A PLATFORM FOR INTEGRATED WATER RESOURCES MANAGEMENT FORMEGA DELTASUNDER CLIMATE CHANGE −JSPS MEGA DELTA PROJECT

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ABSTRACT

Large deltas are facing common environmental problems mainly due to human activities such as water development projects, water use demands, industry, agriculture, and groundwater over-exploitation. The main objective of this paper is to provide an overviewof the major environmental problemson the deltas of Nile and Mekong rivers and to introduce an ongoing international research platformaiming to propose strategies to mitigate those problems. The intensive literature review and on-going researches allowed us to identifyeight major environmental problems including increasing water demand, pollution, water management, and so forth. Therefore, research and governmental institutions in five countries tackle withthose major problems from the viewpoint of integrated watershed-coast management, water resources, water quality, and climate and social impacts. Through this platform within the life span of the project, it is expected to identify potential mitigation strategies to reduce the present and anticipated negative impacts on delta environments.

Keywords: Mega Deltas, Nile Delta, Mekong Delta, Water Resources Management, Environmental Management, Trans-boundary Rivers

1 INTRODUCTION

Asia and Africaare enriched with eleven fertile mega-deltas. They are located at the downstream ends of large river basins, whichprovide large fluxes of water, sediment, nutrients, and so forthbringing opportunities for millions of people to develop their livesand societies on these deltas (Lenton and Muller, 2009). Despite of such importance and their differences in geography and societies, these mega-deltas are commonly facing acute and chronic environmental problems due mainly to economic development, rapid urbanization, and climate change (Seto, 2011). A number of people in lowland riparian countries immigrate to delta regions looking for sources of economic benefit. This uncontrolled immigration inevitable sacrifices the environmental condition in deltas, for example,on water, land use and water quality. The rapid urbanization and development without proper measures for environmental conservation typically result in the reduction in social and ecological sustainability in mega-deltas includingNile and Mekong Deltas (e.g.,Ali et al., 2011;Tortajada et al., 2012).

Trans-boundary issues are mainly raisedfrom the development of hard structures, which might affect both local and neighbor countries. For instances in Nile River, Ethiopia, one of upstream countries, is attempting to develop water resources and hydroelectric energy production in the country by building dams so-called the Investment Model for Planning Ethiopian Nile Development (IMPEND) (Block and Rajagopalan, 2007), which is concerned in downstream countries. Water managers need to pay attention not only to hard structures but also to social, economic, and cultural impacts in involved societies (Mustafa, 2013). Water conflicts can be studied for example from game theory (Madani and Hipel, 2011). It is also important for not only researchers in academia but also international legal frameworksto encourage cooperation among riparian countries (Leb, 2013).

Such environmental problems related to quantity and qualityof water resourcescan be easily propagated to several other problems such as reduced sediment supply, saline intrusion, coastal erosion, pollution and deterioration of coastal ecosystems.On top of them, climate change may even aggravate those problems causing for instance sea level rise and extreme hydrological events. Given those important and complicated environmental issues, the present paper aims to provide a concise overview of those environmental problems and then introduce an ongoing international integrated platform attempting to tackle and mitigate them on mega-deltasby highlighting the concept of integrated water resources management.On this platform we conduct a series of comparative studies focusing on two distinct systems,Nile Delta in semi-arid region and Mekong delta in tropical humid region, both of which are located in the lower ends of trans-boundary river basins.

2 TARGET AREAS: NILE AND MEKONG DELTAS

This paper focused on Nile and Mekong deltas, which are globally important in terms of high productivity and unique culture including historical heritages. Nile Delta (area 25,000 km^2)is located in the southern coast of the Mediterranean Sea with total length of about 240 km. The delta is in hot desertand Mediterranean climates.The annual precipitation in the delta is less than 200 mm andthe mean flow of the Nile is around2,600 m^3/s at Aswan (Awulachew et al., 2008).Only approximately 4% of Egypt’s total area is agricultural land,and this area has one of the highest population densities in the world (about 1,600 people/km^2) (Abd El-Kawy et al., 2011). The delta has been affected by both natural and anthropogenic changes in environmental conditions (Syvitski et al., 2009).

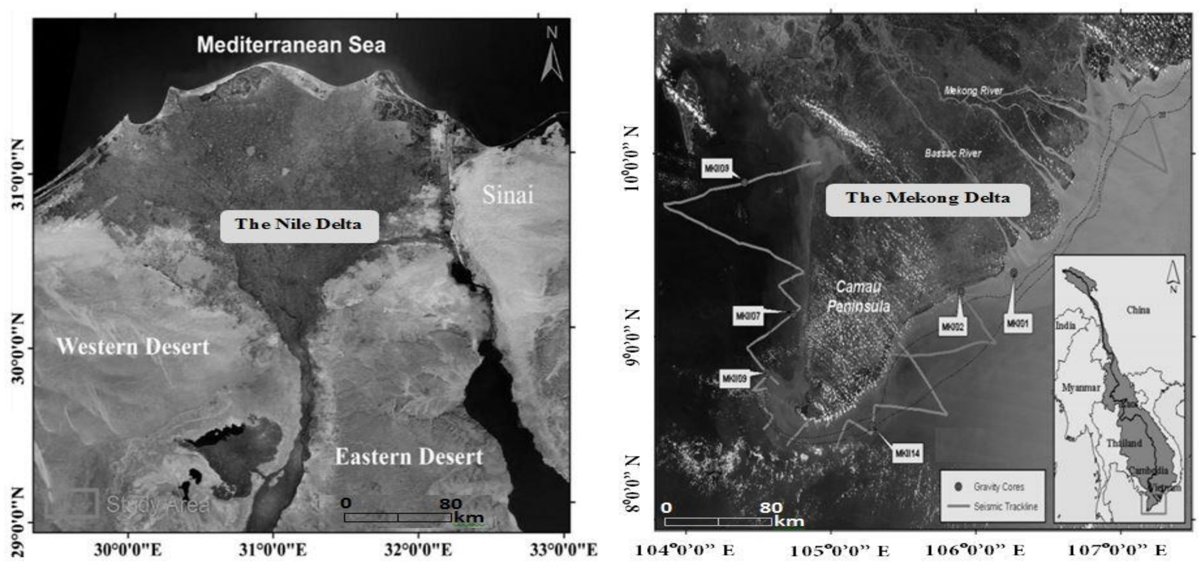

Figure 1.Nile and Mekong deltas (Sherif et al., 2012; Xue et al., 2010).

In contrast, Mekong Delta (area 39,000 km^2, excludingthe inner delta in Cambodia) is located in southern Vietnam and Cambodia with its coastal length about 600 km. Thedelta is situated in tropical monsoon climate.The annual precipitation in the delta ranges from 1,200 to 2,200 mm andthe mean annual flow is around 13,000 m^3/s at Kratie (Toan, 2013). The population on this delta is about 17 million in 2011(about 435 people/km^2) (Vietnam General Statistics Office, 2012). The major concerns in this delta arefloods and droughts, which are related to other environmental consequences, although the degree of anthropogenic impacts is relatively low in Mekong Delta compared to Nile Delta. Major environmental problems in these two deltas are summarized in the following section.

3 MAJOR PROBLEMS IN NILE AND MEKONG DELTAS

3.1 Increasing water demand

The Nile River is the main and almost exclusive source of freshwater in Egypt. The Egyptian part of the Nile is fully controlled by the dams at Aswan and a series of barrages between Aswan and Mediterranean Sea. Egypt relies on the available water stored in Lake Nasser to meet needs within its annual share of water, which is fixed at 55.5 billion cubic meters (BCM) annually by the agreement with Sudan in 1959.According to the MWRI (2014),agriculture consumes the largest amount of the available water in Egypt with its share exceeding 85% of the total water demand mostly in the delta and adjacent areas. In next decades, additional demands are expected from other sectors such as domestic use and industries, and thus the development of Egyptian economy strongly depends on how its water resources are managed.On the other hand, water has been used efficiently in the Mekong Delta. However, due to the floods causing serious damages to agriculture and livelihood of local residents, different hard measures were developed in order to quickly route the flood water out to both the East and West Sea. Such measures have been developed quite intensively over the last decade and now received greater attention from scientists and local governments as they lead to the possible lack of freshwater resource for agriculture in the dry period, especially in the coastal provinces (Le et al., 2007 and Toan, 2014).

3.2 Water management

Floods and water resources in Nile Delta has been controlled by High Aswan Dam, which allowed the agricultural development on the delta. The waterdistribution for agriculture hasbeen organized at different levels: main and branch canals and small channel “Mesqa”, which is the water distribution network since the ancient time.Today, however, water is hardly well managed for agriculture due to intensive use of pumps,lack of maintenance of Mesqa, and increasing salinity(MWRI, 2005). The interface of fresh- and salt-water has moved 80 km towards inside the delta in the past 50 years due to excessive pumping rates and declined recharge rate of groundwater aquifer (Kotb et al., 2000).In contrast, Mekong Delta is facingtwo major managementissues: flooding in the upstream regions inrainy season and saline intrusion in dry season(Nguyen et al., 2008 and Takagi et al., 2014). The former causesdamages on livelihoodsandharvests in agriculture and aquaculture while the later causes to damageson freshwater-based agriculture systems. Such facts have leaded to the current policy of building hard-measures (for example, full-dyke in the upstream areas and sluices in the coastal areas) to protect those areas, which in turns resulted inthe shift of natural hydraulic and hydrological dynamics, for example to stagnant and polluted surface water due to the constructed structures.

3.3 Hydraulic infrastructures

Egypt has been maintaining the hydraulics heritage, rehabilitating and reconstructing 16small size regulators and barrages for water security and agricultural sector development in the long term.Some examples of the studies related to the rehabilitation of the major hydraulic structures include Assiutbarrages(Dawouda et al., 2006) and Esna Barrages (El-Fakharany and Fekry, 2014). However, suchhydraulic infrastructures on irrigation networks often perform below the expected level or capacity due to the lack of their proper maintenance.Also in Mekong Delta, water-related infrastructures were rapidly developed mainly to control floods and saltwater intrusion. However, those engineering structuresmay result in higher flow velocities deepening rivers and canalsincreasing the flood risk in the non-protected areas(Le et al., 2007)..Additionally, the siltation of the Mekong estuary and coastal zone erosion might varywithin coming decades mainly due to dam regulation upstream.Then, proper design and maintenance of such infrastructures within integrated water management seems necessary inboth Nile and Mekong rivers.

3.4 Pollution of water resources

The major problem on surface water quality in both deltas is direct discharge of waste water from agriculture, aquaculture, industries, and households to drainages as well as rivers and lakes in deltas (e.g., Bohannon, 2010; Islam et al., 2015). In Egypt, for instance, 60% of sewerage water is treated through WWTPs; the other 40% are discharged directly to agricultural drains without any treatment (El-Sheikh et al., 2010; Ali et al., 2011). Similarly, different sources of pollutants can be recognized in Mekong Delta. The major source of pollution on these deltas are accounted by (i) intensive use of fertilizer, pesticide and herbicide for agriculture (El-Mowelhi, 2006; Fleifle et al., 2014); (ii) intensive use of commercial feed and chemicals for aquaculture (Marcussen et al., 2014; Nhan et al., 2008;Phong et al., 2013) and, (iii) wastewater from both urban and industrial areas (Minh et al., 1997; Toan et al., 2014). The quality of the surface water resources is hardly mitigated only bydilution with limited environmental water (Wilbers et al., 2014) and such prevailing pollution in drainage networks hinders the implementation of potential strategies for water reuse (Debenay and Luan, 2006; Ali et al., 2011). Water pollution possibly causes serious health, environmental, and ecological problems on the deltas depending on the load and type of pollutions (e.g., Tarazona, 2014).

3.5 Decreased sediment transport and coastal retreat

Currently, the fluvial sediment transfer from land to sea has significantly decreased in a number of river basins over the last century mainlydue to sediment retention in reservoirs (Paolus and Collins, 2002) and soil conservation measures(Walling, 2006).For example, the planned dams or already under construction along the main stream of the Mekong basin possibly alter the sediment regime of the Mekong Delta drastically (Lu and Siew, 2006; Fu et al., 2008; Gupta et al., 2012; and Liu et al., 2013). Kummu et al. (2010) estimated that hydropower reservoirs could trap 67 % of the sediment reaching the Mekong Delta if all the planned dams are built. Such a shift in sediment dynamics is evident in the Nile Delta. The pre-dam sediment load for the Nile River was estimated to be in the order of 100Mton/year (Walling, 2006), which dropped nearly to zero after the construction of Aswan and Aswan High dams (Ahmed and Ismail, 2008;Marriner et al., 2013). Since then the supply of sediment reaching the river mouth at Rosetta and Damietta has no longer been sufficient to stabilize the delta coastline, causing coastal erosion (Stanley, 1996; ElBannaandFrihy, 2009; Frihyet al., 2008). Moreover, the reduced sediment flux may reduce nutrient inputs to deltasand the long term stability of ecosystem functions in the deltas (Stanley and Warne, 1998; Saito et al., 2007).

3.6 Groundwater degradation and land subsidence

Groundwater availabilityis limited due to increasing groundwater salinity in the both delta, especially in Nile Delta due to the limited local precipitation and the slow rate of its infiltration(NourEldin, 2013). At the same time, the land subsidence of the northern 30 km of Nile Delta is also one of major concerns. Ongoing subsidence rates are estimated to be 8mm/yearat highest (double of Holocene rates), which is related with the distribution of the youngest deposition (Becker, 2008). In addition, subsidence rates based on different techniquesranged from 2 to 8 mm/year (Stanley and Goodfriend, 1997; Stanley and Toscano, 2009; Becker and Sultan, 2009). Similarly, Mekong Delta has beenalso experiencing the degradation of groundwater resources both in terms of quantity and quality (mainly salinity). It can be caused by the over-extraction of groundwater for different purposes: industrial activities, household consumption and irrigating farms. The land subsidence is taking place also in Mekong Delta as a result from the combined impacts of natural processes of soil compaction, the decreasing sediment-supply due to the hydropower development at the upstream and the dyke-system development within the delta, and the over-extraction of groundwater resources (Costa-Cabral et al., 2008 and Park et al., 2011).

3.7Sea level rise

Ongoing climate change would pose a serious risk to these deltas in terms of water supply under the increasing demographic pressure. Rising temperature alone would evaporate more water, increase the need for water supplies, raise heat stress, and exacerbate air pollution, which in turn may drive away tourists. In addition, sea level rise threatens settlements and agriculture in the mega-deltas. According to the IPCC's fifth assessment report (AR5), Nile Delta is one of the most extremely affected river deltas in the world by climate change (Sabine, 2014), whereas the reports on Mekong Delta is scarce. Schubert (2006) estimated the induced sea level rise along the northern coast of Nile Delta and foundthat the coastal area is vulnerable to the projected sea level rise in terms of both social and biophysical aspects (Figure 2), which can be accelerated by the above-mentioned land subsidence.

3.8 Other water related issues

The legal framework for protecting water and its allocation is also a critical issue in the both deltas. The environmental mitigation and management of delta regions are hindered by the lack of closecooperation with upstream countries in the basin, the inadequate institutional framework, and deficiency of legislation (Allam, 2007). Strong water legislation is one of the pillars for integrated water resources management (Lenton and Muelller, 2009).

Water resources management involves different governmental units, which leads to difficulties insharing relevant data (database), making the best use of available database, and creating a common platform to discuss and seek solutions.Decentralization of the decision-making processes as well as coordination among the involved institutions seems to be essential to overcome such difficultiesin the existing institutional framework (Allam, 2007;Khalifa, 2011). It is also important to recognize and enhance roles of local residents and famers in addition to the improvement of institutional framework.

Local expertise and academicians attempt to solve environmental problems in both mega deltas.However, most of the research results are not effectively implemented in actual management, which is mainly caused by the facts that (i) they did not have opportunities to be involved in the policy-making processes from initial stages; (ii) the accuracy of the available database is not good enough to support a solid conclusion from the scientific community; and, (iii) Data-sharing between the government and research units and between the research units themselves are still limited.

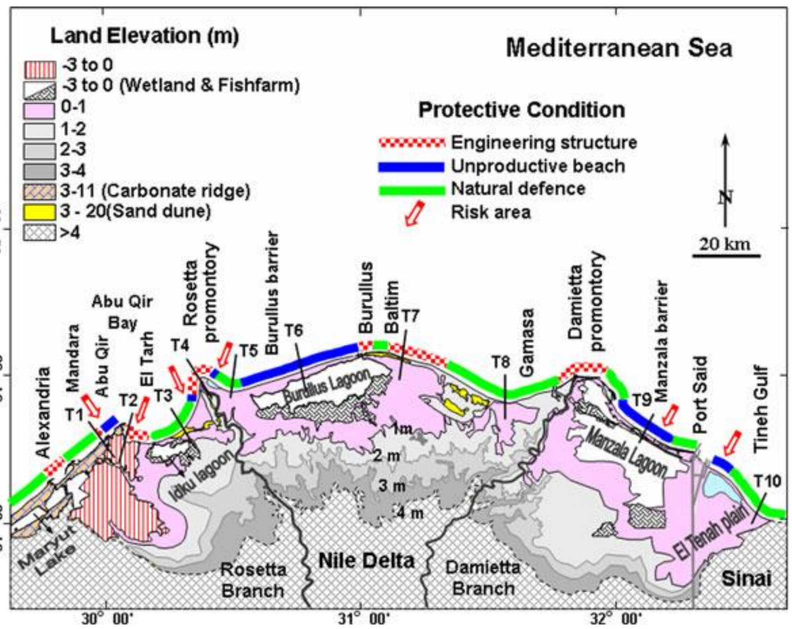

Figure 2.The elevation and protective condition of the lower coastal plain of Nile Delta (Khalid and Omran, 2010).

4 JSPS MEGA DELTA (JMD) PROJECT

JMDproject is funded by Japan Society of Science Promotion (JSPS) and was launched in April 2013 with an initial3-year period. JSPS' core to core program is designed to create top world-class research centers that partner over the long term with other core research institutions around the world in advancing research in leading-edge fields, on issues of high international priority, and in areas that contribute to the solution of prevailing problems in the Asia-African regions. In this project, we plan to address long term effects and come up with a feasible strategy to understand both vulnerable Nile and Mekongdeltas in terms of water resources and management (Figure 3). This framework allows usto expect synergy effectsby combining expertise and experiencesin different counties in modeling techniques and understanding processes related to hydrology, water quality management, coast ecosystem, and climate change effects. In summary, the objectives of this project is 1) to establish a network within institutions in five countries, 2) to develop a feasible strategy to understand the long term potential socio-economic effects in both mega delta areas, and 3) to foster young researchers in institutions at collaborating countries.To carry outthe project smoothly, we have set up four working groups as shown in Figure 4 and hold annual seminars at different cities (Ho Chi Minh City in 2013; Tokyo in 2014, Alexandria in 2015) to share our approaches and new findings among members.

Participating institutions in Japan are Tokyo Institute of Technology (Tokyo Tech), Kyoto University (KU), Tokyo University (TU), and Tohoku University (TOU). The counterpart institutions in Africa are Egypt-Japan University Science of Technology (E-JUST), Alexandria University (AU), National Water Research Center (NWRC), Coastal Research Institute (CoRI), and Bahar Dar University (BDU) while institutions in Asia are Ho Chi Minh City University of Technology (HCMUT), Can Tho University (CTU), Southern Institute of water Resources Research (SIWRR), Ministry Of Natural Resources and Environment (MONRE) and Institute of Technology of Cambodia (ITC).Existing collaborative research in Egypt (EJUST, AU, NWRC, CoRI), Ethiopia (BDU), Vietnam (HCMUT, CTU, SIWRR, MONRE) and Cambodia (ITC) provides a great opportunity to enhance cooperation focusing in mega delta regions where various vulnerable aspects can be studied jointly. Through this project, we also expect to foster young researchers including graduate students.Our outputs are expected to be published in journal papers, reports, conferences and website. The details of the project can be also accessed online (URL. https://sites.google.com/site/jspsmegadelta/).

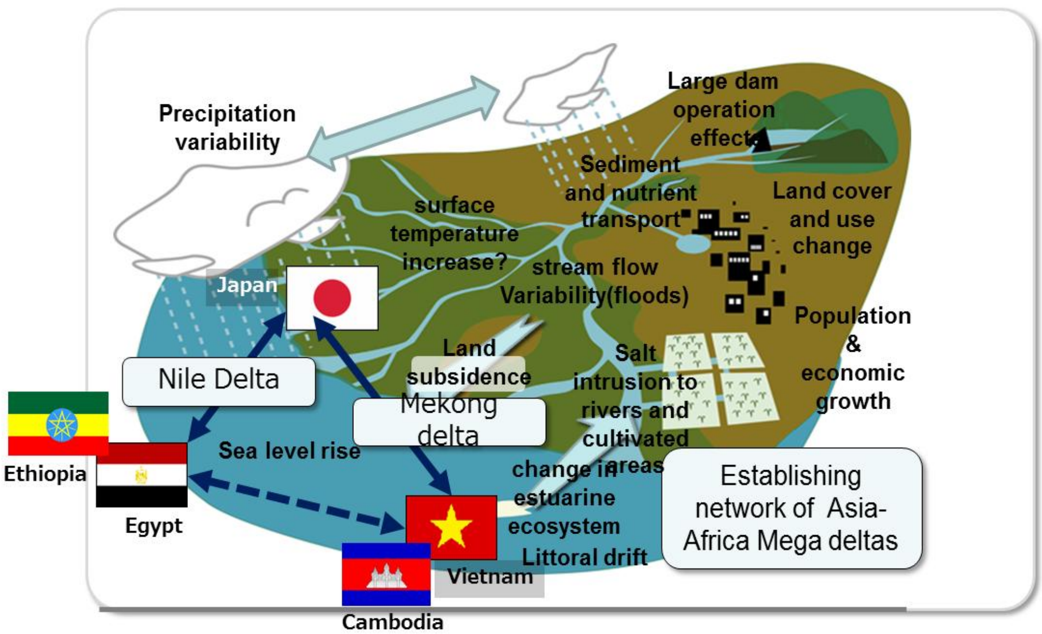

Figure 3.Scheme of the studied delta with the topics to be addressed by five countries.

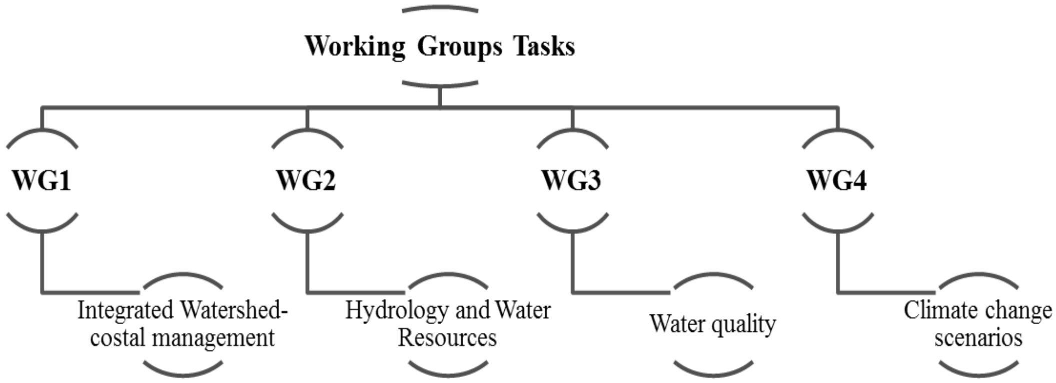

Figure 4.Working groups in JSPS Mega Delta Project (JMD).

5 EXPECTED OUTCOMES OF JMD PROJECT

5.1 Integrated watershed and coastal zone management (WG-1)

This group analyzes the current status and its historical change of the delta system with focuses on local and global environmental impacts and develops the comprehensive numerical model system to predict possible changes in the delta system under various future development scenarios. With these results we will further develop a model system to quantitatively evaluate the processes of water resources/quality/ecosystem variations under these environmental impacts and the associated change in the disaster vulnerability of the delta system. Thereby we attempt to provide scientific knowledge to support policy decision making and others for achieving the sustainable development of the delta areas by keeping the disaster risks below the acceptable levels. These attempts will be performed in close cooperation with other working groups to properly integrate the prospective outputs also from these different groups.

In 2013, various historical data including socio-economic, meteorology, hydrology, and water quality data of the Mekong delta region were collected and partially prepared into the digital format. The spatio-temporal analysis of water quality and socio-economic data were also performed aiming at differentiating the socio-environmental conditions across the delta area. Moreover, the future development scenarios of the Mekong Delta both at regional and sub-regional scale were formulated based on the integrated analysis of the available information and climate change scenarios. As for Nile Delta, the water quality dynamics in BurullusLagoon (Figure 2) was analyzed using a numerical simulation model.

In 2014, field surveys in Mekong Delta were conducted to fill the water level and salinity data gaps by implementing a collaborative monitoring scheme with logger-type sensors and to find public awareness with questionnaire surveys about the flood disaster and its prevention. At the same time, we developed the scenarios assessment tool (SAT model) and applied it to three representative sub-watersheds in Mekong Delta region to reveal the socio-economic benefit and environmental impact of each development scenario on this region. Furthermore, we extended our activities to assess the mangrove species and status across the coastline of the delta region, which was also important for the development of future management plan. Field surveys were also conducted to identify the mangrove species composition and distribution, height, diameter, canopy closure, and leaf area index, etc. We analyzed high resolution satellite data (World-View 2) to develop maps on mangrove species composition, height, productivity and biomass for Can Gio mangrove area. As for Nile Delta, we performed field surveys and related numerical simulation model development for assessing coastal sedimentary and water quality processes in the Delta, especially in Rosetta Promontory and its adjacent areas.

5.2 Hydrology and water resources (WG-2)

In trans-boundary river basins, hydrological modeling has been expected to be one of useful approaches to support decision making in integrated water resources management and planning for regional development and to reduce trans-boundary conflicts by promoting equitable allocation of and access to water, particular in basins located within developing countries (Johnston and Smakhtin, 2014). This group, therefore, make best use of hydrological modelling techniques to understand basin hydrology, which will provide a link between river basin and delta in terms of water resources management. The local and global hydro-meteorological data related to Nile and Mekong river basins were collected and uploaded in a simple database format in our website to be shared among members internally for research purposes. These observed data allowed us to calibrate and validate our hydrological models, and thus prediction of stream flow variability considering high and low flows will be possible.

Our specific working plan is as follows:1) Weapply hydrological models (SWAT, GBHM, and BTOP) to Nile and Mekong river basins based on the long-term hydrological observations. 2) These models (SWAT, GBHM) are used to evaluate potential effects of climate change (e.g., 30-year forecast of precipitation and temperature). 3) Then, we will use those basin outputs as input to models specific to delta regions, which will be implemented jointly with other groups.For this purpose, we jointly with WG-4 are preparing several climate change scenarios based onoutputs from major general circulation model including the method for bias correction. Besides, potential hydrological effects of precipitation pattern and land cover under climate changes might be simulated and evaluated.

In Nile basin, White Nile River basin will be combined with Blue Nile and Atbara river basins to investigate spatio-temporal flow changes under different scenarios in water resources policies including Sudd swamps as potential source to increase water volume in the basin. In Mekong River basin, we additionally focus on one or two sub-basin(s) inside Cambodia for the simulation of detailed hydrological processes including soil moisture, evapo-transpiration, river discharge, and sediment transport. The interaction with Tonle Sap Lake and Mekong River will be also addressed. On those tasks, inter-comparison of model outputswill be carried to ensurereliability of results.To date, we identified the key comparative indicators between Nile and Mekong river basins. These indicators were related to hydro-meteorology, model applicability, irrigation activities, water use, and policies. More than one model/approach would be applied for such comparative study. The effect of operating and planned dams would be addressed using different scenarios allowing us to suggest alternative water resources management in both trans-boundary river basins.

It is also important for this group to have tight interactions with other working groups as we highlight integrated water resources management in this project. For example, the simulated rivers discharge from basin hydrological models will allow us to consider the water balance in deltas. Not only sediment transport but also potential climate change and socio-economic projections may be included as scenarios for water resources management in the both deltas. Through those activities, we continue fostering young researchers from participating countries by carrying out joint research and holding short training courses in Japan about the necessary modeling tools such as hydrological model, GIS, and exploitation of remote sensing data.

5.3 Water environment and aquatic ecosystem in mega-delta (WG-3)

The research objective of this group is to propose methodologies to properly manage water environment, including groundwater, and aquatic ecosystems in Nile and Mekong deltas. The network of researchers among Japan, Egypt, and Vietnam was established by the exchange of graduate students, postdoc researchers, and young faculties while we jointly work for the important research topics. The specific topics in this group are 1) sediment transport, sediment-related nutrient dynamics, and human influence on sediment and nutrient dynamics and further on aquatic ecosystems, integrating sediment-related processes in the upstream regions of the delta, 2) development of in-situ treatment to reuse typical drainage water in the delta, and 3) assessment and management methodology of groundwater quality in the delta focusing on arsenic pollution. Common keywords among the counterparts are water quality, sediment transport, and ecological consequences of human impacts in the Nile and Mekong Delta and tasks mentioned above would be completed within three years of this project.

In task (1), the monitored data on water environment and ecosystem in Nile and Mekong deltas will be collected and analyzed to elucidate the current condition in each delta and its long-term shifts considering climate change as well. Then, the distributed transportation model is set up for assessment of sediment transport down to the delta through the two river systems, which is jointly conducted with WG-2 and WG-4. The framework of this modeling has been already completed, and calibration and validation of the model parameters ware completed also in 2014, based on the collected environmental data (e.g., Suif, et al. 2013). In task (2), we are conducting water treatment experiment using aquatic plants and floating media, for the development of in-situ treatment system for agriculture drainages, mainly in Tokyo Institution of Technology and E-JUST (e.g., Ateia, et al. 2014) because this task has a close relevance to water resource problems in Nile delta. In task (3), water quality data of groundwater in Mekong delta are being collected and we will review appropriate methods to model arsenic pollution. In addition to the annual seminar of this project, this group holds the workshop in three main institutions in Ho Chi Min City, Alexandria, and Tokyo, inviting graduate students and young researchers.

5.4 Climate change and social scenarios (WG-4)

The environmental assessment model in coastal and future climate data to input the hydrological model is made with coupled model inter comparison project phase 5 (CMIP5) output based on the current future scenario of greenhouse gas emission until now. The one of the objective is to apply these data to simulation in large river which has large delta, for example Nile and Mekong rivers. In this step, the collection of the systematic bias in CMIP output data is required, while the development of method to collect the data for flooding in delta is also important. This development is the one of the major scientific challengeto meet our objective. An bottom-up information storage about the assessment of climate change will be organized by considering the background and implications of future climate data, outputs of hydrological simulation for researcher and technical expert, and the corresponding risk and vulnerability in each sector. Then, downscaling data of social scenario will be implemented based on the shared socio-economic pathway (SSP) follow CMIP5.

CMIP5-based climate datasets, spatially-downscaled socioeconomic datasets are prepared in accordance with SSP,which is an internationally coordinated set of future socioeconomic scenarios for CMIP5. The results of the hydrological and water environmental projections are coupled with the SSP-based socioeconomic datasets to demonstrate future potential human-nature interactions in two mega-delta regions. These future projections are carried out not only by WG-4 but in collaboration with other groups. In addition, the possibility of bottom-up type climate change impact assessment is examined by trying to incorporate local/regional information of vulnerability and risk into future projections. The development of bottom-up type climate change impact assessment requires local/regional knowledge, experiences, and wisdom. Thus, international collaboration under this program is crucial. An inventory of future water-related vulnerability of two mega-delta regions can be also one of outputs of such collaborative works.

6 CONCLUDING REMARKS

Interestingly, our intensive review identified the common environmental problems on Nile and Mekong delta, although climate and historical backgrounds are distinct between the two regions. The major causes (driving forces) for the environmental problems are 1) increasing water demand in deltas and basins, 2) unsustainable activities in deltas, 3) climate and social changes, and 4) inefficient management related to infrastructures, legal framework, and technical development. Their consequences are found in several serious symptoms such as water shortage, pollution (surface and ground water), land subsidence, sea level rise, saltwater intrusion, coastal retreatand deterioration of coastal ecosystems.Such causal relations are closely interlinked at different temporal and spatial scales, and therefore, the concept of integrated water resources management is critically important to mitigate those problems and provide sustainable environments and societies on the deltas for present and future generations.

Given those important and complicated environmental issues, therefore, the authors wish the present paper draw sufficient attention of the stakeholders, international researchers, decision makers, and research funding units.The present paper is one of first outcomes from JMD project. Based on the findings, the ongoing international project will come up with knowledge, tools, strategies, and polices to tackle and mitigate environmental problemson selected mega-deltas by highlighting and implementing integrated water resources management along with solidlegal frameworks and strong participation of local communities.

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