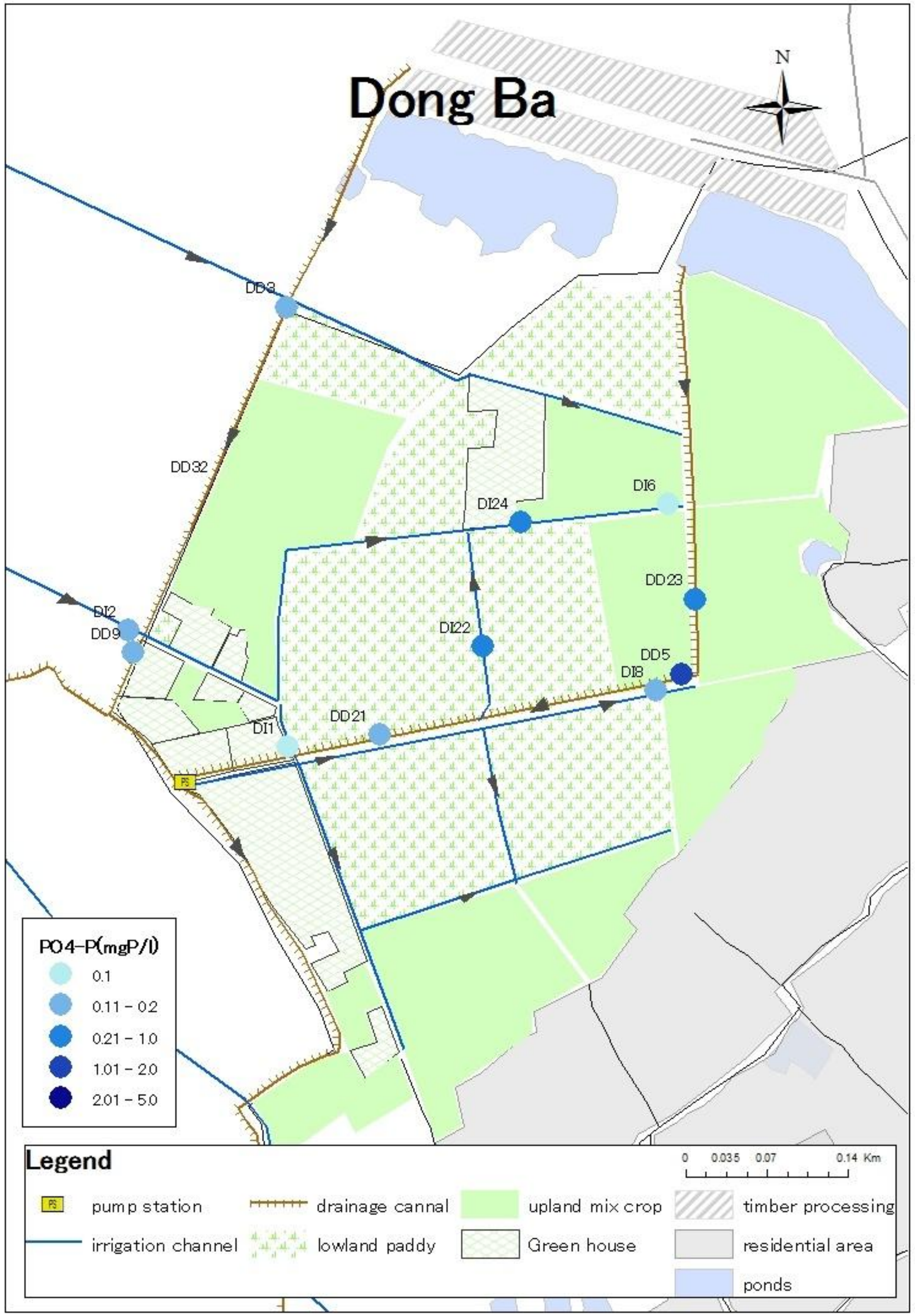


Figure 41. Phosphate level of water samples taken at different locations

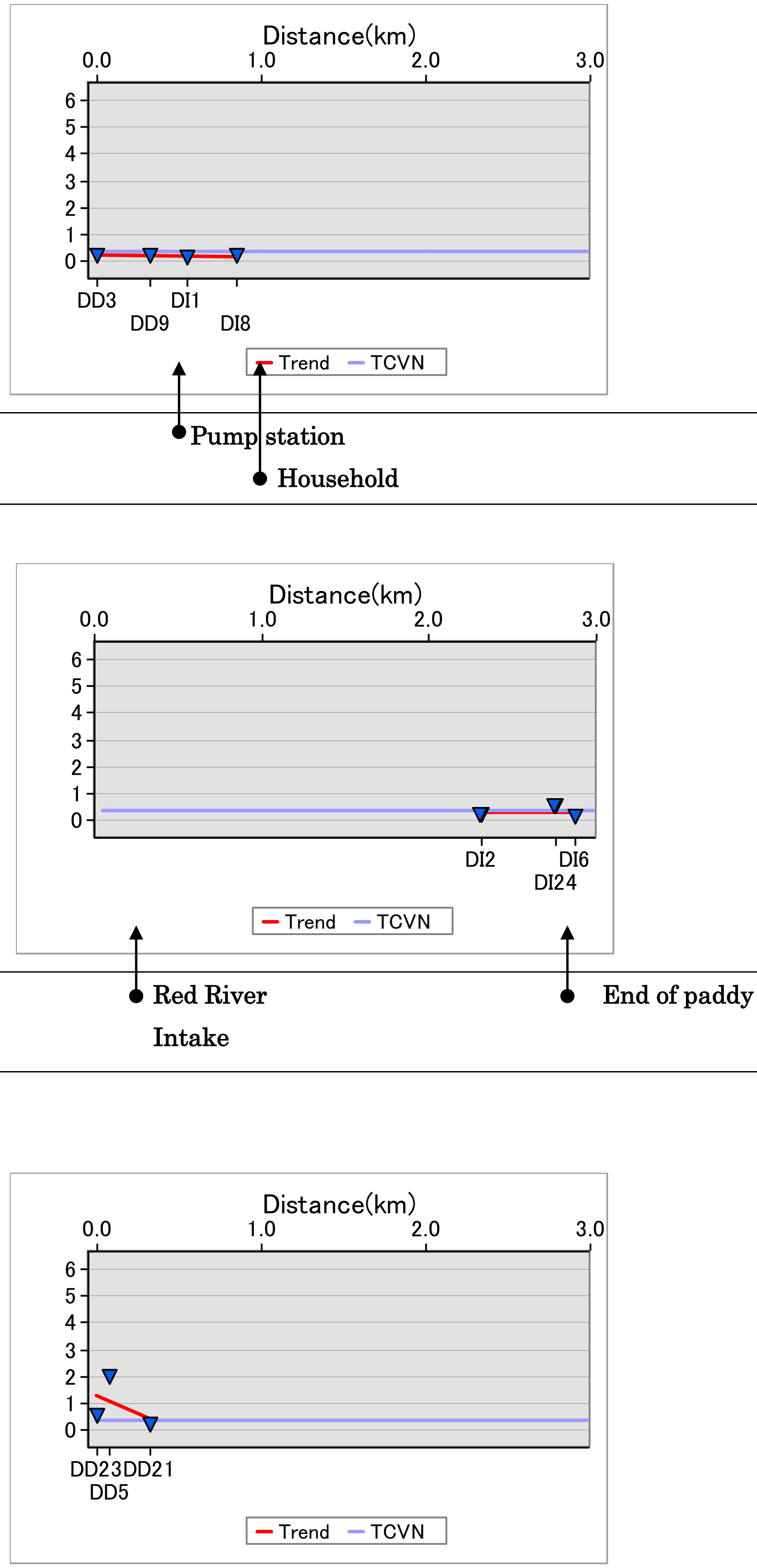


Figure 42. Phosphate Oxygen level variation of water sample along channels

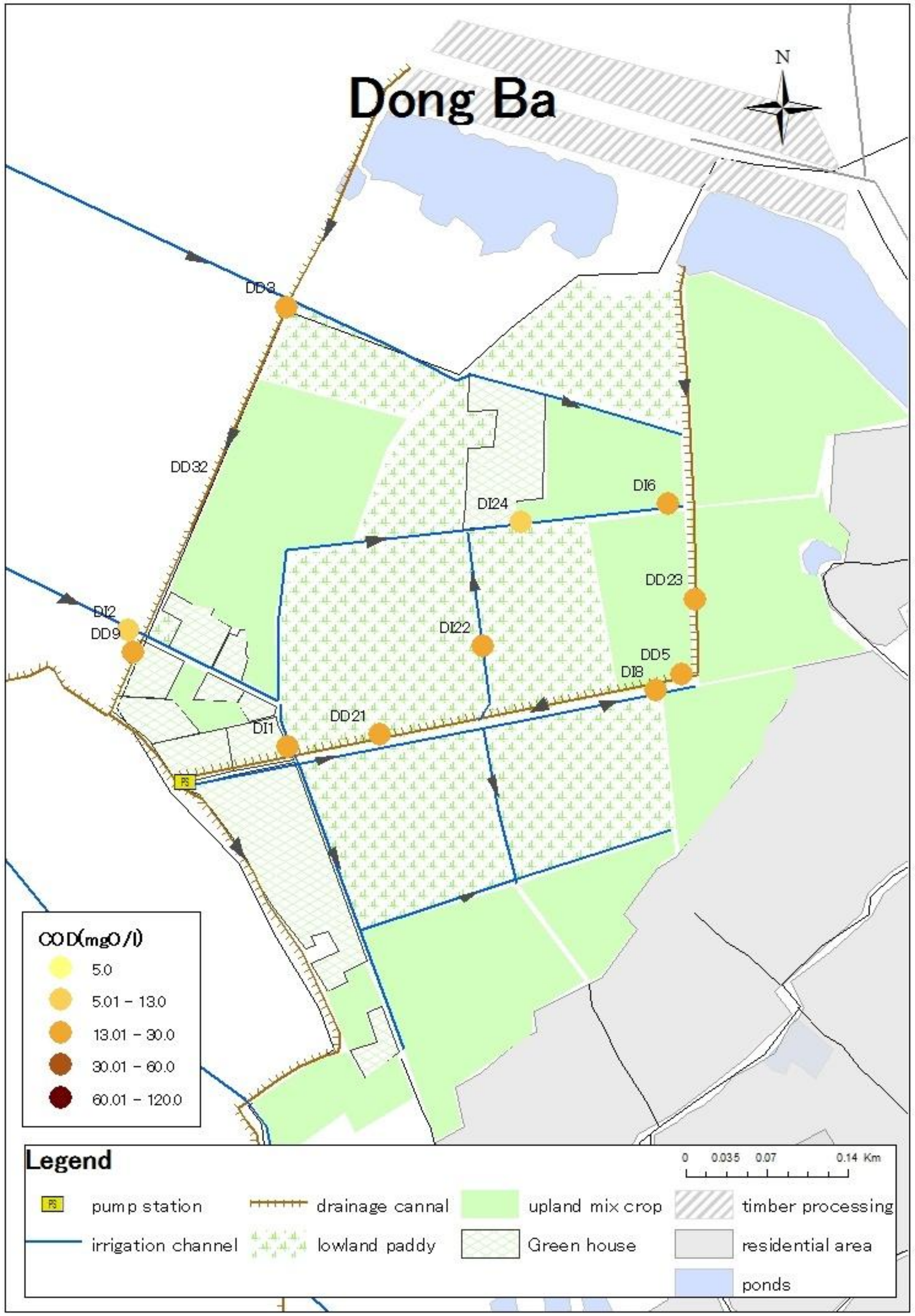


Figure 43. Chemical Oxygen demand ($KMnO_4$) level of water samples taken at different locations

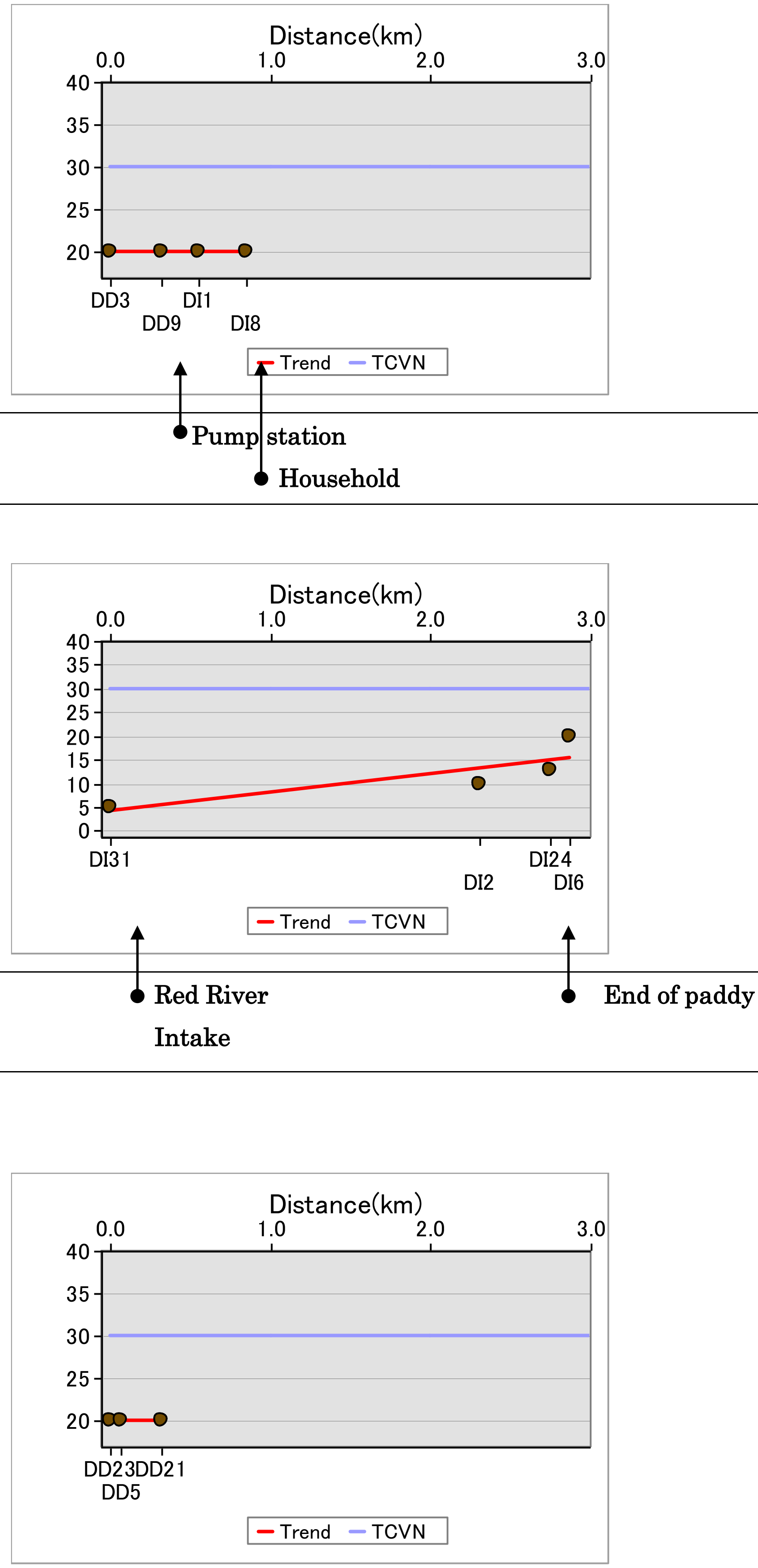


Figure 44. Chemical Oxygen demand ($KMnO_4$) level variation of water sample along channels

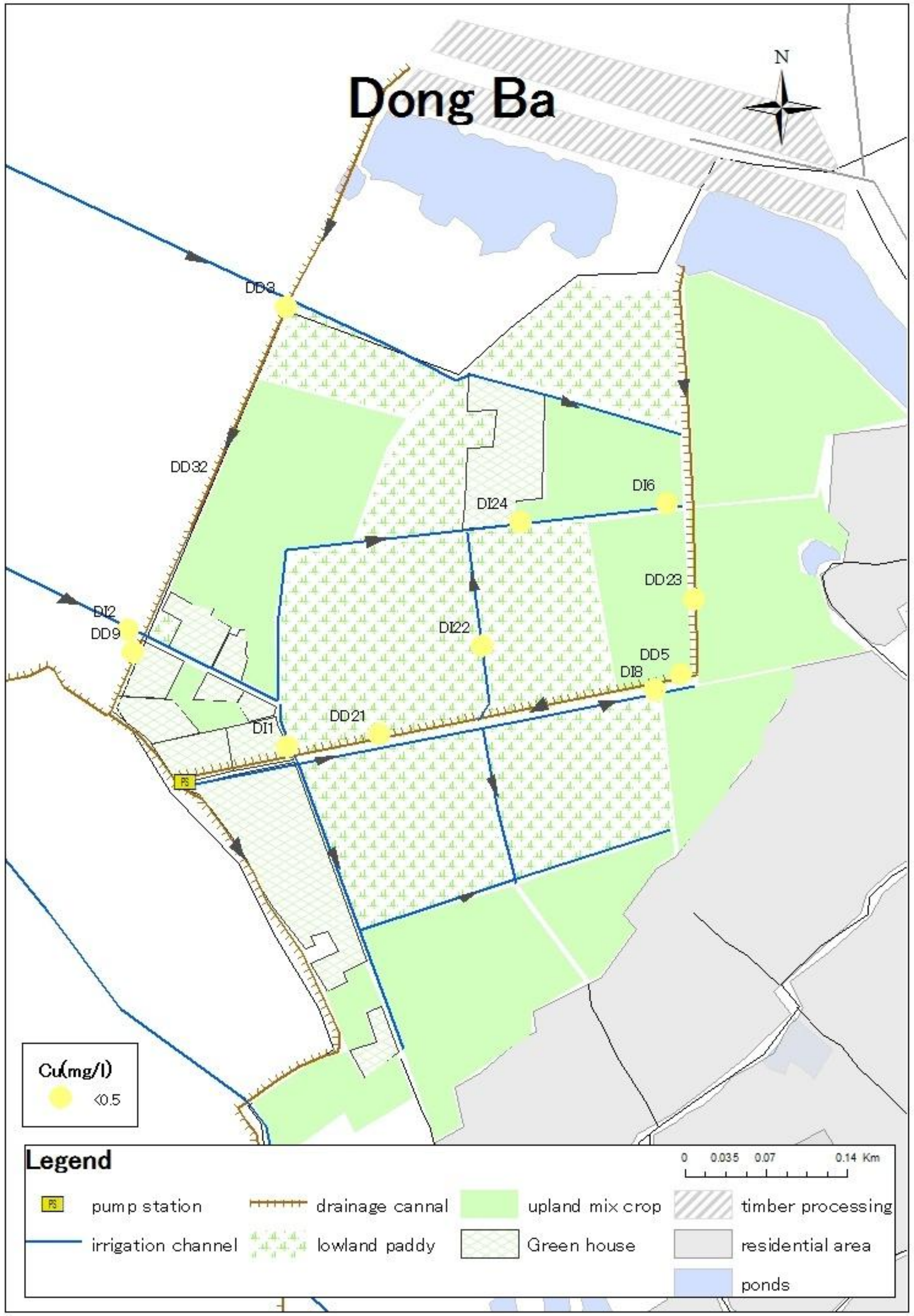


Figure 45. Copper level of water samples taken at different locations

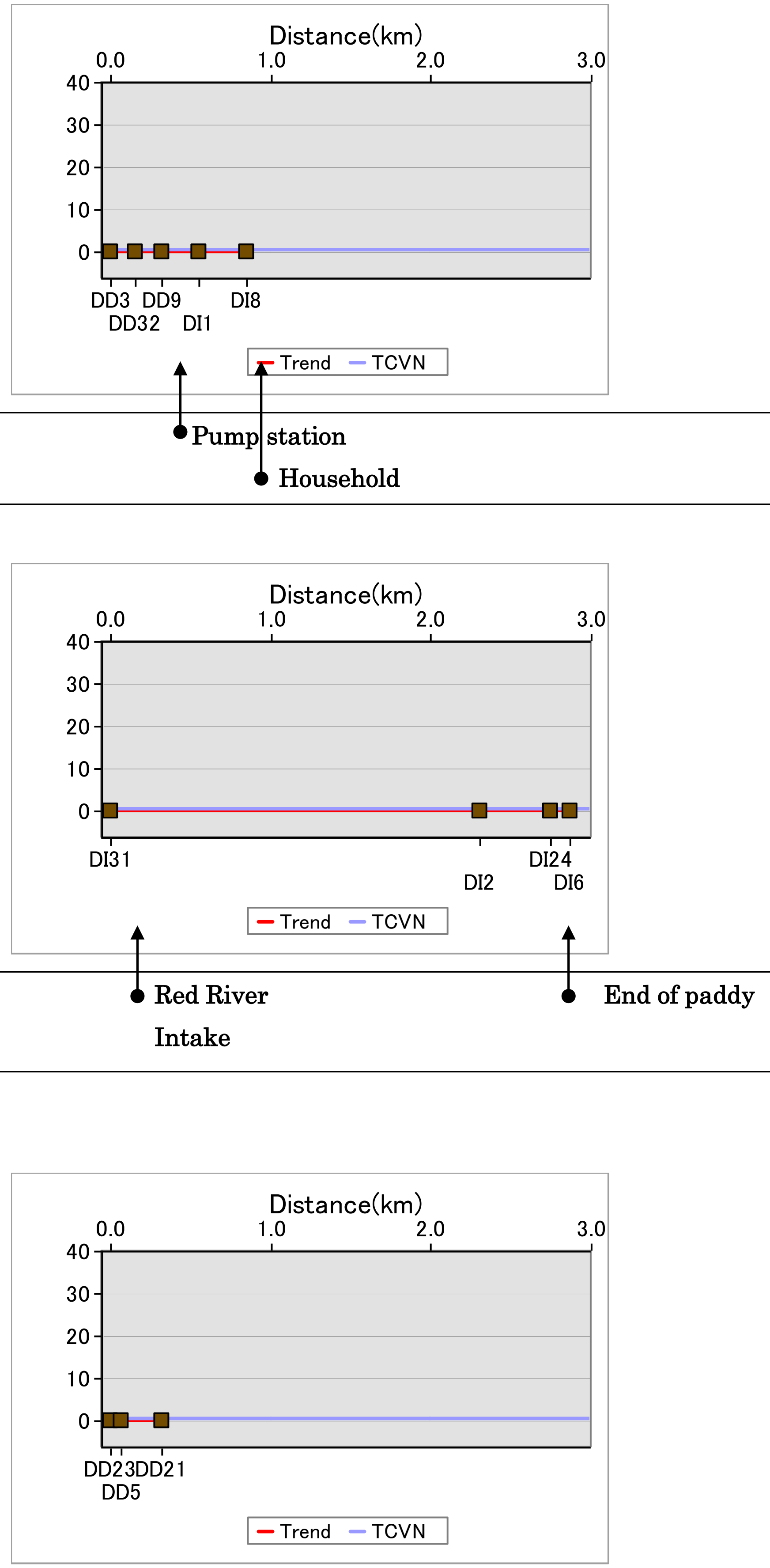


Figure 46. Copper level variation of water sample along channels

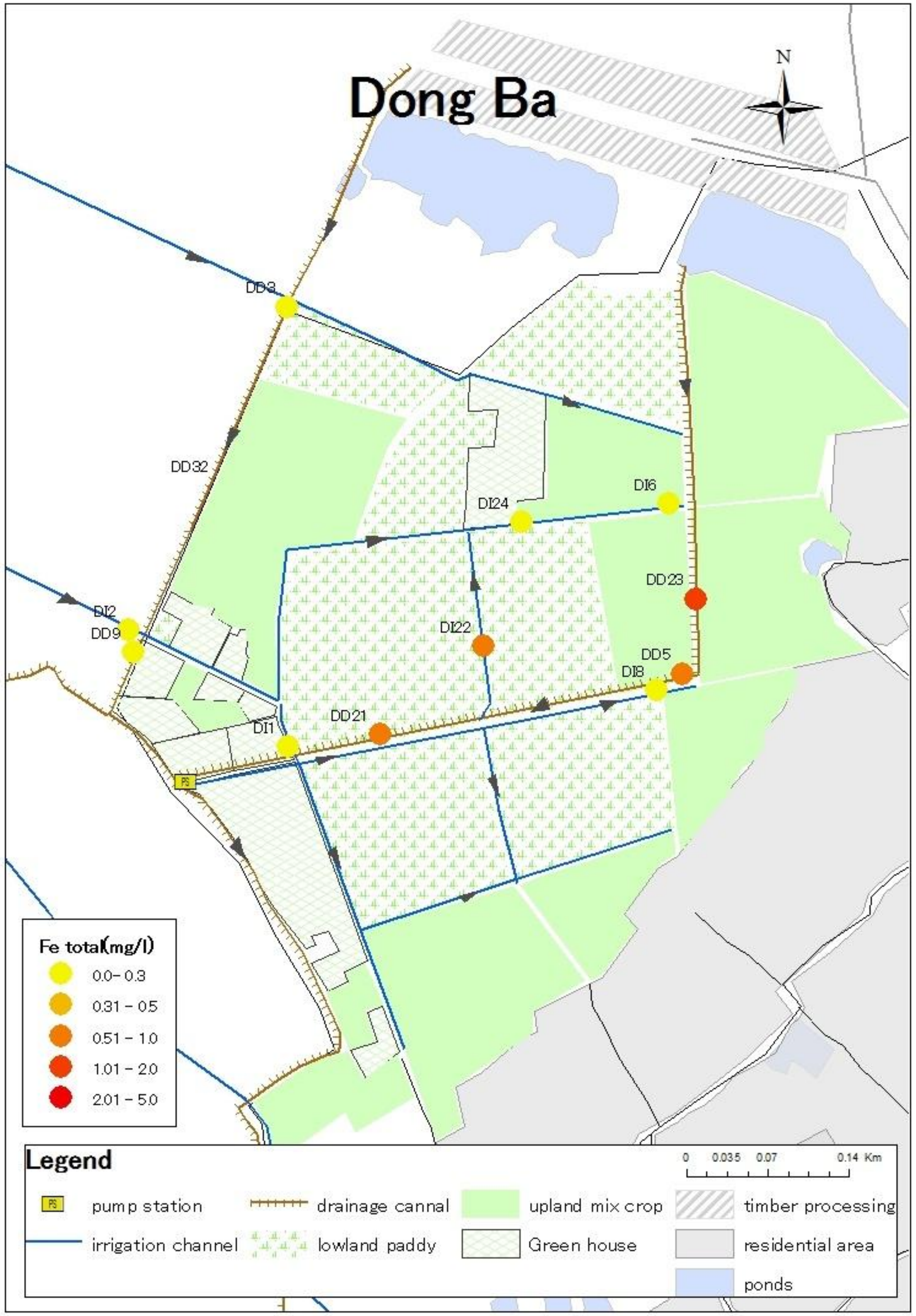


Figure 47. Total Iron(Fe^{2+} Fe^{3+}) level of water samples taken at different locations

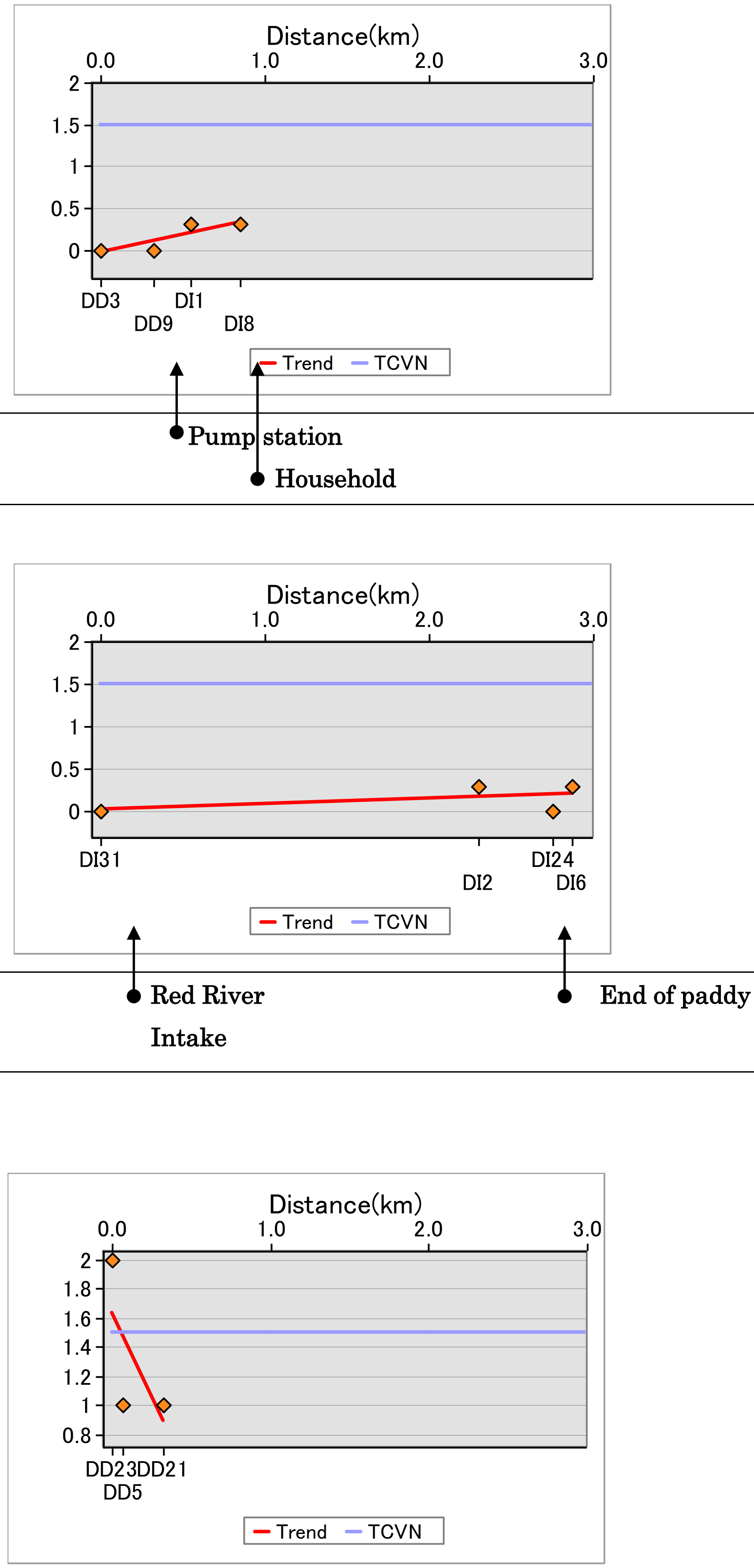


Figure 48. Total Iron(Fe^{2+} Fe^{3+}) level variation of water sample along channels

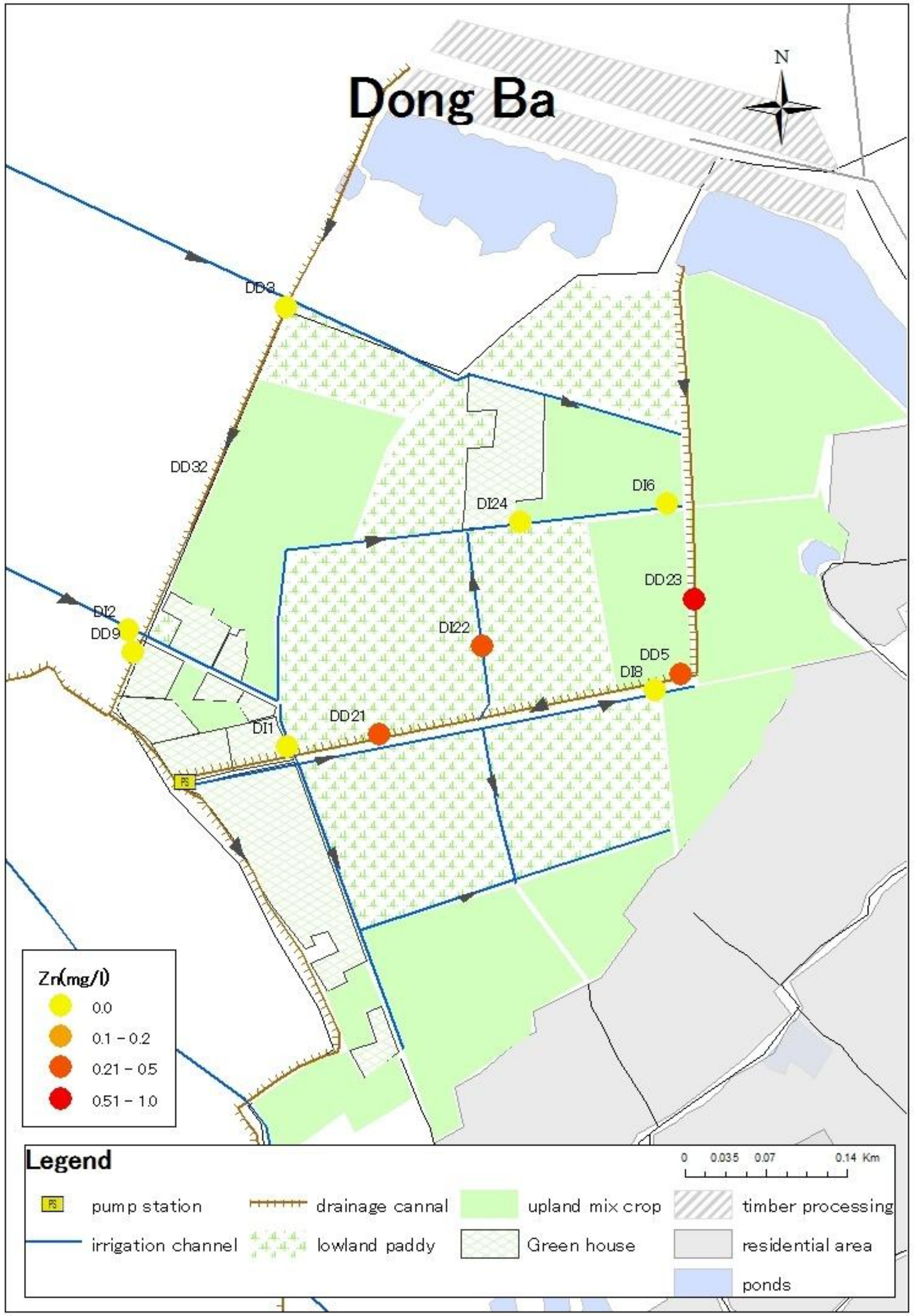


Figure 49. Zinc level of water samples taken at different locations

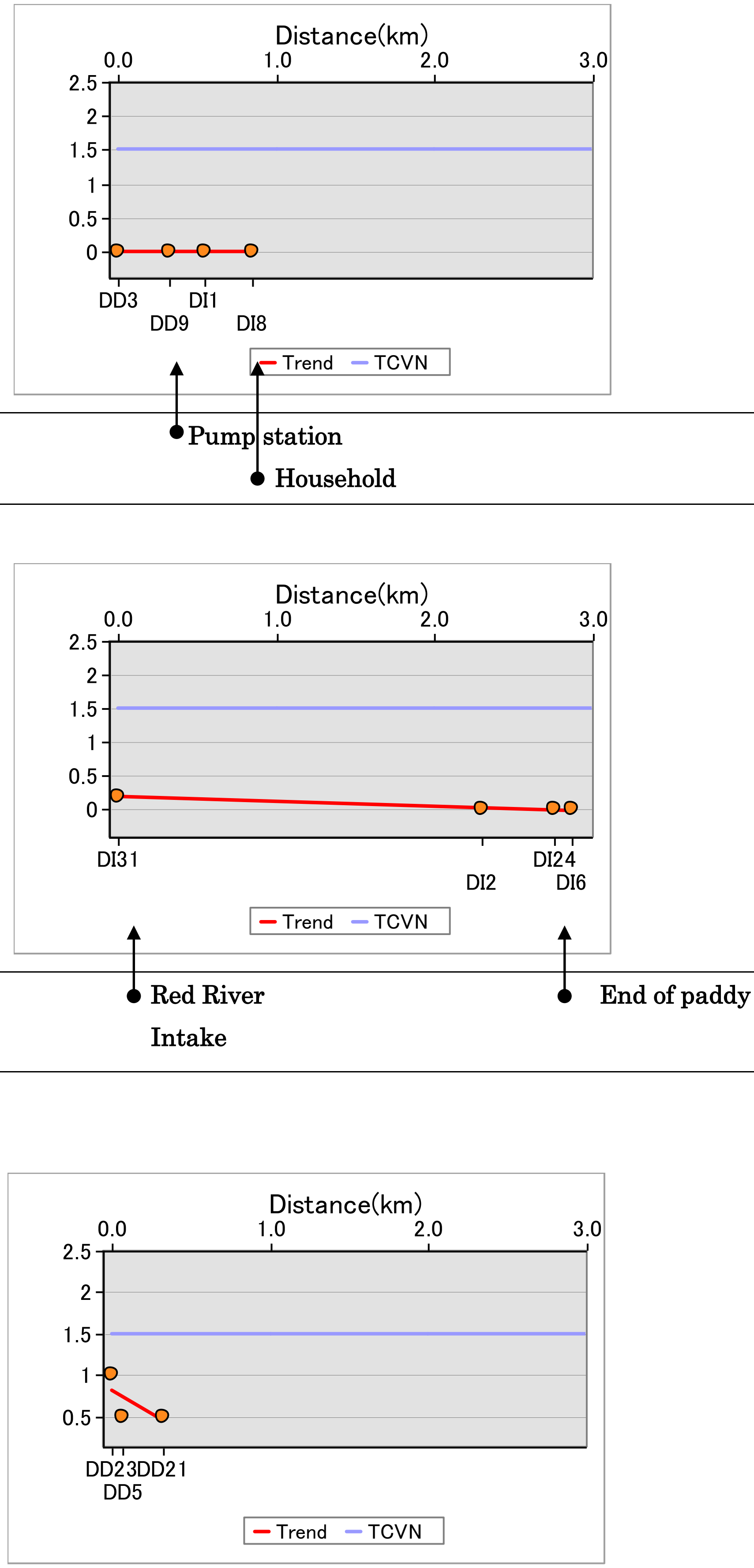


Figure 50. Zinc Oxygen level variation of water sample along channels

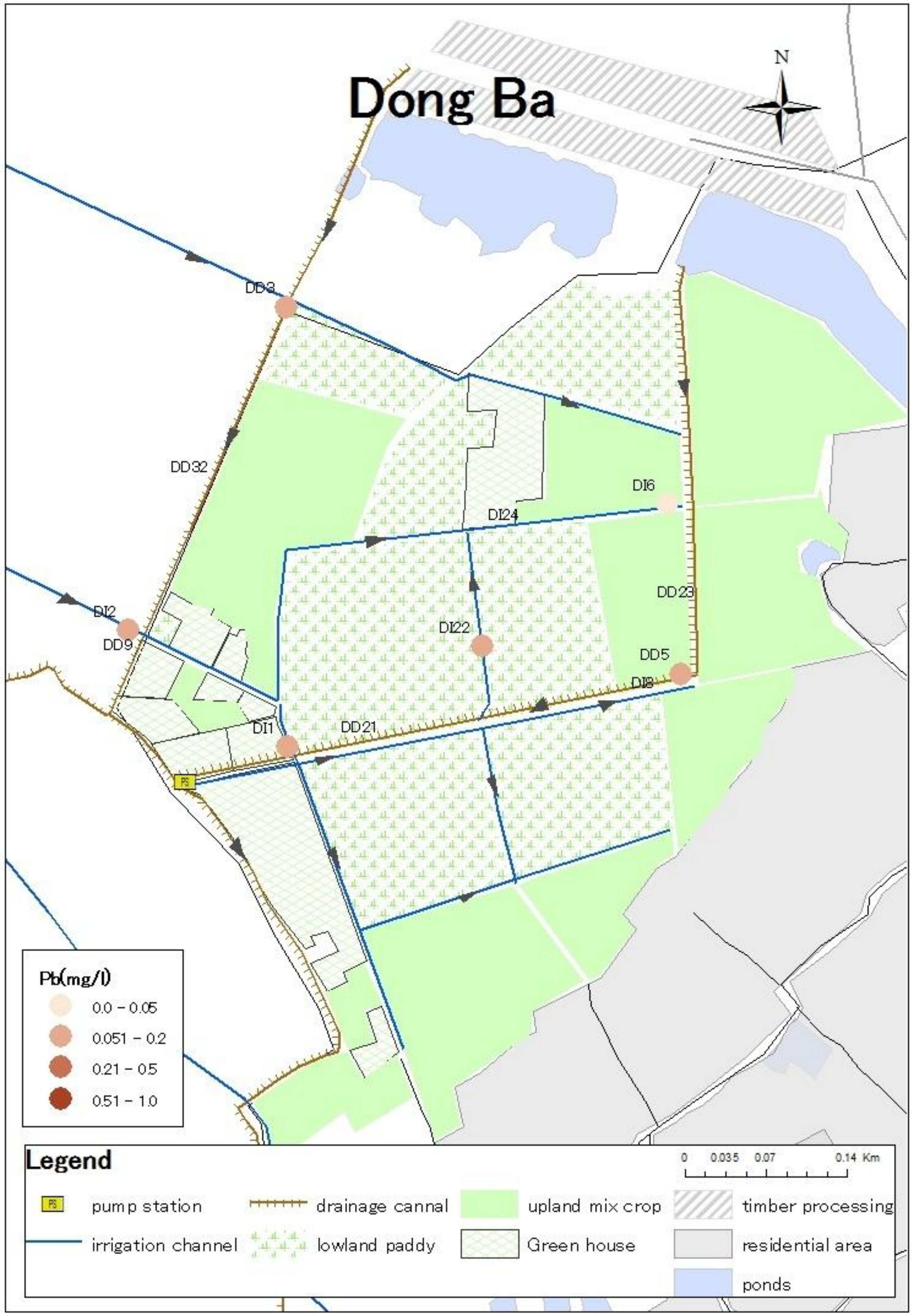


Figure 51. Lead level of water samples taken at different locations

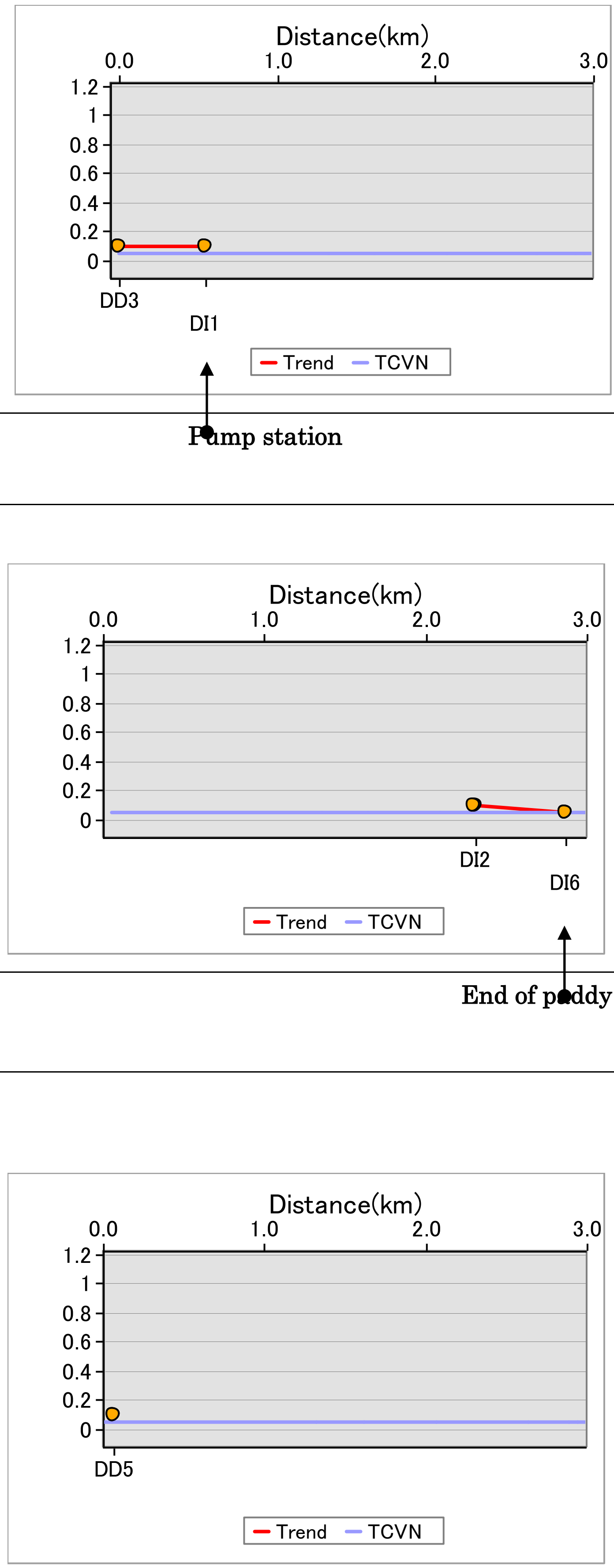


Figure 52. Lead level variation of water sample along channels

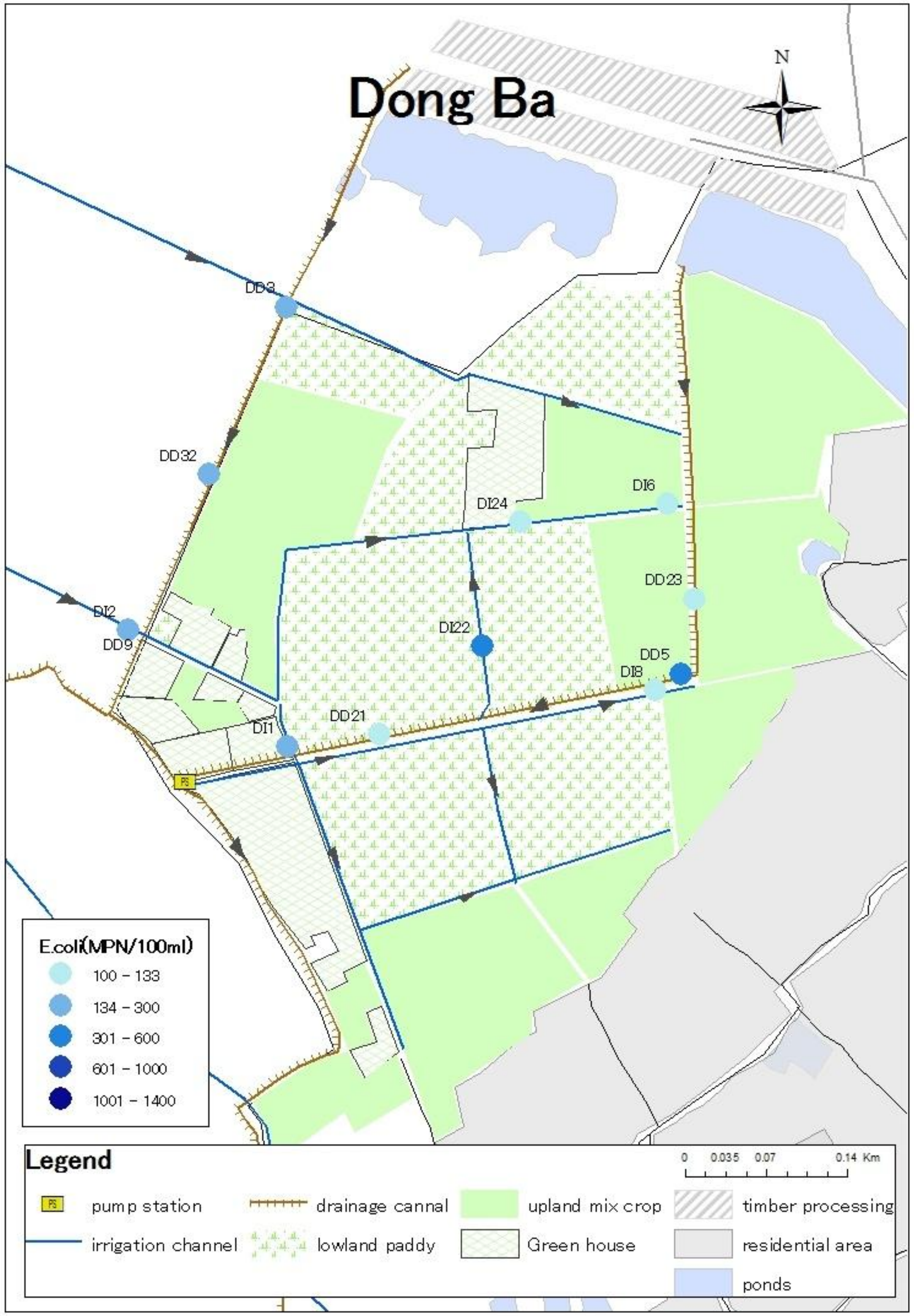


Figure 53. E.coli level of water samples taken at different locations

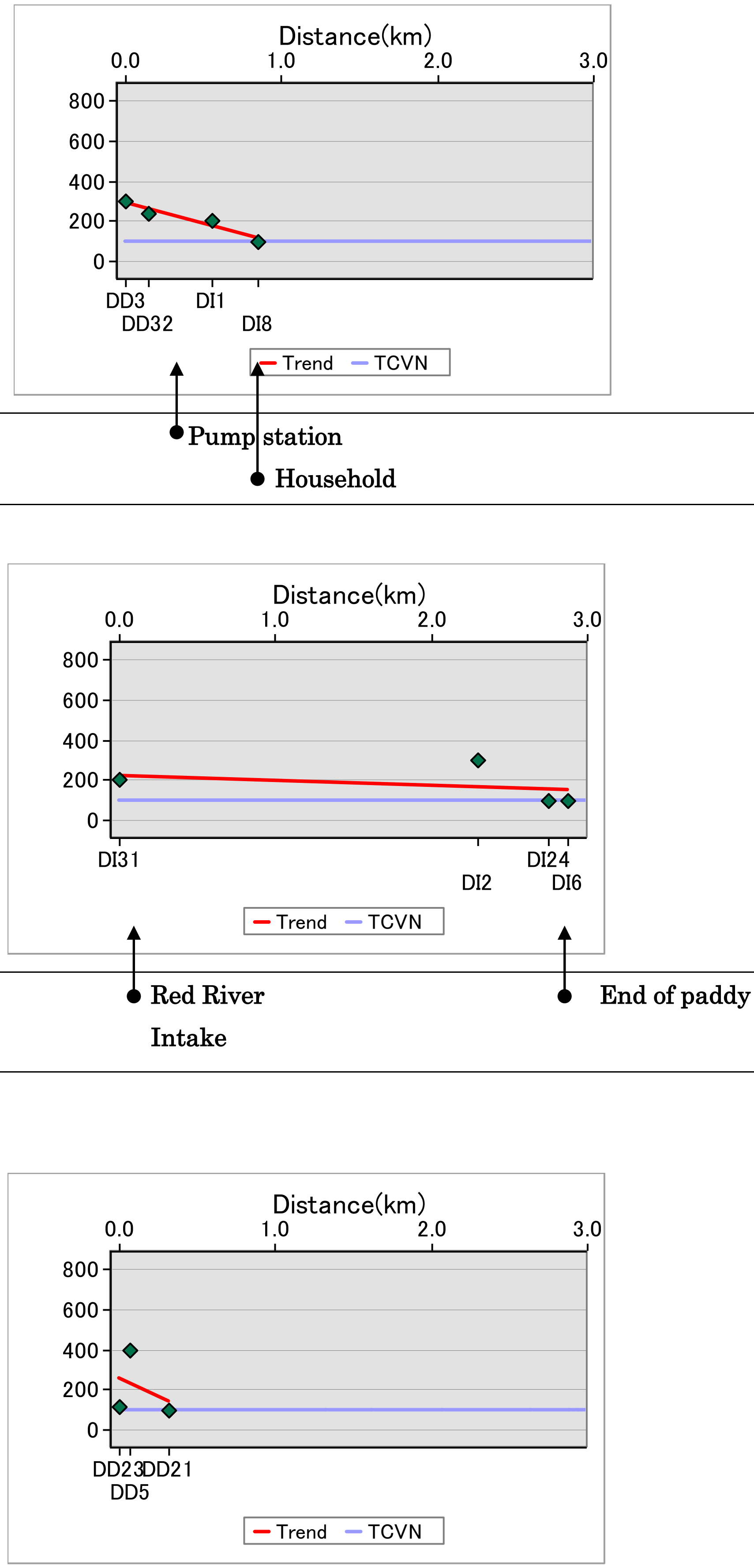
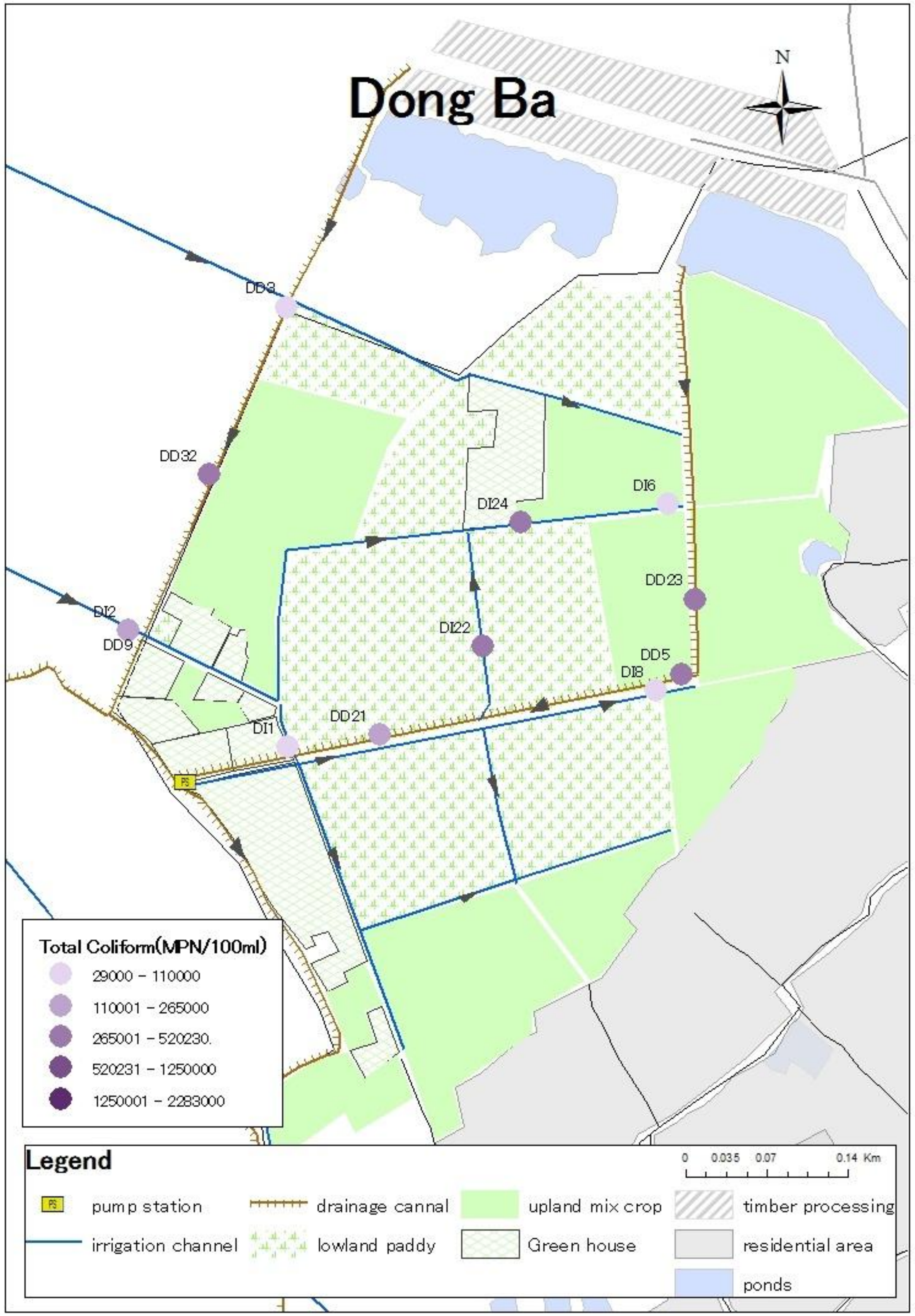
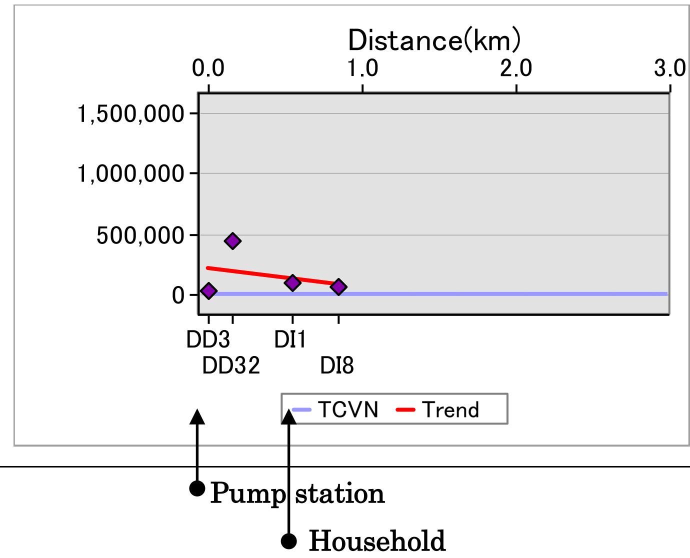
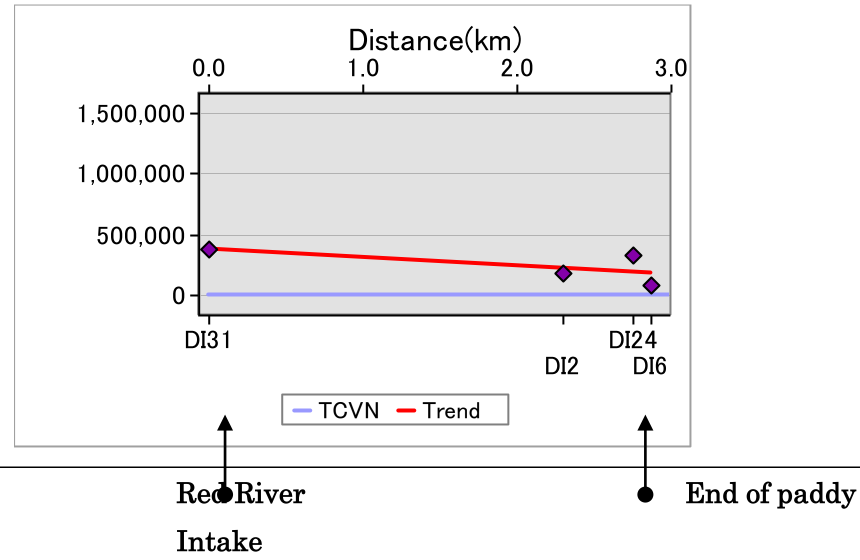


Figure 54. E.coli level variation of water sample along channels







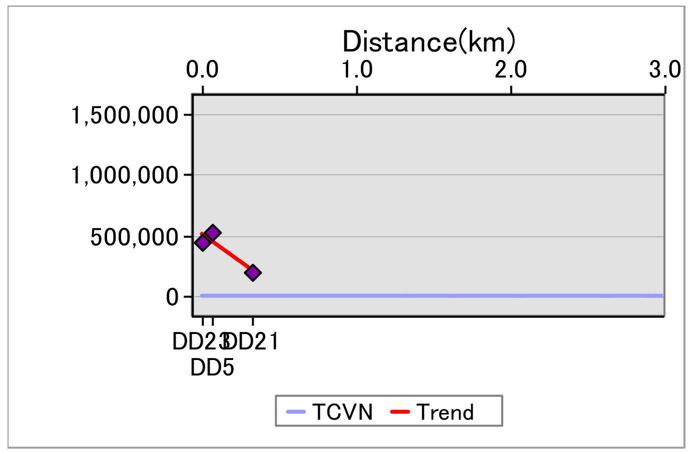


Figure 55. Total Coliform level of water samples taken at different locations

Figure 56. Dissolved Oxygen level variation of water sample along channels

Annex 3. Farmers questionnaire and result sheet

"This page is intentionally left blank"

Table 3. Summary of Farmer Questionnaire sheet and result
(Field survey on Mar-Apr/2011)

		Thanh Liet		Dong Ba	
PART I	GENERAL INFORMATION OF THE FARM HOUSEHOLD	n=13		n=16	
Part 1.1.	Respondent and Household charateristic		%		%
Q1	Sex:	1.54*		0.56*	
	0- Female	11	84.62	7	43.75
	1-Male	2	15.38	9	56.25
Q2	Age Group	1.85*		2.44*	
	1- under 40	4	30.77	3	18.75
	2-40~55	7	53.85	4	25.00
	3-55~60	2	15.38	8	50.00
	4- 60~	0	0.00	1	6.25
Q3	Educational level:	2.62*		2.69*	
	1-no education	0	0.00	0	0.00
	2-priliminary	6	46.15	9	69.23
	3-Secondary	6	46.15	4	30.77
	4-High school	1	7.70	2	15.38
	5-College/university	0	0.00	1	7.69
Q4	Do you and your family living in this village?				
	1- Yes	13	100.00	14	87.50
	2- No, another village but same district;	0	0.00	2	12.50
	3- No, another district but same province;	0	0.00	0	0.00
	4- no, another province	0	0.00	0	0.00
Q5	Do you yourself work on this farm (that is including all farming				
	0 - No	0	0.00	10	62.50
	1 - Yes	13	100.00	6	37.50
Q6	Do you hire other people to work on this farm (some farming				
	0 - No	12	92.30	6	37.50
	1 - Yes	1	7.70	10	62.50
Q7	How many people, including yourself, live in your immediate	4.77*		4.81*	
Part 1.2	Property and crop characteristic				
Q8	Proportion of households Involved in				
	Aquatic plant cultivation including rice	13	100.00	12	75.00
	Vegetable and horticulture farming	3	23.10	7	43.80
	Flower farming	0	0.00	2	12.50
	Aquaculture production	3	23.10	0	0.00
Q9	Size of production land(sao)				
	Aquatic plant cultivation including rice	4.4*		1.4*	
	Vegetable and horticulture farming	0.3*		0.4*	
	Flower farming	0.00		1.4*	
	Aquaculture production	0.00		0.0	
Q10	Landuse characteristic				
	1-Own;	10	76.90	13	81.20
	2- Rent;	2	15.40	0	0.00
	3- both	1	7.70	3	18.80

**Mean value*

Table 3. (cont.)

Q11	Last year crop consumption				
Q11.1	Aquatic plant cultivation including rice				
	1-Household's consumption	3	23.08	11	91.67
	2-Sell	0	0.00	0	0.00
	3-Both	10	76.92	1	8.33
Q11.2	Upland crops/Vegetable				
	1-Household's consumption	1	33.33	2	28.57
	2-Sell	0	0.00	0	0.00
	3-Both	2	66.67	5	71.43
Q11.3	Flower farming				
	1-Household's consumption	0	0.00	0	0.00
	2-Sell	0	0.00	2	100.00
	3-Both	0	0.00	0	0.00
Q11.4	Aquaculture production				
	1-Household's consumption	0	0.00	0	0.00
	2-Sell	0	0.00	0	0.00
	3-Both	3	100.00	0	0.00
Q12	Did you borrow money for crop production in 1 year back				
	0 - No	12	92.30	15	93.80
	1 - Yes	1	7.70	1	6.20
Q13	What is the last year main income from the following sources				
	1-Crops	6	46.20	3	18.80
	2-Animal/ husbandry	0	0.00	0	0.00
	3-fishery	2	15.40	0	0.00
	4-hired labor	4	30.80	8	50.00
	5-Trading/service	1	7.70	5	31.20
Q14	Household with				
	TV	12	92.31	16	100.00
	Motorbike	12	92.31	16	100.00
	Mobile phone	8	61.54	15	93.75
	Personal computer	5	38.50	5	31.20
	Refrigerator	8	61.54	13	81.25
	Tap water	7	53.85	3	18.75
	Hygienic bathroom and toilet(with septic tank)	11	84.62	14	87.50
PART II	IRRIGATION PRACTICE				
P2.1	Source of water for irrigation				
Q15	What is the main source of water that you use to irrigate your crops				
Q15.1	Low land paddy/Aquatic plant				
	0-No answer/don't know	0	0.00	0	0.00
	1-Irrigation channel	13	100.00	12	100.00
	2-Well	0	0.00	0	0.00
	3-Rain water	0	0.00	0	0.00
	4-Other(please specify)	0	0.00	0	0.00
Q15.2	Upland crops/Vegetable				
	0-No answer/don't know	0	0.00	0	0.00
	1-Irrigation channel	3	100.00	2	28.57
	2-Well	0	0.00	4	57.14
	3-Rain water	0	0.00	1	14.29
	4-Other(please specify)	0	0.00	0	0.00

Table 3. (cont.)

Q15.3	Flower				
	0-No answer/don't know	0	0.00	0	0.00
	1-Irrigation channel	0	0.00	0	0.00
	2-Well	0	0.00	0	0.00
	3-Rain water	0	0.00	0	0.00
	4-Other(please specify)	0	0.00	2	100.00
Q15.4	Fish				
	0-No answer/don't know	1	33.33	0	0.00
	1-Irrigation channel	0	0.00	0	0.00
	2-Well	2	66.67	0	0.00
	3-Rain water	0	0.00	0	0.00
	4-Other(please specify)	0	0.00	0	0.00
Q16	How do you evaluate irrigation water -interms of quantity?				
Q16.1	Irrigation channel				
	0- No concern/don't know/no answer	0	0.00	1	7.69
	1-Very unsatisfy	1	7.69	0	0.00
	2-Unsatisfy	3	23.08	0	0.00
	3-Neutral	8	61.54	9	69.23
	4-Satisfy	0	0.00	2	15.38
	5-Very satisfy	1	7.69	1	7.69
Q16.2	Well				
	0- No concern/don't know/no answer	0	0.00	0	0.00
	1-Very unsatisfy	0	0.00	0	0.00
	2-Unsatisfy	0	0.00	0	0.00
	3-Neutral	1	50.00	1	25.00
	4-Satisfy	0	0.00	3	75.00
	5-Very satisfy	1	50.00	0	0.00
Q16.3	Rain water				
	0- No concern/don't know/no answer	0	0.00	0	0.00
	1-Very unsatisfy	0	0.00	1	100.00
	2-Unsatisfy	0	0.00	0	0.00
	3-Neutral	0	0.00	0	0.00
	4-Satisfy	0	0.00	0	0.00
	5-Very satisfy				
Q16.4	Other(please specify)				
	0- No concern/don't know/no answer	0	0.00	0	0.00
	1-Very unsatisfy	0	0.00	0	0.00
	2-Unsatisfy	0	0.00	0	0.00
	3-Neutral	0	0.00	0	0.00
	4-Satisfy	0	0.00	0	0.00
	5-Very satisfy	0	0.00	2	100.00

Table 3. (cont.)

Q17	How do you evaluate irrigation water - interms of quality?				
Q17.1	Irrigation channel				
	0- No concern/don't know/no answer	0	0.00	2	14.29
	1-Very unsatisfy	2	15.38	0	0.00
	2-Unsatisfy	1	7.69	1	7.14
	3-Neutral	10	76.92	6	42.86
	4-Satisfy	0	0.00	3	21.43
	5-Very satisfy	0	0.00	1	7.14
Q17.2	Well				
	0- No concern/don't know/no answer	0	0.00	1	25.00
	1-Very unsatisfy	0	0.00	0	0.00
	2-Unsatisfy	0	0.00	2	50.00
	3-Neutral	1	50.00	1	25.00
	4-Satisfy	0	0.00	0	0.00
	5-Very satisfy	1	50.00	0	0.00
Q17.3	Rain water				
	0- No concern/don't know/no answer	0	0.00	0	0.00
	1-Very unsatisfy	0	0.00	0	0.00
	2-Unsatisfy	0	0.00	0	0.00
	3-Neutral	0	0.00	1	100.00
	4-Satisfy	0	0.00	0	0.00
	5-Very satisfy				
Q17.4	Other(please specify)				
	0- No concern/don't know/no answer	0	0.00	0	0.00
	1-Very unsatisfy	0	0.00	0	0.00
	2-Unsatisfy	0	0.00	0	0.00
	3-Neutral	0	0.00	2	100.00
	4-Satisfy	0	0.00	0	0.00
	5-Very satisfy	0	0.00	0	0.00
Q18	Do you have to pay for using the water? If yes, How do you evaluate this cost				
Q18.1	Irrigation channel				
	0- No concern/not pay/no anwer	0	0.00	3	23.08
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	13	100.00	8	61.54
	4-Cheap	0	0.00	1	7.69
	5- Very cheap	0	0.00	1	7.69
Q18.2	Well				
	0- No concern/not pay/no anwer	0	0.00	2	50.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	2	100.00	2	50.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap	0	0.00	0	0.00

Table 3. (cont.)

Q18.3	Rain water				
	0- No concern/not pay/no anwer	0	0.00	1	100.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	0	0.00	0	0.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap	0	0.00	0	0.00
Q18.4	Other(please specify)				
	0- No concern/not pay/no anwer	0	0.00	2	100.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	0	0.00	0	0.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap				
Q19	How do you get the water/evaluate the cost				
Q19.1	Gravity				
	0- No concern/not pay/no anwer	13	100.00	15	100.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	0	0.00	0	0.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap	0	0.00	0	0.00
Q19.2	Man power				
	0- No concern/not pay/no anwer	0	0.00	0	0.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	0	0.00	0	0.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap	0	0.00	0	0.00
Q19.3	Pump with motor				
	0- No concern/not pay/no anwer	0	0.00	0	0.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	2	100.00	2	100.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap	0	0.00	0	0.00
Q19.4	Other(please specify)				
	0- No concern/not pay/no anwer	0	0.00	0	0.00
	1- Very expensive	0	0.00	0	0.00
	2-Expensive	0	0.00	0	0.00
	3- Afordable	0	0.00	0	0.00
	4-Cheap	0	0.00	0	0.00
	5- Very cheap	0	0.00	0	0.00

Table 3. (cont.)

P2.2	Health protection habit				
Q20	Please choose from the list which you use to produce your crops:				
	Human waste/animal manure	0	0.00	2	12.50
	Wastewater	8	61.54	0	0.00
	Chemical fertilizer	13	100.00	13	81.25
	Organic fertilizer	12	92.31	3	18.75
	Pesticides (chemical)	2	15.38	13	81.25
	Pesticides (bio-degradable)	0	0.00	0	0.00
Q21	What do you wear typically while applying pesticides/ chemicals?				
	boots	13	100.00	4	25.00
	gloves	13	100.00	5	31.25
	hat/head cover	12	92.31	6	37.50
	mask	11	84.62	6	37.50
	glasses	0	0.00	0	0.00
	full sleeve shirt	13	100.00	7	43.75
	full length troussers	13	100.00	7	43.75
	other	4	30.77	8	50.00
Q22	What do you wear typically when working on field (other than applying pesticides)?				
	boots	13	100.00	3	18.75
	gloves	9	69.23	1	6.25
	hat/head cover	8	61.54	4	25.00
	mask	6	46.15	3	18.75
	glasses	0	0.00	0	0.00
	full sleeve shirt	13	100.00	9	56.25
	full length troussers	13	100.00	11	68.75
	other	0	0.00	0	0.00
PART II	PERCEPTIONS OF FARMERS ON RISK				
Q23	What are the health risks accociated with wastewater irrigation?				
	Headaches	0	0.00	5	31.25
	Skin infections;	0	0.00	7	43.75
	Sore feet	0	0.00	5	31.25
	Bad odor	0	0.00	7	43.75
	Muscular pains	0	0.00	4	25.00
	Cancer	0	0.00	6	37.50
	Intestinal pain/disease	1	7.69	9	56.25
	Other health risks (related to farming activities)	1	7.69	5	31.25
	Crops contamination	2	15.38	2	12.50
	Soil polution	1	7.69	2	12.50
	Diseases on crops	3	23.08	2	12.50
	Low crop yield	2	15.38	2	12.50
	Water bodies contamination	1	7.69	2	12.50
	Family's health	2	15.38	2	12.50
	Family's health	2	15.38	2	12.50
	Consumer's health	2	15.38	2	12.50
	No answer/don't know	10	76.92	5	31.25

Table 3. (cont.)

PART II	PERCEPTIONS OF FARMERS ON RISK MANAGEMENT MEASURES				
Q24	If you are recommended to practice safe irrigation, do you agree with the following terms?				
	Wearing Protective gears	12	92.31	5	31.25
	Safe food and drink	13	100.00	9	56.25
	Deworming	3	23.08	3	18.75
	Injection	3	23.08	0	0.00
	Crop restriction measures	5	38.46	3	18.75
	Water application technique	3	23.08	2	12.50
	Wastewater treatment	0	0.00	0	0.00
	Health promotion	5	38.46	5	31.25
	Other suggested measures	5	38.46	0	0.00
	No answer/ don't know	0	0.00	4	25.00

"This page is intentionally left blank"