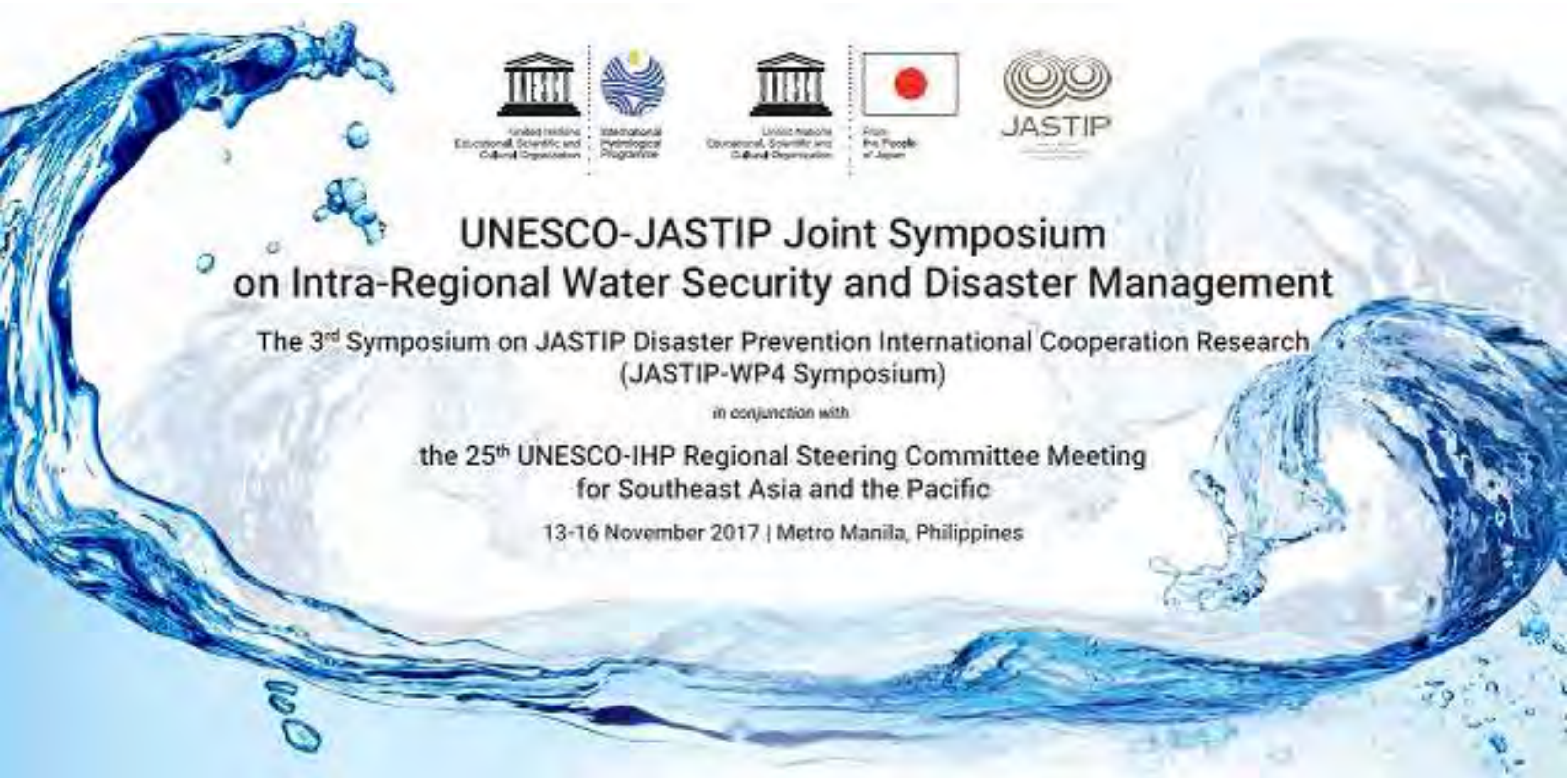

PROCEEDINGS

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PREFACE

On the occasion of the 25th UNESCO-International Hydrological Programme (IHP) Regional Steering Committee (RSC) meeting held in Manila, Philippines, the UNESCO-JASTIP Joint Symposium on Intra-Regional Water Security and Disaster Management was organized by the Philippine Water Partnership, the UNESCO Regional Science Bureau for Asia and the Pacific and Kyoto University, in partnership with JASTIP - the Japan-ASEAN Science, Technology and Innovation Platform. Held on 15-16 November 2017, the activity also served as the 3rd JASTIP-WP4 Symposium.

The UNESCO-IHP is the intergovernmental programme of the UN devoted to water research, water resources management, and education and capacity building. Since its inception in 1975, IHP promotes and develops international research in hydrological and freshwater sciences through interdisciplinary and integrated approach to watershed and aquifer management, which incorporates the social dimension of water resources. UNESCO-IHP's eighth phase (IHP-VIII) programme for the period 2014-2021, focuses on six thematic areas namely: 1) water-related disasters and hydrological changes, 2) groundwater in a changing environment, 3) addressing water scarcity and quality, 4) water and human settlements of the future, 5) ecohydrology, engineering harmony for a sustainable world and 6) water education, key to water security.

JASTIP is a research project funded by the Strategic International Collaborative Research Program (SICORP) of Japan Science and Technology Agency (JST) in order to promote international cooperative research that can contribute to the Sustainable Development Goals (SDGs). It has three research areas: Energy and Environment, Bio resources & Biodiversity, and Disaster Prevention. Its research group for Disaster Prevention, called Working Package 4 (WP4), is responsible for carrying out implementation of disaster-related research in the ASEAN region under the JASTIP project. The last two JASTIP-WP4 Symposia in March 2016 and March 2017 were held in Kyoto University, Japan.

The symposium featured 45 technical presentations - representing the cutting edge of water and disaster research in the region – as well as two special addresses on the history and achievements of the RSC delivered by founding members Prof. Kuniyoshi Takeuchi of Japan and Prof. Soontak Lee of the Republic of Korea. The subthemes for the symposium included river basin management and water governance; SD6 and ecohydrology; climate change and resilience; disaster preparedness, recovery and governance; floods, earthquakes, geologic and coastal hazards; and winds and building structures. Participated by JASTIP-WP4 and UNESCO-IHP RSC members, as well as researchers, practitioners, students, government officials, academicians and scientists from various countries in Asia and the Pacific such as Indonesia, Japan, Mongolia, New Zealand, Fiji, Thailand, China, Australia, Pakistan, India, Singapore, Lao PDR, Vietnam, Australia, Germany, Myanmar, South Korea, Malaysia and the Philippines, the Joint Symposium did not only provide the platform for sharing and discussing current scientific work but also networking opportunities for experts, researchers and practitioners from the UNESCO-IHP and JASTIP linkages to come up with new ideas in developing new projects and collaborative research on intra-regional water security and disaster management.

This symposium was made possible through funds from UNESCO Jakarta Office through Dr. Shahbaz Khan and Dr. Hans Thulstrup and JASTIP through Prof. Kaoru Takara. The organizers also wish to acknowledge the support provided by Maynilad Water Services Inc., Hedcor, Inc., Manila Water Company, Inc., Philippine Valve Manufacturing Company and CMC Di Ravenna and the tireless efforts of Bea of Unesco, Noemi of PWP, Abner of NHRC and many volunteers who served as members of the various committees and the secretariat.

CONTENTS

Challenges to Water Security: Hetao Irrigation District, Yellow River Inner Mongolia

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INTRODUCTION

The Hetao Irrigation District in China's Inner Mongolia Autonomous Region is one of the county's three largest irrigation areas. Irrigation in the Hetao Basin using water from the immense Yellow River (Huanghe) commenced in the Qin Dynasty, 2,300 years ago. Farmers there, over a long time, have adapted very successfully to the harsh arid and semi-arid conditions, extremes of temperature, soil salinity and short cropping season. The District produces substantial proportions of China's wheat, maize and sunflower outputs as well as vegetable and fruit. Initiation of the modern irrigation and drainage system in 1961, however, has imposed new challenges such as over-use of water, leakage of supply canals, rising saline water tables, soil salinity, decreasing water levels in lakes, and crop impacts as well as the complex issue of equitably sharing water with the growing demands from downstream industries and communities. These are all added to concerns caused by climate variability and change.

The competition for water from the non-agricultural sector and from downstream communities, industry and power generation has resulted in a mandated 18% ($7x10^8$ m^3/y) decrease in the annual amount of water available for irrigation in Hetao, to be introduced progressively. The challenge to the Basin's water security of achieving that decrease in demand, while managing salinity, maintaining productivity and improving equity, is significant. This paper concentrates mainly on the technical issues. The water and salt balance of the Basin is examined to identify emerging threats to water security and agricultural sustainability.

METHODS

Climate

Data on the Basin's meteorology, hydrology and hydrogeology is dispersed and the task of pulling together relevant information is significant. The Basin is semi-arid with annual rainfall around 150 mm/y and pan evaporation around 2,000 mm/y. On average, the peak in monthly evaporation occurs earlier in the growing season, so evaporation from partially covered soil is significant. Monthly rainfall, on average, peaks later in the growing season, so that interception losses are expected to be higher, reducing the influence of rainfall on crop growth. From 2000-2013, the Variability Index of annual rainfall varied between moderate to high. The limited annual rainfall available for the Basin, 1990 to 2013, showed no significant trend in rainfall.

Hydrogeology

The hydrogeology suggests the Basin is closed with three main features: a surface aquitard layer, up to about 20 m in depth, an unconfined Aquifer 1 whose depth varies between about 20 and 240 m, and below that a confined, deeper aquifer, Aquifer 2. The piezometric head distribution of the unconfined aquifer has an hydraulic gradient of 30 to 40 m across the entire Basin flowing generally west to east towards Ulansuhai Lake. Recharge inputs from Yellow Rivers seepage in the south-western part of the Basin and discharge from the northern mountains are evident in the head distribution.

Salinity distributions in the surface aquitard, Aquifer 1 and Aquifer 2 show higher concentrations of salinity in the aquitard and Aquifer 2 than in the intermediate Aquifer 1, the main aquifer used for domestic, industrial and irrigation in the Basin. In general, the western part of the Basin has lower salinity than the eastern part. All three groundwater units show apparent recharge from the western part of the Yellow River and areas of the northern mountains, which may suggest that Aquifer 2 is not entirely confined. Whether Aquifer 2 is totally confined or not is an important issue in the salt dynamics of the Basin.

RESULTS

Irrigation and Drainage

Annual irrigation supply from the Yellow River and annual drainage to Ulansuhai Lake data for the whole Basin show increases in time between the 1960s and 2006 due to development of the system. Irrigation supply is very significantly dependent on annual rainfall decreasing at a rate of (-580±130) x10^4 m^3/mm increase in annual rainfall. In contrast, annual drainage has no significant trend with rainfall.

Water Losses from the Basin

A simple whole Basin water balance approach was used to examine water losses from Hetao, assuming a hydraulically-closed Basin. Mean specific irrigation water loss (the difference between Yellow River Supply and drainage discharge over the area of the Basin) from 1967 to 2006 was 421±23 mm. There is a significant increasing temporal trend in irrigation water losses of 1.3±0.6 mm/y. Annual irrigation losses show a very significant decreasing trend with increasing annual rainfall of (-0.64±0.15) (mm/y)/mm. Using a range of values for annual actual evaporation from the Basin in a long-term water balance, it was estimated that the combined annual recharge from the western portion of the Yellow River and the northern mountains was (2.8-5.7) x10^8 m^3/y, between 6 to 12% of the mean annual irrigation supply extracted from the Yellow River.

Salt Accumulation in the Basin

Analysis of the salt input and output from the assumed closed Basin found that salt is accumulating in the Basin at a rate of (1.5±0.3 to 1.6±0.3) x10^9 kg/y, equivalent to an increase of 1500 to 1700 kg of salt/ha/y. The rate of salt accumulation shows a decreasing trend with increasing annual rainfall of (-4.3±1.3) x10^6 kg/mm, apparently due to the decreasing trend in annual water losses from the Basin with increasing rainfall.

It is suggested that density-driven convection moves the accumulated salt from the surface of the aquifer to lower depths. If Aquifer 2 is completely confined, the analysis suggests that the TDS is accumulating in Aquifer 1 at a rate of 0.004 kg/m^3/y or about 0.2 kg/m^3 over the 46-year period of intensive irrigation. If there is no leakage to Aquifer 2 and the Basin is closed then the continued salt accumulation cannot go on indefinitely without agronomic impacts. If it is assumed that when the mean concentration of Aquifer 1 reaches an average salt concentration of 4 kg/L significant agronomic and water supply impacts will start to occur, then it is estimated that, with the current rate of salt accumulation, this limit will be reached in less than 240 years. Data shows the area-weighted TDS salinity in the Basin has been increasing by 0.04 kg/m^3/y since 1980.

CONCLUSIONS

Restoring the Salt Balance

The long-term water security and agriculturally sustainability of Hetao Basin are threatened by salt accumulation. To restore salt balance in the Basin, drainage out of the Basin needs to be increased. The extensive, existing drainage system in Hetao is largely gravity-driven and it is difficult to see how this could be increased. One way drainage could be increased is by pumping saline water from lower layers of Aquifer 1. An excellent place for this pumped drainage is in Wulate sub-district in the south-eastern part of the Basin adjacent to Ulansuhai Lake where the thickness of Aquifer 1 is only 40 to 80 m and groundwater salinity is at least 5 kg/m^3. With this concentration, the drainage rate from the Basin would need to be increased by about 50% to 8.7x10^8 m^3/y, or about 19% of the annual irrigation supply, to balance salt accumulation in Aquifer 1.

Keywords: *Irrigation, salinity, groundwater, water security, drainage*

Implementing Change: Low –Cost, High Impact Approaches to Meet Water Quality Targets Identified Through an IWRM Process

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INTRODUCTION

Integrated Water Resource Management (IWRM) approaches such as the Canterbury Water Management Strategy (CWMS), result in "aspirational" targets. The challenge then becomes to effect change across a wide range of partners and stakeholders to achieve these targets. Many approaches have been attempted historically to effect change in the past with water quality in Canterbury on a piecemeal basis. Often there have been attempts to use either non-regulatory and regulatory approaches in isolation. This paper describes impacts of the early stages of a co-ordinated approach between non-regulatory and regulatory that has emerged to implement real change in both rural and urban practices. Regulatory approaches are carried out under the auspices of the Canterbury Regional Councils known as Environment Canterbury (ECan). This body works alongside ten Territorial Authorise that regulate some aspects of land use and supply "three waters" (water supply, wastewater and stormwater) services.

METHODS

Rather than attempt to give an overview of all aspects of the CWMS this paper describes how nonpoint source pollution is being addressed in rural and urban areas. The focus on nonpoint source pollution is important as it is one of the greatest current challenges in water management and requires approaches that are not only technically correct but which change the behaviour of individuals, businesses and local government.

It has been observed that three factors underlie much of what is occurring with water:

1. Complacency. Some issues have been identified for considerable time but have not been acted on. Examples in Canterbury include the rising level of nitrate in groundwater, the risk of pathogens in shallow groundwater wells used for water supply and the failure to put water quantity abstraction limits in place in a timely manner due to a mistaken belief that water supplies were large compared to potential demand.
2. Equitable treatment. Having recognised that a resource is overallocated or that emissions of contaminants (e.g. Nitrates) are too great, approaches must be developed that are viewed as providing equitable treatments of different individuals, groups, companies etc. Note the term "equitable" is widely used in respect of access to water and to widespread use of cooperatives in agriculture in New Zealand.
3. Cost and affordability. Correction of an "overshoot" in meeting economic and business goals is the responsibility of individual and commercial organisations, given the low level of government involvement in New Zealand. Given the importance of agricultural land use, changes in practices to meet environmental targets needs to be done in a manner that does not cripple business outcomes. The same applies to communities with limited resources from property taxes (rates) to provide community services and outcomes.

Considering the three factors above activities and approaches have been developed for rural and urban activities. Both sectors are subject to an evolving mix of regulatory and non-regulatory approaches that are being developed collaboratively. While collaboration is a complex concept the most important elements are coordination, cooperation and communication. A key component of the CWMS are committees drawn from the community that are active within 10 zones plus a regional committee.

For rural application, Environment flows are being updated and limits have been set to nitrates in different parts of Canterbury. The regulatory system sets limits through rules that are generally expressed as a maximum annual tonnage of nitrate from a catchment. At the same time as catchment limits are set, individual farms above a relevant threshold of scale are required to prepare a Farm Environment Plan (FEP). FEPs are developed by farmers to identify at risk areas on farms. FEPs also outline actions needed to improve management of nutrient, soils and water bodies including wetlands. The goal is to have all farms at Good Management Practice (GMP).

Urban areas face more complex issues with contamination coming from a mix of e-coli (canine, human, waterfowl), chemicals (including Polycyclic aromatic hydrocarbon (PAH)) and metals (including copper and zinc). The regulatory approach has been to make the operators of stormwater networks, which are local councils, progressively responsible for applying for a consent for a consent to discharge into waterways by 30 June 2018 and to take responsibility for what is entering their stormwater networks by 30 June 2025.

RESULTS

Target 1 (2015): *Set environmental flows for surface streams, rivers and groundwater that are consistent with the fundamental principles of the CWMS. Set catchment load limits for nutrients for each water management zone that are consistent with the fundamental principles of the CWMS. Established and begun to implement a programme to apply environmental flows to existing consents.*

Outcome for Target 1 at 2017: Environment Canterbury has made significant progress towards setting environmental limits through the Land and Water Regional Plan (LWRP). The LWRP, effective from January 2012, sets environmental limits that require farmers and other land users to 'hold the line' and not increase nitrate losses.

The LWRP provides a region wide planning framework within which catchment specific plan changes (subregional chapters) are added which introduce local limits. Several catchment specific plan changes are either completed or underway in each zone. The sub-regional chapters are developed via a detailed and intensive community engagement and planning process. In addition to sub-regional plan changes, a suite of improvements has been made to the LWRP relating to improved biodiversity outcomes, protection of īnanga (indigenous fish species) spawning habitat, storm-water management, drinking water source protection, and the exclusion of livestock from lakes and rivers.

The latest update to the LWRP will require farmers to reduce nutrient losses and manage their land in an environmentally sustainable way. Environment Canterbury has worked with the primary sector to define acceptable farming practices. These 'Good Management Practices' (GMPs) now provide farmers and council with a shared understanding of how to limit nutrient losses and manage environmental impacts. Zone committees are central to developing the planning framework, and are focused on a work programme to deliver a range of on-the-ground projects to improve water quality,

Target 2 (2020): *Review of environmental flows and catchment load limits in response to changing monitoring information, new understanding and technologies, and if requested by regional and Zone Committees.*

Outcome for Target 2 at 2017: Catchment loads and flows are being monitored by Environment Canterbury through the regular state of the environment monitoring programme. Water levels and river flows and water quality are monitored monthly and include over 100 recreational sites. Zone committees are regularly updated with this information which is used for decision making for the sub-regional plans.

Target 3 (2020): *Established and begun to implement a programme to review existing consents where such review is necessary to achieve catchment load limits.*

Outcome for Target 3 at 2017: Specific catchment load limits have been, or are being, set in sub-regional plans. Environment Canterbury continues to monitor and model catchment loads and work through zone committees to determine whether consent reviews are necessary to achieve catchment load limits. Because there have been several recent updates to the planning framework the approach has been to set consent durations to deliver on catchment load limits. Consent reviews are a substantial task that often ends in legal proceedings. Hence the need to build a strong evidence base through science is challenging as legal proceedings are expensive and uncertain with no guarantee science based information will prevail.

The overall outcome sought by 2040 provides an insight into expectations from advances in biophysical sciences and its application through a social science process as follows. *Review of environmental flows and catchment load limits in response to changing monitoring information, new understanding and technologies, and if requested by Regional and Zone Committees. Environmental flow and catchment load limits achieved in all water-bodies*.

CONCLUSION

Approaches to implement water quality targets set through an IWRM process are challenging and take time. To identify and implement low cost, high impact work with industry and community groups is essential. A key part of this is the use of "Good Management Practice" approaches that identify methods that high performing organisations use in each sector and to provide information on the methods and motivation to uptake to the rest of the sector,

While this paper focuses on rural issues, urban issues are following a similarly prioritised approach. For example, the difficulties with retro-fitting stormwater treatment point to "behavioural change" programmes as the most cost effective first step. This is due to the lack of performance information on installations to date, weaknesses in flow estimation methods making design problematic and diversion of scarce capital and maintenance resource to earthquake damage recovery.

Keywords: *IWRM, implement, water quality*

IWRM at Watershed Scale Helps District Government for Water Security

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INTRODUCTION

IWRM is being implemented all over the world considering its wide area of applications and flexible spatial scale. Scientists have found IWRM being useful in Indian context also where a coordinated development of water and land resources is sought as part of complete economic, social and environmental welfare. There exist challenges of IWRM implementation in India on river basin scale, especially in the context of water laws and water conflict resolution process. Due to functional inadequacies in several districts within river basins in various parts of India, such areas have to be left while implementing IWRM at the basin scale. Too many policies within a single river basin further complicate matters because of overlap and contradictions. As such, the other viable option of implementing IWRM is at the watershed scale (better if falling within a district), blending the formal and informal mechanisms of governance for promoting livelihood of the people.

We have to realize that the decision makers and planners need a practical approach to transposing the IWRM concept into an operational tool for their water resources management plans. At the district level, IWRM addresses almost the complete supply chain of water management (from rainfall inputs to water consumption by different users to wastewater generation and subsequent handling) and, most importantly, builds on the existing institutions. In Indian context, the inherent cross-sectoral integration requirements of IWRM planning can be best achieved at the district level where the District Magistrate is the single controlling authority for various organizations (e.g. line departments) dealing with the different resources. Author's experience of working for the water conservation and management in a water-scarce area in India brings out that a "local IWRM approach" can be effective if combined with the appropriate hydrological tools. The paper presents a case study demonstrating the application of "Local IWRM" for water conservation and management planning at the district level, and realizing its potential through internalizing with the government functioning.

METHODS

Although it is often argued that using hydrological unit (e.g. a watershed) for implementation of IWRM Plan may not be feasible as it does not necessarily coincide with the administrative unit (e.g. Tehsils/Blocks- local administrative units), GIS technology can very well take care of this requirement. A good use can be made of the commonly available GIS software to handle the variety of spatial information collected from the study area. Another useful tool to enhance the utility of an IWRM Plan is a Decision Support System (DSS), which facilitates the decision-making process for the stakeholders in selecting appropriate water management practices on a sustainable basis.

Government of India has introduced a scheme on "Pradhan Mantri Krishi Sinchai Yojna (PMKSY)" in 2015 with the vision of extending the coverage of irrigation, accelerating watershed development activities and improving water use efficiency. Under PMKSY, each district is required to prepare a "District Irrigation Plan (DIP)", which provides a comprehensive plan for the future water resources development of the district. The plan includes district water profile, water availability, water requirement/demand, and provides a strategic action plan at Block/Sub-district level for improving groundwater levels through recharge measures, enhancing irrigation coverage, soil and water conservation through structural and non-structural watershed measures, improving the agriculture production and other livelihood activities. The Agriculture Department is the designated nodal agency for this plan, which is envisaged to be implemented with cooperation of various concerned key departments at the district level.

The present case study was undertaken in two watersheds of Madhya Pradesh in the central part of India. The geographical area covered under Ur river watershed of Tikamgarh district and Kathan river watershed of Chhatarpur district is approx 1000km^2 and 1341km^2, respectively. In Tikamgarh district, parts of 4 Blocks covering 183 villages fall in the Ur river watershed. Similarly, in Chhatarpur district, parts of 5 Blocks (including 1 Block of Sagar district) covering 238 villages fall in the Kathan river watershed. The area has semi-arid climate and receives an average annual rainfall of about 900mm, 90% of which is received during monsoon season (between June-September). The region experiences once in a five year drought conditions; however the ratio has been increasing for last few years. The other conditions making this region backward are erratic rainfall pattern, water scarcity, poor soil health, low crop productivity, low groundwater recharge potential due to hydro-geological situation and, finally, and lack of sound water management planning.

Development of the IWRM plan started with holding an interaction workshop with the local stakeholders in the two watersheds. The development issues and water-related problems in the two watersheds were mapped and possible solutions discussed with the local stakeholders. A vulnerability assessment exercise was conducted using IPCC's approach of Livelihood Vulnerability Index (LVI) to identify the vulnerable areas in the watersheds, which need to be focused in the IWRM Plan.

RESULTS: "IWRM PLAN"

IWRM Plan framework prepared for the watershed areas comprises of three components: (i) Water management, (ii) Land management, and (iii) Livelihood management (Fig). The water management component deals with the recommendations for domestic water demand, water harvesting for irrigation requirements and for groundwater recharge. The location of water harvesting structures is shown on the maps (on sub-watershed or Block basis). The land management component deals with the recommendations for improved agricultural practices and efficient irrigation techniques.

3.1 Water Management

In this section, various structures have been suggested to be built at the proposed locations, which are supposed to feed the current population of watershed in the form of drinking water, irrigation water, bathing and other purpose water, and also to provide alternative water supply sources. Identification of suitable sites for water harvesting structures is done on the basis of natural (hydrological) boundaries, i.e. sub-watersheds, and have been suggested considering topography, soil type, soil texture, slope, land use, percolation, infiltration rate, drainage or stream network etc. However, the locations of the identified sites are made available to the local user organizations on administrative units e.g. district, block, Gram Panchayat or a village, through a Decision Support System (DSS) developed for this purpose.

3.2 Land Management

The main emphasis of land management is to maintain a judicious combination of crops, water, human and financial resources, to ensure long term sustainability. The planning is done in order to create agri-based livelihood opportunities, increase productivity, maintaining soil health, etc. and suggestions are aimed at ensuring more production with less crop failure. Suggestions pertaining to the major crops that are grown in the area included System of Crop Intensification, drip irrigation for high value vegetable and fruit crops, Wadi model for fruit and vegetable crops, crop rotations, line sowing, and crop diversification, considering the local soil conditions, nutrition value of crops, crop diversification potential, etc.

3.3 Livelihood Management

As a part of livelihood linked natural resource management, the aim is to increase both availability and options of livelihood while conserving the natural resources in terms of quantity as well as quality. Through this approach, emphasis is given on utilizing the locally available resources to create livelihood opportunities that ensure food security and nutrition, curb poverty, provide sustainable agricultural practices and help in combating climate variability and related impacts, etc.

The conventional livelihood practice in both these watersheds has been agriculture, which as a result of climate variability and other crop failure consequences, has resulted in diminishing employment and financial gains. A focus shift on non-agricultural, employment generating opportunities will help prevent people from migration, which is one of the biggest social challenges these watersheds are currently facing. Off farm activities like poultry, fishing, handicrafts, are being suggested to engage people in a variety of livelihood activities. Within this study duration, various training programmes were conducted where livelihood activities related to handicraft, bee keeping, etc. were demonstrated to the villagers.

CONCLUSION

The paper presents the concepts of “Local” IWRM planning applied to water conservation and management in two case studies- in Ur river watershed in Tikamgarh district and Kathan river watershed in Chhatarpur district of Madhya Pradesh (India). IWRM planning is shown to be a practical tool in district level planning for implementation of water management activities. The IWRM Plan, designed in three sections of (1) water management, (2) land management, and (3) livelihood management, provides suggestions on the activities under these three themes. The Plan considers effective utilization of land, water and other available natural resources, linked to the vulnerabilities and livelihood opportunities in the geographical area. The Plan is designed in such a way that it provides useful inputs to the District Irrigation Plan (DIP) of the Government, both in terms of water supply and demand management synergized with the land management and livelihood improvement. Identification of the needs and priorities of various water users, as well as the threats that water poses in terms of land degradation, droughts, contamination of water sources, were deliberated with the stakeholders during consultations at various stages. Some of the suggestions, involving technology interventions, were pilot tested in the field in collaboration with the local villagers.

The IWRM Plan intends to promote the component of water demand management in the district level planning. A unique feature of the IWRM plan presented in this study is that mostly secondary data as available at the district level was used in developing the plan. The framework used for developing the IWRM Plan can be further downscaled to the GP level, addressing the lowest unit of governance in India.

Keywords: *Watershed, IWRM, water management, Bundelkhand, India*

Understanding Potential Conflicts Among Sectors Due to Spatial and Seasonal Water Use and Availablity in Bali, Indonesia

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INTRODUCTION

In water scarce area or during dry seasons when water is limited, the diversification of economic activities requires shifting in water allocation from one sector to another. Particularly in developing countries, improving economic welfare significantly influences the decision making over water reallocation. Water reallocation due to limited amount of resources has been known as source of conflicts among sectors. To balance the sectorial needs, conflicts handling is a major concern of many recent literatures in water management (Molle, 2006).

This study takes an example of development in Bali as one of the world's tourist destinations (Fig. 1). Bali's Gross Regional Domestic Product (GRDP) was supported by agricultural sector back in 1980s (more than 40%). Since 1990s, tourism started to develop rapidly. Recently, it contributed up to 30% of total GRDP in Bali (BPS Provinsi Bali (Statistics of Bali Province), 1979-2016). The shifting water distribution from agriculture which is mostly owned by the locals to tourism industries about 85% of which is owned by non-Balinese (MacRae, 2010) is one of the examples of a conflict ridden process. Research on water conflicts in Bali were mostly discussed through social and political perspectives (Cole, 2012; Tarigan, Dharmawan, Tjondronegoro, & Suradisastra, 2014; Trisnawati, 2012) and very little research were published about the scientific reasons behind these conflicts. The objective of this paper is to understand conflicts between sectors in Bali by comparing the spatial and seasonal variabilities of water uses and availability. Based on the availability of water resources and needs by different sectors, this study discusses potential conflicts among sectors in water resources management in Bali.

METHODS

In order to clarify when and where water is lacking in Bali, we calculate water use and water availability. We calculated water use for agriculture, domestic and tourism sectors and water availability from rivers, springs, and groundwater. The calculation is carried out on monthly or yearly basis for 20 years from 1994 to 2013 at each regency/city. The calculation of domestic water use the population data and each person use 100 liters (BSN (National Standardization Agency of Indonesia), 2002). The calculation of tourism water use was based on number of occupied room for each month and water requirement per room was referring to Wiranatha (2001). The agriculture water use was calculated based on harvested area and the need of irrigation water per month. Water availability from rivers was calculated based on 31 main catchments using rainfall and evaporation. The springs and groundwater availability were calculated based on Public Works' data and recharge volume based on report of the Integrated Urban Infrastructure Development Program-Bali.

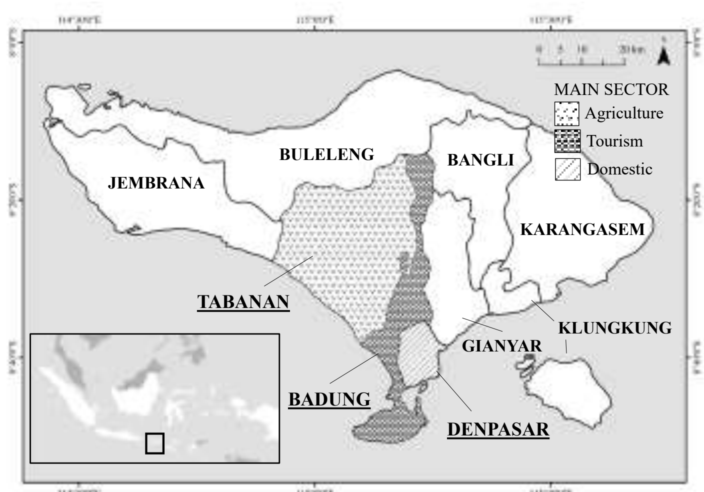

Fig.1 Map of study site

RESULTS

Results shows that the total use in Bali was declining until 2003 and back increasing until 2013. The ratio of water use among sectors (agriculture:domestic:tourism) changed from 92%:7%:1% (in 1994) to 89%:9%:2% (in 2013) suggesting reallocation from agriculture sector to tourism and domestic sector for 51.63 million m^3. Water use was only slightly decreased in 20 years with total amount of about 1.6 billion m^3 while water availability ranged between 3.5 billion m^3 to 7.1 billion m^3. The comparison of yearly water use and water availability shows the use of 22%-43% of water resources in Bali. Therefore, for most of the years between 1994 and 2013, water in Bali considered under high stress and in a couple of years (2001 and 2002) were under extreme stress (based on United Nations (1997) water stress scale).

The spatial calculation shows that the distribution of water use and availability in Bali varies. The highest water resources available in Buleleng Regency (17%) and the lowest is in Denpasar City (1%) while the highest water use is in Tabanan Regency (25.49%) and the lowest is in Klungkung Regency. Therefore, water stress among regencies varies. Water stress in Bangli Regencies are considered low to moderate while in Badung Regency and Denpasar City, water stress are under extreme condition since 1994. The two regions were known to be prone to water conflicts (Strauß, 2011; Trisnawati, 2012). Interviews with 21 farmer leaders in Denpasar City revealed that they are aware of water shortages in agriculture and that they are competing with water consuming sectors associated with tourism (Strauß, 2011). The interview also revealed farmers perceive that water for agriculture is being prioritized for other purposes. From 1994 to 2013, water for agriculture in Denpasar City decreased by 20% (13.59 million m^3) and reallocated for domestic (18%) and tourism (2%). Water for agriculture in Badung Regency was also decreased by 9% (19.20 million m^3) and reallocated for domestic (6%) and tourism (3%). The biggest amount (52.77 million m^3) of water reallocated from agriculture to domestic happened in Tabanan Regency where water stress is under high to extreme. Water conflicts among farmers themselves and between farmers and the water supply company were among the famous ones (Bali Post, 2009, 2011a). Due to the lack of water in Badung and Denpasar, the government developed agreement with neighborhood regencies to share water called "SARBAGITAKU", consists of Denpasar, Badung, Gianyar and Tabanan and Klungkung. However, these regencies which are under agreement for water sharing are all under high to extreme stress. This condition may lead to conflicts not only between sectors in one regency/city, but also between regencies.

The seasonal calculation shows (Fig. 2) that during months of August and September, water stress in all regencies in Bali is under extreme condition.

Most water crisis which were reported in the local newspapers during July to October were caused by lack of water resources while those which were reported during February to April were caused by damage in water infrastructures (due to landslides or floods). Some of the reported crisis were escalated to conflicts and destructions of public properties (Bali Post, 2011b, 2011c, 2016) happened in Badung (July 2011), Karangasem (July 2011), Gianyar (Octobe r2017), Klungkung (November 2016), and Tabanan (October 2009). All of these conflicts happened when water stress level in extreme condition.

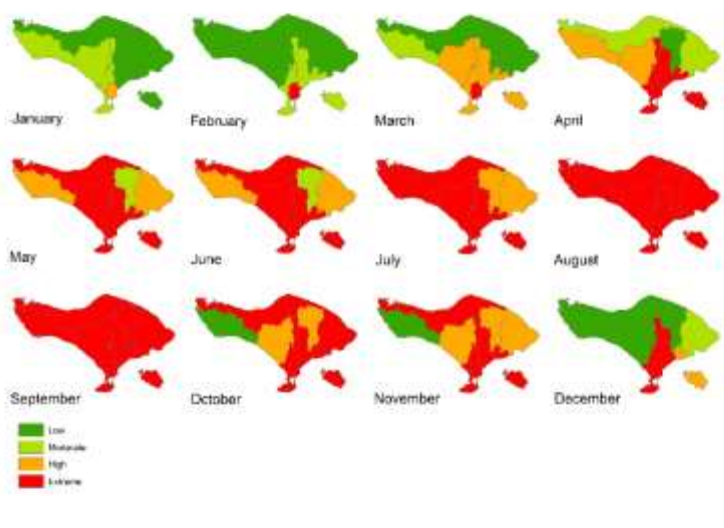

Fig. 2 Spatial water stress level in regencies/city in Bali

CONCLUSION

This study concluded that even though the Bali's GRDP shows a change in regional income from agriculture to tourism, but agriculture water use was only slightly decreased (2.73%) from 1994 to 2013. It even shows increasing trend since 2003. As the original income for the Balinese, this may cause conflicts between farmers and other sectors. It should be therefore well regulated in terms of timing and location based on available water resources. Accurate information with scientific evidence on spatial and temporal availability of water as well as suggestion on planting schedule should be communicated through proper method such as through the traditional subak system.

Urbanization and tourism development happened in Badung Regency and Denpasar City and water was reallocated from agriculture sector (decreased to 62.78 million m^3) to tourism and domestic (increased to 33.83 million m^3). Furthermore, these regencies have in nature smaller water availability compare to other regencies (9% of all Bali). This situation makes these regions prone to conflict due to hydrological variation especially in prolonged dry period. The use of relatively stable water sources such as springs and groundwater should be therefore regulated and monitored in a better way to avoid uncontrolled use during dry period. On the other hand, assessment on the sustainable limit of the use of these resources particularly for these regency and city should be done more carefully to allow access during dry period.

The spatial and temporal variations of water use and availability in Bali together with its increasing trend due to economic growth require better accuracy in predicting hydrological variation in particular to detect prolonged dry period. Therefore, more research to better predict hydrological condition, particularly prior to rice planting seasons, is necessary.

Multi-Level Stakeholders' Engagement for Strategic Strengthening of Flood Warning and Management Capacity in Pakistan

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INTRODUCTION

During 2010 monsoon season which lasts from June to September every year, the mega floods triggered from the Upstream of Indus system extended on 64% of Indus river basin in Pakistan, leaving 20 million of people affected, claiming 2000 lives with economic losses direct and indirect estimated at more than 10billion USD. Based on UNESCO flood experts' recognition missions conducted in 2010, UNESCO prepared a response project with the Pakistani authorities to reinforce the country's capacity in flood management by: 1) Strategic Augmenting of Flood Forecasting and Hazard Mapping Capacity by developing the first locally tuned hydrological model for main Indus, Indus-IFAS and remote sensing based floodplain and hazard mapping of Lower Indus, 2) establishing a Knowledge Platforms for Sharing Transboundary and 3) strengthening Capacity Development for Flood Forecasting and Hazard Mapping and Community Data. These activities were conducted during phase 1 of a JICA supported project from 2011 to 2014 with ICHARM/PWRI, JAXA as Japanese partners and PMD, SUPARCO and PCRWR as main Pakistani partners. One of the most significant contributions from this project is the capacity building and local knowledge development of local stakeholders. The new expertise acquired from this project would provide leadership role for flood management efforts in Pakistan as well as for the whole South Asian region. However due to likely climate change impacts, heavy monsoons rain are more frequently affected the Eastern part of Indus river system which is mainly transboundary with Afghanistan, China and India, affecting yearly billions of people and inflicting significant economic damages and losses in the entire basin and not only in Pakistan. Hence the following remaining needs where identified 1) the need to continue flood management capacity building in Pakistan, 2) the need to further improve the accuracy of Indus-IFAS modelling by reducing forecasting uncertainties by ground observation system for meteorological and hydrological parameters, input data for the models, needs to be enhanced to meet the minimum international standards and in collaboration with JAXA and 3) the need to extent Indus-IFAS to Eastern rivers for integrative watershed approach and transboundary flood management. This paper presents how those above needs are being progressively tackled in this JICA assisted project through multilevel stakeholder engagement.

METHODS & RESULTS

Three major components were implemented since 2015 in partnership with ICHARM/PWRI, JAXA in Japan and PMD, PCRWR, NUST, UET-Lahore, CDPM and SAWCRI in Pakistan as follows:

1) The establishment of the technical foundation for sustainable capacity development on the flood management, forecasting, early warning and flood hazard analysis in Pakistan agencies
    - Technical studies were conducted on the improvement of the accuracy of flood forecasting and early warning system in Pakistan. This was done first by improving local data availability with the local development and deployment of Automated Weather Stations, the measurement of local soil hydraulic properties, the measurement of river morphological data (Figure 1). Second, the upgrade of Indus-IFAS model was performed to include snowmelt and glacier melt calculation and greater flexibility in setting input data with the possibility to integrate several sources of rainfall (satellite based and ground) and boundary conditions. The new Indus-IFAS was test run during monsoon 2017 with improved results for Upper Indus discharge forecasts (Figure 2).
    - Strengthening the flood forecasting and warning capacity in Eastern Rivers (Jhelum, Chenab, Ravi and Sutlej rivers): with extending Indus IFAS modelling coverage. (Figure 2)
    - Strategic and continuous enhancement of the flood management capacity in Pakistan and Afghanistan including Master degree course enrolment in ICHARM. As September 2017, a total of 178 water professionals in Pakistan and Afghanistan (14) have been trained during this phase.

2) Technical studies to promote strengthening of cooperation with Indus river basin countries for transboundary flood management and transboundary data sharing:
   - Technical studies on strengthening of the transboundary flood management capacity of the Indus river basin countries through a series of international workshops and enrolment of Afghan officers to MSc degree course in NUST, Pakistan
   - The reinforcement of the relationship within the Indus river basin countries for transboundary flood management and data sharing through conferences sessions and UNESCO IHP Asia-Pacific regional coordination mechanism such as the IHP-Regional Steering Committee meeting inviting both Pakistan and India IHP National Committees as observers. China IHP national committee is already a member of the RSC.

3) Capacity building and education of local communities on flood management for proper utilization of flood hazard information and tools
   - (i) Technical studies on utilization of the hazard information for better understanding of the local people with the development of manuals in 4 local languages and national language based on a nation-wide governmental organizations'' training need assessment.
   - (ii) Education on flood management, response and evacuation for school teachers and children
   - (iii) Training workshops on flood management for local government officers and local leaders and 4 trainings were delivered for a total of 132 participants, 40 female, 92 male for Punjab, Sindh and KPK provinces. (Figure 3)

CONCLUSION

So far in this project, the following achievements have been made:

- At the technical stakeholder level: Improvement of IndusIFAS simulations capacity for Upper Indus by including snowmelt component and glacier melt component will be added in the upcoming version.
- At the national flood coordination level: IndusIFAS has been extended to the Eastern Rivers and data are being collected for calibration.
- At interprovincial and community level: the 178 water professionals among them 14 Afghans have been trained on IWRM, Flood Management, IndusIFAS and river morphology measurements.
- At international level: exploration of Transboundary aspects through IHP Regional implementation mechanism.

Keywords: *Indus river basin, flood forecasting, transboundary flood management.*

ACKNOWLEDGEMENT:

- *Funding support: JICA and MOFA Japan*
- *Technical Support: UNESCO IHP, Category 2 centres*
- *Stakeholders' engagement: PMD, PCRWR, NUST, UET-Lahore, SAWCRI, CDPM, FFC.*

Figure 1 Young engineers of PMD with their in house developed Automated Weather Station (AWS) (more than 80% lower than international standard price) (left), ADCP River Pro (right)

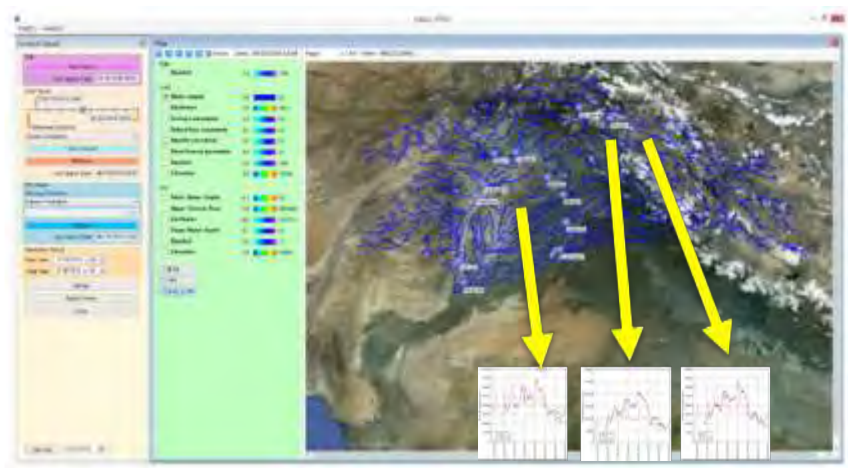

Figure 2 phase 2 modelling coverage IndusIFAS including Eastern Rivers IFAS part (left), simulation results for monsoon 2017 (bottom)

Figure 3 Sindhi Participants of Community-based Training Program for drought and flood control at BARI on 5 August 2017 and farmer training manual

ENSO Impact to the Hydrological Drought in Lombok Island, Indonesia

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INTRODUCTION

Drought-related ENSO (El Nino Southern Oscillation) event is likely increasing due to climate change. This study aims to investigate the correlation of ENSO and hydrological drought in Lombok Island, Indonesia. Furthermore, we examine the lag correlation between the two variables to see the possibility of using ENSO indicator for drought prediction.

METHODS

Our research area is Lombok Island, Indonesia. We used daily discharge data from two Automatic Water Level Recorder (AWLR) stations in the Island, namely Lantandaya and Bug Bug Stations. The data was collected from River Basin Organization of West Nusa Tenggara, with the data period 22 years for Lantandaya Station and 19 years for Bug Bug Station. Hydrological drought event is identified by using discharge index (Q_i) following the equation:

$$Qi = \frac{\overline{Q} - Q}{\sigma} \tag{1}$$

where Q_i is discharge index, $\bar{Q}$ is monthly average discharge, Q is monthly discharge in a particular year, and σ is standard deviation. We classify the hydrological condition as having wet/high events if the $Q_i < -1$, normal if $-1 \leq Q_i \leq 1$, and dry/low events (drought) if $Q_i > 1$.

Furthermore, the ENSO indices used in this study are Oceanic Nino Index (ONI) and Nino3.4. Based on the ONI, the El Nino events are illustrated by ONI > 0.5, while La Nina events are illustrated by ONI < 0.5. Finally, the correlation between drought and ENSO is investigated by using simple correlation (R-value).

RESULTS

The hydrological drought condition illustrated by drought index has a similar pattern with the ENSO events (Figure 1).

Based on the ONI from the period of 1986 until 2010, there are 8 El Nino events and 6 La Nina events happened. The strongest El-Nino events happened in 1997-1998. Both of the discharge index in Lantandaya Station and Bug Bug Station at the same time shows high value, which represents dry condition. Furthermore, in Lantandaya Stations during five El Nino events, namely 1997-1998, 2003, 2005,2006-2007 and 2009 events, the discharge index shows high value which indicates drought events also happening at the same time. The similar but less prominent pattern is also seen in Bug Bug Station. Except the El Nino in 1997-1998, El Nino event was accompanied by less severe and short drought period. Meanwhile, The El Nino events in late 1992 could not be identified whether it causes drought in Bug Bug Station or not since the data in this period is missing. Nevertheless, if we refer to the Lantandaya condition, the 1992 El Nino is likely also give an impact to the dry condition in the catchment.

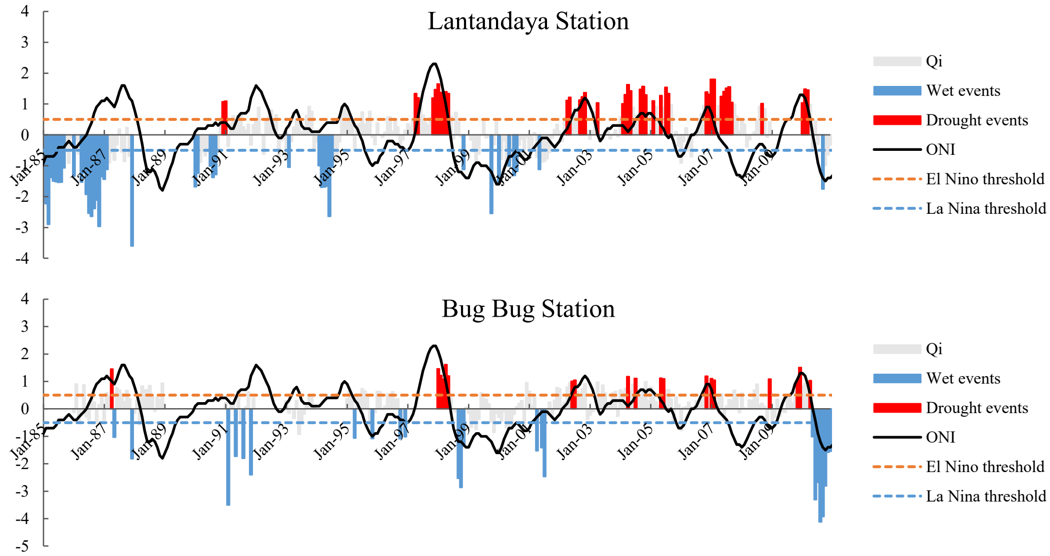
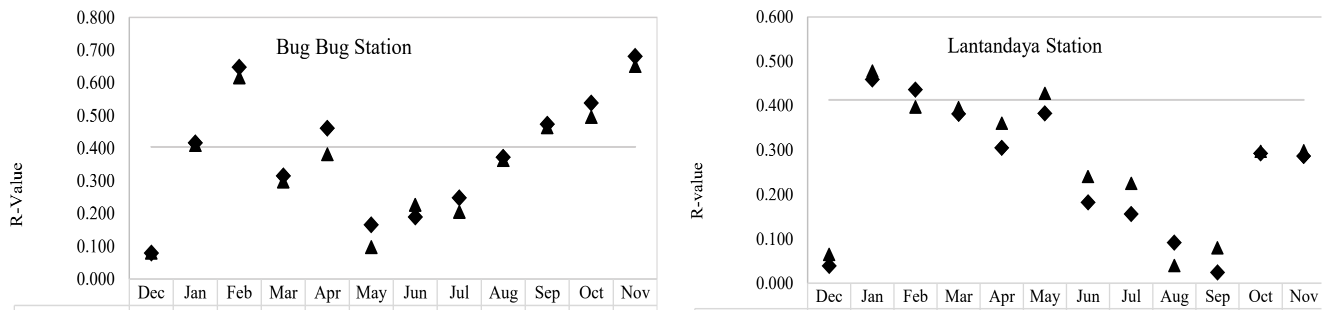


Figure 1 Drought and ENSO event showed by discharge index and ENSO indices.

In order to see the correlation of the drought with El Nino, we used the simple correlation (R-value) of discharge index and ENSO indices. We investigated the correlation on the seasonal basis. The result of the seasonal correlation is illustrated in
Figure 2.



Bug Bug Station:

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
◆ ONI	0.079	0.416	0.648	0.315	0.461	0.166	0.189	0.248	0.372	0.473	0.538	0.681
▲ Nino 3.4	0.080	0.410	0.617	0.297	0.381	0.097	0.227	0.205	0.363	0.463	0.495	0.651
R-critical	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404

Lantandaya Station:

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
◆ ONI	0.039	0.459	0.436	0.382	0.305	0.382	0.182	0.156	0.091	0.025	0.292	0.287
▲ Nino 3.4	0.065	0.478	0.397	0.395	0.360	0.428	0.240	0.225	0.040	0.080	0.297	0.298
R-critical	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413

Figure 2 Seasonal correlation of discharge index and ENSO indicator

The result shows an unclear relationship of the drought and ENSO in the Lantandaya Station. The R-values for the Q_i and ONI correlation are 0.377, 0.388, 0.105 and 0.217 consecutively for Dec-Jan-Feb (DJF), Mar-Apr-May (MAM), Jun-Jul-Aug (JJA) and Sep-Oct-Nov (SON) season. As for the Q_i and Nino3.4 R-value are 0.373, 0.423, 0.188, and 0.245 consecutively for DJF, MAM, JJA, and SON season. The R-value shows no significant correlation between discharge index and ENSO indicator for all seasons. The no significant correlation of ENSO and discharge in this station may be caused by the small discharge of the river with relatively high baseflow and small fluctuation among seasons. This condition may be affected by the location of the station which is in the upstream area of the catchment. Besides, since the location of the station is in the high land of Rinjani Mountain, the streams may also receive water from the natural reservoir in the top of the mountain, Segara Anak Crater Lake.
The result of the discharge index and ENSO indices correlation in Bug Bug Station indicated that the strongest correlation is seen during SON season. The R-value of Q_i with ONI and Nino3.4 in the SON season are 0.612 and 0.587 consecutively (the R-value has 95% confidence level). The significant but weaker correlation is also seen in

the DJF season with R-value 0.495 and 0.488 for Q_i-ONI and Q_i-Nino3.4 consecutively. Meanwhile, the other seasons (MAM and JJA) show no significant correlation. The high correlation of the streamflow and ENSO in the SON season is agreed with the study of Sahu et al. (2012). They investigated the ENSO impact on the extreme stream-flows of a river in Indonesia and found out there is a seasonal correlation of streamflow and El Nino in the SON season.

Besides the seasonal correlation of discharge index and ENSO indicator, we also investigated the lag correlation of the ENSO with streamflow in the following season. The result of the lag correlation is presented in

Table 1. There is a significant lag correlation when ENSO of JJA season leads the streamflow of SON.

Table 1 Lag correlation between ENSO with the discharge in the coming season.

Nino3.4 - Qi lag correlation (R)

Time lag of Nino3.4 (months prior to)	Rainfall Season			
	DJF	MAM	JJA	SON
9	-.058	.413 *	-.014	.548 *
6	-.176	.405 *	.299	-.280
3	-.257	.021	-.136	.539 *
0	.549 *	.559 *	.316	.595 *

*significant at 95%

ONI - Qi lag correlation (R)

Time lag of ONI (months prior to)	Rainfall Season			
	DJF	MAM	JJA	SON
9	-.109	.432 *	.012	.561 *
6	-.200	.443 *	.281	-.207
3	-.265	.055	-.097	.541 *
0	.524 *	.597 *	.305	.633 *

*significant at 95%

CONCLUSION

The ENSO impact to discharge in Bug Bug Station is more significant than in Lantandaya Station. The strongest ENSO-discharge correlation in Bug Bug Station happens during SON season, and the weakest one occurs during JJA season. There is a lag correlation between JJA ENSO and SON Discharge in Bug Bug Station.

Keywords: *El Nino, discharge index, low flow*

Optimization of the Net Revenue of Rice Production in Pampanga

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INTRODUCTION

Rice is the main crop produce in the country and agriculture is still the backbone of the Philippines economy. In terms of food security, the country remains extremely vulnerable that at certain times would need to import rice, far from being self-sufficient. Adequate water supply is one of the most important factors in crop production. This paper presents a water resources simulation model with optimization of rice production in the Pampanga River Basin of Central Luzon an area known also as the "rice bowl" of the Philippines. Crop yield prediction models were utilized to simulate the response of rice crop as a function of the amount irrigation water applied and other parameters. The output of this study is a useful tool for planning on efficient and optimal use of water irrigation supply for agricultural production. This study demonstrates how irrigation management can be appraised from a business perspective so that the objective function of the optimization tool developed for this study is based on maximization of net revenue. Finally, the output of this study can generate recommendations to assist in attaining self-sufficiency in rice production and elevate the socio-economic status of the farmers.

METHODS

This study has three components: (1) rice production simulation using multi-regression analysis, which determines the total crop production for a given season; (2) reservoir simulation using GAMS, which simulates the operation of reservoir system, and (3) optimization, which determines the maximum net revenue of rice production in Pampanga River Basin.

Rice Production Simulation using MLR Analysis

In order to create the rice production model, historical data on climatic variables such as rainfall, temperature, relative humidity, solar radiation, wind speed, ENSO classification, and number of cyclones; and agronomic variables such as area planted, irrigated area, fertilizer usage, labor inputs, loan interest, and relative price of rice in the world market which are hypothetically related to rice production in Pampanga River Basin were gathered and analyzed. Data on all variables used in developing the rice production model only covered the period of 1990 to 2016 because of limited available data from government. The important variables that influence the rice production were first screened using correlation analysis. Multiple linear regression (MLR) analysis was used to develop the rice production model for the study area. Diagnostic tests and necessary adjustment were done to the model to ensure that the basic assumptions in regression modelling were satisfied. Transformation of all the continuous variables to logarithmic form was employed in attempt to satisfy the basic assumptions in regression (e.g. normality and constancy in variance).

Reservoir Simulation using GAMS

Pantabangan Watershed with a catchment area of 94,000 hectares is located upstream of Carranglan River and Pantabangan River. Pantabangan Dam is a multi-purpose reservoir for hydropower and irrigation was strategically located and then followed by Masiway Reservoir. A model of reservoir releases by Pantabangan Dam were generated using General Algebraic Modelling System (GAMS) are subject to the constraints of the water availability and water balance of the reservoir, considering the storage continuity equation. Operation of the reservoir is simulated given series of inflows and downstream water demand targets. Evaporation from the reservoir surface is calculated using relation between storage volume and surface area needed. A linear approximation to the surface area -volume relation is used between the storage and total storage levels. In order to account for the overall efficiency of the irrigation system, the amount of water that is reaching the field and the corresponding irrigation depth are also computed. The maximum irrigation depth proposed to be given at any irrigation event is 10 cm (I_{max}) of water and the maximum area that can be irrigated during any season is the total cultivated command area. The reservoir simulation will give the timing and quantity of water release from the reservoir which will then be used in the optimization model as a decision variable.

Rice-Paddy Water Balance Model

The water balance equation of a single paddy field plot is equal to the sum of the amount of effective rainfall and irrigation water supplied to it subtracted by the loss due to evapotranspiration, surface runoff, seepage and percolation. Then the change of storage in the system is the difference between the water that is coming in and out of the system in each time period. These components are expressed in depth units (mm) and the time period considered is one day. The assumptions made are that the field storage is considered sufficiently represented by the impounded surface water and the soil moisture is constant throughout the growth period. If the maximum depth of water possible is the rice field depth, the optimum depth and the minimum depth at which irrigation is to be given, are known or preset, then the water balance equation can be used for determining the irrigation schedules and the depth of water to be applied at each irrigation event.

Formulation of the optimization model

The nonlinear model aims to maximize the net revenue of rice production, subject to various constraints. The model was formulated to attain the maximum possible yield of rice by integrating the dynamics of water requirements for rice paddy at different growth stages relative to the water availability at reservoir level during operation. With these considerations, it follows that constraints are driven from the farm level conditions dealing with crop water allocation decisions and the flood water level for rice paddy; and also for the reservoir level conditions dealing with reservoir release decisions and the storage related constraints.

The net revenue which depends on the rice yield during wet and dry seasons is related to the amount of allocated water for irrigation. The rice crop achieves its potential yield if the water allocation for irrigation satisfies the water requirements of the rice during its growth periods. The irrigation is then very essential to attain maximum yield and there are two factors which are deem important relative to production, these are timing and quantity of water released from the reservoirs. The objective function aims to maximize the net revenues of rice production during wet and dry seasons and is drawn by the influence of the production cost and crop irrigation requirement. The constraints at the farm level include the cultivated land, available water for irrigation (dam release), water allocation, and actual evapotranspiration.

RESULTS

A rice production model was formulated from historical data on climatic variables such as rainfall, temperature, relative humidity, solar radiation, wind speed, ENSO classification, and number of cyclones; and agronomic variables such as area planted, irrigated area, fertilizer usage, labor inputs, loan interest, and relative price of rice in the world market which are hypothetically related to rice production in Pampanga River Basin were gathered and analyzed using MLR. The resulting rice production model for Pampanga River Basin is a function of rainfall during wet season, relative humidity, relative price of rice in the world market, area of plantation, and irrigated area.

GAMS was used to simulate reservoir operation using historical data, reservoir model results using both average and dry inflow conditions show that the UPRIS supply for irrigation is sufficient for its service area. The monthly water delivered by the Casecnan project is 66.82 million cubic meters, which translates to 25.8 cubic meters per second per month. It is assumed that water is only used for two cropping seasons (about 220 days per year), the available irrigation water is 42.8 cubic meters per second. Irrigating 16,879 hectares of paddy rice (Phase 1 or irrigation component of the CMIPP) requires 18.9 cubic meters per second at 1.12 liters per second per hectare (with wasted water). The total area of 37,200 hectares in Phases 1 and 2 requires 41.7 cubic meters per second. Thus, the irrigation water available in the Casecnan project is adequate for its design irrigation service area provided that the irrigation facilities are operated efficiently and with minimal irrigation losses.

Simulation of the effective rainfall, ponded water level, and losses such as percolation, evapotranspiration, etc. of the services areas of UPRIS and PDIS shows the optimum values of field irrigation requirements were drawn which are

36.207, 42.703, 16.197, and 12.671 in million m3. These FIR values will attain the maximum yield ratio but will allocate the least amount of irrigation water and were used for the computation of the maximum net revenue for both UPRIS and PDIS.

Irrigation water requirement was determined by calculating crop evapotranspiration and effective rainfall, and simulate rice-paddy water balance. The amount of irrigation at the cropping pattern of May to August gives the highest initial irrigation of 181.56 mm to attain a saturation depth of 200 mm needed to create a good environment for the germination of the seedlings until development of the roots of rice at the nursery stage. Initial irrigation of 3.04 mm and 11.21 mm are needed for cropping patterns in June to September and July to October, respectively. Moreover, the highest amount of excess water amounting to 2,362.46mm is needed to be released from the paddy fields for the July to October crop, most probably due to the occurrence of rainfall and cyclones during this period. A much relatively lower amount of excess water was attained during May to August and June to September crop periods amounting to 1581.07 and 1,169.64, respectively.

The amount of irrigation for the cropping pattern for December to March gives the highest cumulative irrigation water of 864.59 mm to maintain ponded water for the rice paddy. While the cumulative depths of irrigation amounting to 698.22 mm was estimated for the November to February crop and the lowest amount of 258.80 mm for October to January. During dry season with few rainfall occurrences, there is no excess water for the entire cropping period, instead water deficits at the end of each months of January, February, and March amounting to 54.41 mm, 43.65 mm, and 26.81 mm, respectively. The water deficit that will deplete the saturated soil depth of 200 mm to the advantage of the ripening of the palay, and may contribute to the attainment of maximum yield which will result to more revenue.

The maximum net revenue for the 102,000 ha. service area of UPRIS is Php 19.77 Billion while for the approximately 4,000 ha. service area of PDIS is Php 0.78 Billion. Maximum net revenue can be attained using a total field irrigation requirement for two cropping seasons in UPRIS of 78.91 Mm^3 including the effective rainfall for the two seasons. The field irrigation requirement to attain maximum net revenue for the service area of PDIS is 5.55 Mm^3. The next best option for each system yields Php 16.38 and Php 0.64 Billions, respectively, with the use of certified seeds and the same field irrigation requirements for the rice paddy.

CONCLUSION

This study is useful for allocating water resources subject to its availability and proper crop management. A non-linear optimization model was developed to simulate the response of rice production to the amount of resources and crop water management applied. Simulation of the model integrates the dynamics associated with the water releases from a reservoir with the actual water utilized by the rice crop at farm level. In order to represent the model closer to reality, it also considers nonlinear relationships for different variables in the model objective function and constraints. The applicability of the model is demonstrated through the study of an existing irrigation reservoir system namely Upper Pampanga River Irrigation System (UPRIS) and Pampanga Delta Irrigation System (PDIS) both of which are located at the Pampanga river basin which serves as the main source of irrigation water for the major farm areas in Nueva Ecija and Pampanga.

Keywords: *Optimization, crop yield prediction model, irrigation, agricultural hydrosystem.*

The Global Runoff Data Centre (GRDC)

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Facilitator between data providers and data users

The Global Runoff Data Centre (GRDC) was established in 1988 at the Federal Institute for Hydrology (BfG) under the auspices of the World Meteorological Organization (WMO). It is a contribution of the Federal Republic of Germany to the World Climate Programme and the Hydrology and Water Resources Programme of the WMO. The WMO mandates and directly supports the GRDC through its Resolution 21 (Cg XII, 1995: Request to the member states to provide GRDC with river discharge data) and Resolution 25 (Cg XIII, 1999: Free and unrestricted exchange of hydrological data).

The Global Runoff Database at GRDC is a unique collection of river discharge data collected at daily or monthly intervals from more than 9400 stations in 160 countries. This adds up to more than 410.000 station-years with an average record length of 43 years.

The GRDC archives international data of up to 200 years old, and fosters multinational and global long-term hydrological studies. The aim of the GRDC is to help earth scientists analyse global climate trends and assess environmental impacts and risks and assist with transboundary water resources assessment.

The GRDC maintains a number of specialised databases such as the Climate Sensitive Stations Dataset of the WMO Commission for Hydrology or the Global Terrestrial Network for River Discharge (GTN-R) to support the Global Climate Observing System (GCOS) in assessing total freshwater fluxes to the world oceans.

The GRDC supplies in addition products such as GIS maps on the Major River Basins of the World and watershed boundaries for more than 7000 GRDC stations.

The GRDC completely relies on the voluntary contribution of river discharge data and associated station metadata from National Hydrological Services and related authorities dealing with discharge monitoring to expand and update its river discharge database.

Positioned as a facilitator for exchanges between data providers and data users, the GRDC has become a focal point for international cooperation. National Hydrological Services and River Basin Authorities are encouraged to supply suitable data so that the GRDC can provide on request the available discharge data and data products for non-commercial applications to science and research, as well as to the water resources assessment and management communities.

Distributed Data Validation and Reconstruction for Water Distribution Monitoring Systems

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INTRODUCTION

Telemetry systems allow for water utilities to efficiently operate their distribution systems and ensure that service obligations to customers, such as adequate supply and pressure, are met. However, current water distribution monitoring systems often suffer from instances of faulty and missing data. Several methods exist for validating and reconstructing data to recover from these types of errors, but most such methods are performed by a central server. A centralized architecture for data gathering and repair makes data recovery highly dependent on a communication system that is not always reliable, and thus may be unsuitable to support real-time systems. Such systems also typically rely on manual processing of sensor data to detect and correct errors. In this work we formulate and evaluate a distributed approach to water sensor data validation. This algorithm relies on sensor nodes exchanging data with each other and performing in network processing to reconstruct water flow data, thus reducing dependence on processing by a central server.

METHODS

The Distributed Data Validation and Reconstruction (DDVR) algorithm works by utilizing the principles of mass and energy balance, derived from the Laws of Conservation of Mass and Energy, to detect and correct errors in the transmitted data. Instead of sensors directly communicating with a centralized server, sensors route data through other sensors in a wireless sensor network until the intended destination for the data (a sink or gateway), is reached. As data is passed through the network, the sensor nodes determine if the data fit into a certain threshold around a certain *Validation Value*. If the data is outside this threshold, the erroneous data is replaced with a corresponding *Replacement Value*, and this replaced value is sent to the next sensor node in the path. The process repeats until the intended destination is reached. The *Validation and Replacement Values* are computed by gathering data from nearby sensors and calculating for the flow value based on equations of Energy and/or Mass Balance. The algorithm is shown in the figure below:

Algorithm 1: Pseudocode for the Distributed Data Validation Algorithm %

```
SINK = destination of data, usually server or control point
% PATH = series of pipe sensor nodes toward sink
% i = order of sensor node along PATH
% PATH( i ) = i^th sensor node along PATH
thresh = 0.10;

for i = 1 to length(PATH) {
        Qm = getMeasurement(PATH (i) );
        Qval – getValidationValue (PATH(i));
        if abs(Qm-Qval) < thresh
                Qout = Qm;
        else {
                Qrep = getReplacementValue(PATH(i));
                Qout = Qrep;
        }
          transmit (Qout);
}
```

Simulations were performed in EPANET, a hydraulic network simulator, to evaluate the algorithm. Three networks with different topologies were used to observe characteristic differences in performance. From the original EPANET simulation output, Gaussian noise was added to the data to represent measurement error which is present in all types of measuring equipment. Sensor faults were then introduced by varying the magnitudes of selected measured values. Two sets of tests were performed. The first set of tests evaluated the performance of Mass and Energy Balance Methods with no sensor faults added, to establish the baselines for performance and identify inherent weaknesses of each method. No Gaussian noise was introduced in the first part of this set of tests, and noise was later added in the second part of the set. In the second set of tests, the performance of the algorithm was compared by varying the following five factors:

- Distribution Network – representing the three different water distribution network topologies
- Percent Erroneous - percentage of sensor nodes that experience sensor faults
- Selection - the set of sensor nodes with faults, based on the Percent Erroneous parameter
- Magnitude of Error - magnitude of distortion experienced by sensor nodes with faults
- Method - Energy Balance or different implementations of Mass Balance based on where it is performed and the size of the area considered

The metrics used for evaluation were Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE). The *Replacement Value* was first determined based on the overall performance of the methods across all the networks tested. The *Validation Value* was then selected based on which method worked best with the chosen *Replacement Value* method.

RESULTS

The results showed the strengths and weaknesses of each method. The Energy Balance method was shown to be accurate at higher flows, but had an inherent error at some low flow values even when no Gaussian noise and faults were introduced. At low flow values and high resistance coefficient (a parameter computed using the friction coefficient of the pipe, pipe length and pipe diameter), the corresponding head loss value becomes very low that a precision error emerges. Using this head loss value in computation, the precision error also manifests in the computed flow value. On the other hand, the Mass Balance method was shown to be accurate at low flows, but was very susceptible to errors when large flow values were involved in the computation or when a larger area was considered. For larger areas, more terms were involved in the computation, further increasing the chance of error and decreasing the accuracy of the recovered data. Thus, it was advantageous to select Mass Balance as the method for computing the *Validation Value*, while Energy Balance for the *Replacement Value*. At high flows, since Mass Balance was not particularly high performing at this range, there was a high chance that the replacement function would be triggered. Since Energy Balance works well at this range, the amount of error was significantly decreased. At low flows, there was less chance that the replacement function to be triggered since Mass Balance performed well at this range. This was beneficial since Energy Balance does not yield accurate values at low flows. The Mass Balance method was thus chosen as method for computing the *Validation Value*, while the Energy Balance method was used for determining the *Replacement Value*.

CONCLUSION

The findings of the study show that the formulated DDVR algorithm was able to reduce the amount of error in measurement data, while not relying on server-based operations for data repair. This was achieved by using the complementary performance of Energy and Mass Balance methods, implemented across the wireless sensor network of a water distribution monitoring system. The results also show the potential benefits of adapting wireless sensor network technologies for water utility applications in improving the quality and reliability of data gathering, which will lead to higher operating efficiency and improvements in the overall service of water utilities to customers.

Keywords: *wireless sensor networks, water distribution systems, sensor faults*

Environmental Flow Assessment of Manolo Fortich Hrdro-Electric Power System

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INTRODUCTION

To maintain river health amidst societal demands for water (i.e. hydropower) means considering not just the biological component, but all the three aspects of ecological integrity, namely: chemical, physical and biological. In this study, the Hedcor Bukidnon, Inc. applied design flow diversions at three rivers, namely: Tanaon, Guihean and Upper Amusig, to generate power for Manolo Fortich Hydro – electric Power System. The “with project” conditions on the aforementioned rivers have design flows that correspond to the Q30 or the flow that is equalled or exceeded 30 per cent of the time. Flow diversions used under “with project” condition are greater than the limit equal to Q80 or the flow that is equalled or exceeded 80 per cent of the time. A justification that the “with project” design flow diversions do not impair the ecological integrity of the rivers affected must be done through an environmental flow assessment.

This study aims to maintain the health of Tanaon, Guihean and Upper Amusig rivers through estimating the acceptable flows or in – stream flows required to sustain the ecological integrity of the streams in the Manolo Fortich Hydro – electric Power Systems and recommending the allowable flow diversions at respective intake weirs (Tanaon, Guihean and Upper Amusig) that will maintain the state of river health with respect to the health indicators, namely: water temperature, dissolved oxygen and sediment yield. Specifically, the study aims to: a. establish the ecological criteria for each location (Tanaon, Guihean and Upper Amusig) that will be used as the threshold or limits beyond which irreparable ecological damage results; b. establish the “without project” and “with project” conditions of the water temperature, dissolved oxygen and sediment transport regimes; c. determine the consequences of the gaps between “without project” and “with project” conditions; compare and contrast the “with project” ecological conditions (using flow diversion that is the flow corresponding to the 30% dependable flows) and the acceptable ecological conditions (the environmental flows set at intake locations) with the natural (baseline) ecological conditions with respect to the ecological criteria and key ecological components (water temperature, dissolved oxygen and sediment transport) at intake locations Tanaon, Guihean and Upper Amusig; d. model different flow scenarios in defining environmental flow regimes for Tanaon, Guihean and Upper Amusig reaches if the “with project” conditions fail to satisfy the ecological criteria; and e. determine the flow diversions for the intake weirs and the environmental flows that will ensure the ecological integrity of rivers (Tanaon, Guihean and Upper Amusig) are preserved.

METHODS

To undertake an environmental flow assessment, the ecological criteria must be established first by choosing indicator of river health. After which, the ecological relationships of the indicators shall be discussed and the thresholds below or above which will impair the ecological health of the river ecosystems shall be set. The criteria must be satisfied simultaneously with respect to the requirements of each indicator.

Second, in order to create a comparison and to know how much flows must be diverted, but still maintaining river health, “without project” conditions must first be set. Such is based on the historical method of setting baseline situations representing the five – year period prior to the installation of the hydropower system. Mean daily time series for the water temperature, dissolved oxygen and sediment yield are modelled and represented by duration curves. But, all these can be done after calibrating, validating and analysing the sensitivity of the parameters that affect the observed indicator values.

Further, part of the comparison is to establish the “with project” conditions that represent the current operation of the hydropower systems where flows are diverted according to power generation needs of the hydropower system and a portion of the natural flow is left to the rivers called compensation flows. The resulting duration curves per indicator were also made and thus, compared to the “without project” condition. Ecological consequences may result with respect to the magnitude of design discharge per intake weir. If so, alternative flow diversion scenarios must be modelled to arrive at a condition where the requirements of water temperature, dissolved oxygen and sediment yield must be met, simultaneously, called “modified/with project” conditions.

RESULTS

Ecological criteria are composed of three parameters, namely: water temperature, dissolved oxygen and sediment yield. Two indicators represent the chemical integrity, which are water temperature and dissolved oxygen. The mean daily dissolved oxygen concentration must be greater than or equal to 5.0 mg/L, maximum allowable water temperature increase shall be three (3) degrees Celsius and difference in sediment yield resulting from the "with project" or "modified/with project" conditions must be less than or equal to 110 tons/day per square kilometer of drainage area under the reference ("without project") conditions.

The parameters corresponding to the "with project" condition for the water temperature and sediment discharge shall either pertain to the conditions representing the current operation of the Manolo Fortich Hydro – electric Power System or the "modified/with project" conditions where acceptable flow diversions satisfy the ecological criteria. For the "with project" to be ecologically acceptable, it must not exceed the standards set and thereby prove that the amount of flow diversions represented by design flows of weirs located at Guihean, Tanaon and Upper Amusig equal to 2.14, 3.54 and 6.73 cu.m/sec, respectively; and taking the differences of the resulting ecological parameters' values between the "with project" and "without project" will not be detrimental to the health of the said rivers. Water temperature showed a general decrease for all the Guihean and Tanaon reaches with a maximum mean daily water temperature decrease are 0.42 0C and 0.08 0C, respectively; while a maximum water temperature difference for Upper Amusig was a 0.0186 0C increase. Consequently, the maximum allowable change in sediment discharge for Tanaon, Guihean and Upper Amusig are 5360.7, 2678.6 and 11417.30 tons/day; respectively which were far from the maximum mean daily change of 995.959, 548.91 and 1682.69 tons/day, respectively.

If the two criteria (water temperature and sediment yield change) were within the ecological limits, the dissolved oxygen criterion of the "with project" conditions for all the river reaches was not met. The current operations at the Tanaon, Guihean and Upper Amusig weirs have resulted to 299.3, 2.4 and 149.65 days where DO concentrations were below 5 mg/L, respectively. Thus, a "modified/with project" condition which satisfies all the criteria, especially that of the DO concentration, and recommends the maximum allowable monthly flow diversions in all the intake weirs of Tanaon, Guihean and Upper Amusig rivers (Table 1) was determined. There were very little allowable flow diversions for "modified/with project" conditions and there were months of no flow diversion for Tanaon and Upper Amusig weirs, as opposed to the use of Q30 design flows under "with project" conditions. Such recommendations must be followed to maintain the long – term health of the rivers.

Table 1 "Modified/With Project" Monthly Design Discharge used for Magnitude of Flow Diversion at Intake Weirs That Satisfies the Ecological Criteria

Weir	Design Discharge for Diversion, m3/s											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tanaon	0.50	0.49	0.00	0.21	0.31	0.60	0.00	0.00	0.07	0.11	0.25	0.65
Guihean	0.39	1.46	0.77	1.44	1.61	1.68	1.74	2.44	3.34	2.12	1.64	1.90
U.Amusig	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	1.41	0.65	0.00	0.00

CONCLUSION

The "With project" conditions did not satisfy the ecological criteria, and is therefore detrimental to river health. Thus, the use of compensation flows as an environmental flow may be inappropriate. Moreover, acceptable flow diversions at intake weirs were lesser than that used under the "with project" conditions, which was largely dictated by dissolved oxygen criterion. While many recommend water temperature's significant contribution to maintaining the ecology of rivers, parameters such as water temperature, dissolved oxygen and sediment concentration affect river health and not only flow reduction. This means that the use of physical and chemical indicators, and not those based solely on the biological integrity, may be a better method. Consequently, the use of minimum, percentages, indices of flows or hydraulic - or habitat – based flows as a flow recommendation in an attempt to suggest a sustainable flow is questionable due largely to its lack of ecological bases and must be used with caution. Further, this study contributes to the strengthening water policies that aim to maintain river health while allocating water for human needs, through incorporating all three aspects of ecological integrity and starting a new phase in environmental flows assessment. The results also suggest the importance of including environmental flow assessments in water permit applications for surface water extractions is a way to safeguard the nation's water resources. The same requirements can also be applied in groundwater extractions and impoundments affecting rivers, wetlands and estuaries.

Keywords: *Riverine ecosystems, Ecological integrity, Environmental flows, Water policy*

Analysis of Pollutant Uptake and Runoff Storage of Bioswale with Potential Vegetation

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INTRODUCTION

Too much impervious materials in land such as concrete and asphalt leads to easy ponding of water especially in small catchment areas (eg. local streets, subdivisions, schools and parks). In 2014, 85.5% of all roads in the Philippines were paved, leaving less room for the natural infiltration of runoff water through the soil (DPWH, 2015). Drastic land conversion increases and accelerates runoff, reduces infiltration, and deteriorates water quality. Excess storm water runoff causes flooding, water pollution, and groundwater recharge deficits. To alleviate these effects of land conversion in the natural hydrologic condition of the site, stormwater management practices can be applied, such as construction of bioswales, retention and detention ponds to control rainwater before it goes to stormwater systems.

Biofilter swale (also called as a biolfilter, bioswales, bioretention, storm swale etc.) is an engineered drainage system that makes use of plants and soil layers as the filtering medium. Its main advantage is that it provides a natural infiltration for runoff water while prolonging the retention time to attenuate flow duration curve. It is also capable of removing pollutants in water and thus improving its quality. It is widely used in Europe, America and some parts of Asia (eg. Malaysia, Singapore).

This study aims to broaden the research scope of bioswales in the Philippines, which has a contrasting climate, vegetation, and geology. The objective of this study is to design and construct three laboratory-scale bioswale setups applicable to the Philippines: non-vegetated or control setup, lemon grass (*Cymbopogon citratus*) setup, and vetiver grass (*Vetiveria zizanioides*) setup; and to determine the most feasible locally available vegetation as the top most layer by testing the pollutant uptake and run-off storage capacity of the set-ups.

Vetiver grass is a tall, fast-growing, perennial tussock grass. It has a long, massive and complex root system that can grow up to four meters which can penetrate to the deeper layers of the soil. The dense, high-fiber, fine root system, which forms into an enormous volume accelerated habitat for many symbiotic bacteria and fungi, made the ecology system naturally contributes to the pollutant uptake. Furthermore, vetiver grass has the ability to absorb large amounts of pollutants, such as heavy metals, pesticides, herbicides, and petroleum hydrocarbon without affecting its growth (Syed Hasan et al., 2017). Lemon grass is a commercially important perennial herb with medicinal value and ability to tolerate high alkaline and saline conditions. Lemongrass is a metal tolerant plant, specifically lead, cadmium, zinc, chromium and cobalt, which can be cultivated for reclamation of heavy metal sites (Gautam et al., 2016).

METHODS

The design of the bioswale pilot-scale setup was based from the typical cross-section of a bioretention swale for Singapore's Public Utilities Board's (PUB) Standards. From these standards, a typical bioswale consists of a vegetated swale, 0.3-0.7m of filter media, 0.1m of transition layer, a perforated collection pipe, 0.2m drainage layer and an impervious liner at the bottom. Minimizing the pilot testing setups, the dimensions of the bioswales were taken as 0.6m width and 0.9m length. The particle diameter of the drainage layer is 2-5 mm. Sieve No. 4 with an opening of 4.76 mm was used to separate coarse gravel from fine gravel while Sieve No. 10 with an opening of 2 mm was used to remove the sands from fine gravel. After the drainage layer, transition layer and filter media were prepared, the vetiver grass and lemon grass were planted on the filter media of two separate set-ups. A 100 mm PVC pipe was punctured with holes to serve as the perforated pipe. A wooden ramp with a 4% slope adopted from the PUB Standards was also added at the bottom of the setup to observe the effects of the horizontal flow of water in the system.

Surface runoff water was collected during the February 1, 2017 rainfall event in UP Diliman campus. Rainfall intensity and time of concentration were computed using Izzard's formula and rational method (XPsolutions, 2017). The rainfall intensity was computed to be 198.15 mm/hr for a time of concentration of 0.99 minutes. A runoff volume of 0.034 m^3 was obtained per trial with a total of 0.302 m^3 runoff volume used for all the nine trials of testing.

Soil properties were determined in accordance with ASTM D854, D422, D2216 and D2435-04 for specific gravity, sieve and hydrometer analysis, moisture content, and permeability, respectively. The specific gravity of the garden soil was determined to be 2.51. It was found out that the garden soil is classified as sandy loam from the USDA Textural Triangle. Effluent water was collected through the perforated pipe after every 24-hour period to exhibit the process of phytoremediation (Xiao, 2011). The effluent collected was stored in water sample containers and analyzed for ammonia, nitrate, phosphate, copper, and iron concentrations. Three trials or similarly, three events per setup were observed in the experiment. Retention time, the duration of the surface runoff retained in the system, was measured when effluent was discharged from the perforated pipe. The infiltration rate was computed by measuring the change of height of the water on the filter media over the time elapsed.

RESULTS

Results of the experiments show that the infiltration rate (cm/min) and retention time recorded for the control, vetiver and lemon grass set-ups are: Control – 0.0.94 cm/min and 10 min, Vetiver – 0.060 cm/min and 19 min, and Lemon grass – 0.066 cm/min and 17 min. These properties are important in determining the storage performance of the bioswales so as to examine how fast runoff water will go down in the system and how long it can be stored before its release as an effluent. The vegetated set-ups are observed to have longer retention times. This is due to the root systems of the vegetation that hold the surface runoff on the top layer of the swale, prolonging the surface runoff inside the system. The vetiver grass setup that is characterized by its deep roots has a longer retention time than that of lemon grass. The results are consistent with the computed equivalent vertical hydraulic conductivities. Higher hydraulic conductivity means that the runoff water can pass through the bioswale faster, thus giving a shorter retention time. The lowest permeability and highest retention time was recorded for the vetiver grass setup because of its deep roots that provide more compact filter media.

The effluent water samples from the bioswale set-ups were analyzed for its pollutant and nutrient contents using the CHEMetrics V2000 Photometer. Using the photometer device, the amount of ammonia, nitrate, phosphate, copper, and iron present in the water samples were determined. Other physical properties such as pH, color, electrical conductivity, total dissolved solids (TDS), dissolved oxygen (DO), total suspended solids (TSS), and turbidity were analyzed using the Hanna pH/EC/TDS Meter, Eutech CyberScan DO 110 Meter, Hach 2100Q Portable Turbidimeter. These parameters were measured in the laboratory within 24 hours after the collection of the effluent.

Results of the water quality analysis shows that for all the pollutants, the initial concentration of pollutants in the runoff water has decreased significantly after passing through the bioswale systems, especially for the iron concentrations. There is also a variation in the mean concentrations of the three setups for ammonia, nitrate, and copper while there is a minimal difference for the phosphate and iron concentrations. Turbidity and amount of total suspended solids in the effluent have been significantly reduced after passing through the system.

The pollutant removal efficiency of each setup was also computed. The mean turbiduty, TSS, phosphate and iron removal efficiencies of the three setups are close with one another. For ammonia, nitrate, and copper removal efficiencies, there are variations in the values. The pollutant removal efficiency of the vegetated setups is relatively greater than the control setup. The lemongrass setup has the highest pollutant removal efficiency of ammonia, iron and phosphate (86.6%, 99.3%, 66.9%, respectively) while the vetiver grass setup has the highest pollutant removal of copper and nitrate (74.7%, 60.5%, respectively). Overall, the vetiver grass setup has the most effective overall pollutant removal among the three setups because of its best storage performance.

From DAO No. 2016-08, the Water Quality Guidelines and General Effluent Standards of 2016 were stated. The standards apply to all water bodies in the country including freshwaters, marine waters and groundwater. There are two main classification of water bodies in the standards: freshwater and marine waters. Assuming that the residential areas discharge its wastewater in rivers, DAO standards for freshwaters was used in comparing the quality of surface runoff before and after it has passed through the bioswale. From the result of the water quality analysis, it was determined that the influent run-off water is under classification D. Class D waster is used for navigation. After bioswale treatment, the effluents from all the systems are still under classification D. The water from the control setup passed classification A except for the following parameters: ammonia, copper, nitrate and phosphate. Class A or Public Water Supply Class II is intended as sources of water supply requiring conventional treatment such as coagulation, sedimentation, filtration and disinfection to meet the PNSDW. Both lemongrass and vetiver grass passed classification A except for parameters copper, nitrate and phosphate. Because other parameters such as nitrate, copper and phosphate did not pass the DAO effluent classification, the bioswale effluents are still characterized as class D even with the bioswale treatment.

CONCLUSION

The study aims to design and construct laboratory-scale bioswale setups applicable to the Philippines: non-vegetated or control setup, lemon grass setup, and vetiver grass setup. This was achieved by sieving sands and gravels, obtaining garden soil from a local garden shop, and acquiring grasses. After constructing the setups, runoff simulation and collection of sufficient effluent samples in each event for water quality testing were conducted. This was to determine the storage performance of the three setups as well as their respective pollutant removal efficiencies. After comparing the data gathered from the three groups, the best bioswale setup was then determined.

In terms of the storage performance of the bioswales, the vetiver grass performed best because it has the longest retention time among the three setups. The retention time for this setup was 19 minutes with an effective infiltration rate of 0.060 cm/min. The lemon grass was somehow close with a retention time of 17 minutes and an effective infiltration rate of 0.066 cm/min. The control setup has the poorest performance with a 10-minute retention time and 0.094 cm/min effective infiltration rate. A similar trend among the three setups was observed; higher infiltration rate which also means higher equivalent vertical hydraulic conductivity corresponds to a shorter retention time of runoff water in the swale.

Water quality testing resulted in the increase of pH, DO, EC, TDS, and color of the effluent in the three setups. This was mainly because of the composition of the filter media, which was consisted of minerals and organic materials. On the other hand, turbidity and total suspended solids removal efficiency were almost the same for all the three setups with almost 100 % removal. The decrease in the turbidity and amount of total suspended solids were attributed to the layers of the bioswale setups and not in the vegetation that were present.

To sum it up, the vetiver grass setup has the most remarkable pollutant removal efficiency. The setup has also established a good storage performance. This was attributed to the deep and complex root system of the grass. The pollutant uptake of the plants would have been better if the root system of the plants grew deeper into the soil.

Keywords: *Biofilter, Bioswale, Lemon grass, Water pollution. Vetiver grass*

Ecohydrology Blended Curriculum for Water Security: Case Study of Perceptual Changes in Middle School Level in North Central Timor District

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INTRODUCTION

Drought is one of the major problems in East Nusa Tenggara Province, including North Central Timor district. Most of the territory or 60% of the region in 9 sub-districts facing water scarcity caused by short of rainy season. Availability of fresh water and ground water tends to be decreased with El Nino phenomenon that has a cycle of 4 years. With average rainfall of 1418 mm/year, this region requires water resources management to ensure water security and sustainability. Water sustainability can be achieved through many programs related to water management and biota management. This concept has been known as dual regulation or ecohydrology which is a new approach to develop solutions for integrated water security. However, it's already known among academics and practitioners but never been disseminated and tested at the school level. The aims of this study are (1) to integrate ecohydrology concepts in Biology subject in high school at C1-C4 level and (2) to know the responses and students' perceptual change once given a simple ecohydrology concept at A1 –A5 level. Code C1-C4 and A1 - A5 refers to Bloom's taxonomy.

METHODOLOGY

The research employs empirical class action research with qualitative descriptive method and conducted on September to November 2016 with a sample size of 28 X grade students at Taekas High School of North Central Timor district. The research was conducted through 3 (three) phases: (1) preliminary research or baseline data before students were introduced to the concept of ecohydrology (2) integration of ecohydrology concept on the biology subject (3) measurement of student response. Data collection by class observation and documentation with questionnaire served as the main instrument. The questionnaire is designed according to the students' level of understanding in research purpose. Research indicators based on the questionnaire that contains all aspects of cognitive - affective and psychomotor aspects with focus of comprehension, responding and internalization. Triangulation was set to ensure the accuracy of measurements on questionnaires Q1, Q2 and Q3.

RESULT AND DISCUSSION

Based on preliminary research (Q1) 67% of students have known that water is an important component on hydrological and for human life (C1); but they have not understood that every component of society including students are obliged to maintain water conservation (C3, C4). Teacher develop new Biology syllabus which integrated biodiversity, hydrological cycle, human - ecosystem interaction and human contribution to regulate biota and cycle. Once students were given material of ecohydrology and human, as a component of biodiversity, playing an important role, the response has improved particularly in the aspect of valuing and characterizing their roles (A3, A5), as indicated by the average score of Q2 87%. Students also showed concern to their roles and contributions to maintain and use water efficiently (27%). Students wanted to be involved in maintaining hydrological and biota components (9%). When delivered last questionnaire (Q3) with a 2-week interval, their knowledge of water, biota and hydrological interactions and water resources has increased (12%). Students wanted to contribute actively conserving water in their environment (A3), using water efficiently (A5) and will transfer this knowledge to their environment (P1 and P3). Based on above results, it can be noted that their understanding of water and the hydrological cycle (A4) has improved to enable them to contribute actively (P1 and P3). Level of improvement increased from simply receiving and responding to being articulate and encouraging. According to Widodo et al (2009), the improvement of knowledge transfer from cognitive level to psychomotor level indicated that students have absorbed and be able to articulate their knowledge. The process of environment and water education require alteration of response and behavior. Innovation could improve student curiosity so they will be eager to learn and will push their contribution (Hendriyan, 2013). Ecohydrology and dual regulation developed by Zalewski in 2002 became the new approaches, especially in regulation and interaction between hydrology and the environment. Many stakeholders including teacher and student have been aware of this concept but were unable to define them in a systematic way. Through the integration – ecohydrology blended curriculum – teachers have the opportunity to simplify the concept. In the environment and conservation domain that require behavioral change, the ability to translate in simple and innovative ways will captive student perspective and can drive student responsiveness.

CONCLUSION

Ecohydrology as universal approach can be used to support water security and sustainability in school level. It should be developed in simple biota – hydrological concepts to encourage students to contribute to water security and sustainability.

Keyword: *ecohydrology, integration, cognitive, student, student response, water security*

Ecohydrology Approach as New Way to Support Agriculture and Water Resources Management in Peatland Area-Central Kalimantan

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INTRODUCTION

Peat swamp forest is a unique and fragile ecosystem, which is habitat to specific flora and fauna that play important roles in maintaining healthy natural conditions with high economic values. Peat swamp forest has important role for equilibrium and maintenance of living environment such as water reservoir, carbon storage, climate change and biodiversity. Human interventions to natural conditions that change the characteristics of the peatland, such as peat land subsidence that is irreversible, excessive drying of peatlands that triggered acid soils and vulnerable to wild fires, especially during dry seasons with reduced water levels, but flooding during rainy seasons. Therefore, knowledge of the ecohydrology of peatlands from a comprehensive study would be important for proper management of the resources. New approach and techniques on ecohydrology could play important roles to achieve sustainable goals of the peat resources, including in restoration efforts of the degraded peat land forests. However, much is to be learned on the characteristics of peatland resources that spread in different parts of Indonesia, that apparently each has specific local properties and values. Rieley and Page and Page et al. explained the case of peat swamps mega project experience in Central Kalimantan and explore alternative solutions to restore the damage lands.

Customized ecohydrology principles fitted into the peatland management in Central Kalimantan should consider the basic nature of peatland conditions as described by WidjajaAdhi, into four flooding zones A, B, C, and D. Typically peatland of zones B, C and D are suitable for agricultural practices, therefore will have cultivated plants such as wetland rice with specific water management techniques. Zones B and D with seasonal floodings would certainly be attractive for implementation of ecohydrology principles by controlling water levels in streams and on land through rewetting techniques, though the zone D type also of interest with some engineering approach of ecohydrology principles as it is most vulnerable to wild fire incidences. Therefore, in the present study close attention would be given to find out more on the interactions and interrelationships between controlling environmental factors of vegetation and water regimes.

METHODS

The sampling technique using a random sampling method, the number of samples taken was 20 respondents. The data collected is then processed and analyzed. The economic analysis includes cost, revenue, income and profitability of the farm. To find out the cost of production, reception, revenue and profit calculation used: a) Farming costs including Implicit costs (IC) - costs that are not incurred directly or were not actually incurred in farming activities. This fee is not totally excluded, but it needs to be taken into account, such as family labor, seed, land costs and capital interest alone and b) Explicit costs - the costs seen physically, for example in the form of money or goods released directly into farming activities such as labor outside the family, medicines, and depreciation tool. Data collection is done on the crop. The economic analysis carried out on the magnitude of the result, the amount of input, input prices, output prices. Data analysis is done with the analysis of costs and revenues. Analysis of farming by using financial analysis in the form of an analysis of the balance of receipts and expenses (to determine the efficiency or viability of farming, R / C > 1).

RESULT AND DISCUSSION

Characteristics of farming in peatlands Pangkoh, Pulang Pisau Farmers in peatlands, Kanamit Jaya village average experience working the farm for more than 20 years, whereas in the West Kanamit very varied once (6-24 years). Farmers in Kanamit Jaya has been oriented to plantation crops (oil palm and rubber), whereas in Kanamit Jaya some farmers still cultivate peatlands exist for food crops (rice, maize, pulses and horticulture). Land farmers were generally quite large (> 2 ha), and even though most of the land has been converted from food crops to plantations, mostly farmers still cultivate horticultural crops, particularly in the yard. Most farmers after planting is completed go to other areas as labor (wage labor). Oil palm farmers largely new crop still in production, largely rely on vegetables and daily wage last in oil palm plantations around the site.

Biophysical characteristics of land was made to inventory the environmental conditions supporting both the soil and the plants. Characterization is intended to determine the characteristics of the land that has the potential to influence directly or indirectly the parameters of land productivity. The results showed that the area Pangkoh 10 is already dominated by acid sulfate soil. Acid sulphate soils associated with peat soils were commonly found in the area around the tidal land, which covers go up with the loss of a layer of peat in the upper layers of sulfidic material. Peatland drainage can cause peat subsidence (subsidence). Subsidence of the peat can be caused by physical and chemical processes in the soil. Physical decline can occur due to loss of water and followed by the entry of air into the soil. Loss of water from the mass of peat causes the peat physical maturity (physical ripening), resulting in shrinkage of peat, whereas the influx of oxygen in the soil can increase the decomposition process (chemical ripening).

Existing water management system was not yet equipped with canal blocking. In Pangkoh 10 already use the floodgates, but most of the canal blocking are not effective and are not equipped with floodgate. In Pangkoh 9, most tertiary canals also serve as a means of transportation. This condition makes it difficult to regulate water in peatlands. Hydrology of peatlands must be conducted using the canal blocking on a drainage channel that will serve to regulate groundwater levels in accordance with the purposes of the plant.

CONCLUSIONS

The objective of this research was to study comprehensive ecohydrology aspects in ex mega rice project Central Kalimantan in order to support sustainable agricultural practices and water resources management in peatland areas. The results of the study showed that the sustainability of agricultural systems in peatland was strongly influenced by ecological aspect. This aspect can be carried out from the condition of water management system, water color condition and possible incidence of fires. The level of suitability for crops plantation was low (S3) with the limiting factors of pH, nutrient availability and the risk of inundation. In this case, water gates should be installed to improve water management system. Water quality in this area was characterictic of peat water and does not meet requirements for daily use for local people.

Key words : *peatland, plant suitability, water management, water quality, ex-mega rice project site*

Hydrodynamic Investigation of Laguna Lake, Philippines for Water Security and Flood Risk Management of Metro Manila

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INTRODUCTION

Laguna Lake with substantial economic value for water resource development is the most important natural resource in the Philippines. Strategically located at the center of urban development, Metro Manila, it is the focal point of national development efforts not only in the agriculture and fishery, water supply and energy sectors, but in the regional development program as well. It is the most stressed inland water body at the same time however, with competing and conflicting water-users, and continued environmental degradation from anthropogenic-based stressors. The lakes' dynamic interaction with Manila Bay through Pasig River makes it ideal for fishery and aquaculture with the entry of salt-water, but at the same time discharges nutrient-rich polluted waters of Metro Manila and surrounding coastal provinces to the lake. The lake has also been traditionally utilized as a water resource for irrigation, power-plant cooling, hydropower generation, recreation, and transport route for people and products. It also serves as flood-detention storage for Metro Manila during the rainy season, with flow diversions from upstream Marikina river basin. More recently, it has been tapped as a source of raw water for domestic supply. Discussions on maximizing the use of the lake for this function have become more significant and critical over the past recent years with the aggravating condition of water scarcity in Metro Manila and the vicinity. With the lake's invaluable water resource, competition and conflicts among its stakeholders are common occurrences. Approximately fifteen million inhabitants depend on the lake for environmental goods and services. The pressures of both growing user-demand and declining water quality laid ground the value of scientific knowledge on lake environmental-functioning for the optimal and sustainable use of the lake water resources.

METHODS

This paper presents a three-dimensional hydrodynamic study of Laguna Lake to properly understand the physical processes that govern and influence the circulation and mass transport characteristics of the lake for various water uses. The model was set-up to take into account the physical effects of natural climatic and hydrologic factors such as discharges from rivers, direct lake rainfall and evaporation, lake groundwater interaction, wind induced circulation, and tidal fluctuation at Manila Bay. Fish pen and fish cage structures used for aquaculture, affecting lake circulation were also incorporated into the model, in addition to different lake water withdrawals. The hydrodynamic component of Delft3D (WL|Delft Hydraulics, 2007), FLOW, was utilized to simulate the physics of the lake. The unsteady shallow-water equations were solved in 3D with a vertical sigma-coordinate system laid-out on a horizontal orthogonal curvilinear grid. Flow is forced by tide at the open boundary, wind stress at the free surface, and pressure gradients due to free surface (barotropic) and density (baroclinic) gradients. The hydrodynamic model was calibrated and validated using hydrographic data from field surveys and long-term monitoring information.

RESULTS

Laguna Lake serves as a flood-detention storage for Metro Manila. Excess runoff discharge from Marikina river basin is diverted to the lake for temporary storage until flood waters from the watershed recedes. In September 2009, typhoon Ketsana (Ondoy) dumped about 45 cm of rain in 12 hours that resulted to widespread flooding. A 1.2 m increase in lake level that occurred due to the flood detention operation took months to recede causing flood waters in shoreland areas to last until January of the following year. Although, the volume of water generated by Ketsana would have resulted to flooding nonetheless even with a fully operational flood management and control system, there are measures that can be taken to reduce the impact of such extreme event to a predetermined safety level. Scenario simulations revealed different shore-land flood inundation areas and recession durations for varying lake flood detention levels. A numerical experiment on bathymetric evolution also showed various Pasig River hydraulic discharge features and an increase in hydraulic residence time of the lake that warrants the need for a more comprehensive flood risk management plan and set of priority structural and non-structural measures for sustainable flood management in the metropolis. More polluted seawater was also observed to be intruded during the dry season due to the longer lake residence time. Seawater entry demonstrated larger extent in intrusion plume as a result which further established the increase in eutrophic vulnerability and higher potential for adverse response to eutrophication of Laguna Lake in recent years. Scenario simulations were also conducted to study the impact of increased lake water abstractions on the lake hydrodynamics, particularly the entry of polluted salt water from Manila Bay through the Pasig River. Simulation results reveal a significant increase in lake salinity concentration for incremental increases in lake water abstraction, particularly during the dry season. Different abstraction scenarios corresponded to different movement patterns and concentration distributions of the lake salt water plume (Figure 1). With the drop in lake water level by about 1.5-2.0 cm for every 400 million liters per day lake water abstraction, Pasig River backflow (Manila Bay to Laguna Lake) is induced by the intensified hydrodynamic imbalance between the lake and the bay resulting to higher incidence of lake salinity intrusion. With the drop in annual average Pasig River outflow (Laguna Lake to Manila Bay), the eventual exit of saline water from the lake during the rainy season (the lake hydraulic residence time), will take a longer period compared to the normal hydrodynamic condition without abstraction, increasing Laguna Lake's eutrophic vulnerability.

CONCLUSION

A 3-dimensional hydrodynamic model was set-up for Laguna Lake, Philippines using Delft-3D to properly understand the physical and environmental processes that govern and influence the lake dynamics. The water balance of the lake was analyzed by taking into account the physical effects of all natural climatic and hydrologic factors, as well as man-made interventions. Field measurement data on various water quality and hydrodynamic parameters were used for the calibration and validation of the model. Observed lake parameters were reproduced by the model within acceptable limits of accuracy.

In general, in spite of the data limitations, the hydrodynamic set-up and simulation results showed that the hydrodynamic model can describe the water balance and transport processes in Laguna Lake within sound degree of accuracy. The validated model was able to provide useful information for understanding the dynamic condition of the lake and for predicting the impacts of future man-made interventions, such as temporary flood detention and water abstraction for domestic use. Thus, deeper and better understanding of the lake dynamics generated can serve as a sound basis for lake management options and for further research undertakings, essential for the lake's optimal and sustainable use as a multi-purpose resource, while preserving its environmental integrity at the same time.

Keywords: *Laguna Lake, flood-detention, water-security, flood-risk, management.*

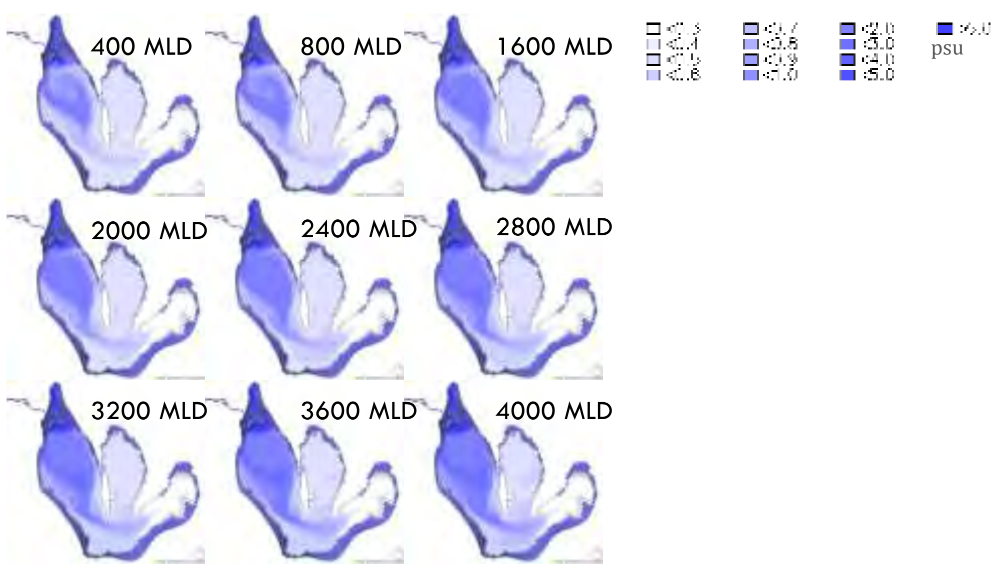

Figure 1. Comparison of lake salinity concentration plume for varying abstraction rates.

Building Climate-Resilient Water Utilities for Water Security

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INTRODUCTION

Achieving water security is a major challenge for countries who are heavily impacted by a changing climate regime. The Philippines has been ranked globally as the third most vulnerable country to the impacts of climate change. As such, water service delivery in the face of a changing climate regime becomes an extremely complex endeavor that is challenging the way water utilities and service providers perform their tasks. Thus, the need for climate resilient water utilities for water security.

METHODS

Through a Water Operators Partnership (WOP) Program of WaterLinks and with assistance from USAID through its Be Secure Project, six (6) water utilities were transformed into climate resilient utilities enabling them to develop and implement climate change adaptation plans and programs- geared to contribute to ensuring water security at the household levels. Under a WOP approach, a peer-to-peer arrangement of mentoring a vulnerability assessment (VA) was carried out to identify climate related risks of water utilities. The VA process involved: identification of historical operational disruptions; assessment of historical rainfall and temperature; projecting rainfall and temperature scenarios; estimating climate change impacts in terms of flooding, drought, sea level rise and saline water intrusion as well as water supply shortfall given the impacts of a changing climate regime.

RESULTS

Climate related vulnerabilities and risks were identified based on the result of the VA exercise. This resulted in the development adaptation option programs by the water utilities to address impacts of climate change. Examples of adaptation options included: hardening of existing infrastructures including building redesign to address flooding and strong wind brought about by more frequent typhoon; aggressive NRW program, groundwater management and rainwater harvesting to combat effects of drought and prolonged dry season; diversification of water sources and water demand management. The adaptation options were prioritized using a spreadsheet methodology that quantified the cost of the adaptation options vis a vis the avoided cost. The priority adaptation options were integrated into the water utility business plan to ensure that it gets the needed budget for its implementation. The output is a climate resilient business plan, the blue print of the 6 water utilities to effectively address impacts of a changing climate regime. Overall, this will enable the 6 water utilities to pursue their mission of providing water service to their consumers, eventually ensuring access of water at the household level and contributing to achieving water security.

CONCLUSION

Building climate resilient water utilities contributes towards achieving water security despite impacts of climate change. WOP is an effective way of helping build climate resilient water utilities based on the experience of WaterLinks, a non-government organization whose core business is promoting WOPs across Asia and the Pacific.

Keywords: *Climate change, Vulnerability, Resilient water utilities, Water security*

International Flood Initiative – Recent Progress in Asian Countries

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BACKGROUND

Flooding is one of the greatest water-related environmental disasters known to us – its human, material and ecological costs are staggering. The number of people vulnerable to a devastating flood is expected to continue to rise due to large-scale urbanization, population growth in flood-prone areas, deforestation, climate change and rising sea levels. New disaster risk reduction approaches are needed to build the necessary capacity to address these challenges. This paper introduces the recent progresses in the Philippines, Myanmar, and Sri Lanka on the activities of the International Flood Initiative (IFI), of which ICHARM has been served as a secretariat since its establishment.

METHODS

1) International Flood Initiative

The IFI is a framework to improve flood management on a global scale in collaboration with such international organizations as the United Nations Education, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization (WMO), the United Nations University (UNU), the International Strategy for Disaster Reduction (ISDR), International Association of Hydrological Sciences (IAHS), and International Association for Hydro-Environment Engineering and Research (IAHR). IFI's official launch was convened at the World Conference on Disaster Risk Reduction held in January 2005 in Kobe, Japan. The first meeting of the Management Committee and Advisory Committee of IFI was held on 26 January 2007 at WMO, Geneva. The draft plan of the IFI was officially adopted, and since then, ICHARM has been working as a secretariat of the IFI. In October 2016, the Jakarta Statement was adopted by the organizations participating in the IFI to establish interdisciplinary cooperation for further promoting flood risk reduction and sustainable development. Based on this agreement, IFI, while keeping close ties with countries and other organizations, will proceed with activities to implement integrated flood management by incrementally moving from "Phase 1: Demonstration," to "Phase 2: Prototyping," and finally to "Phase 3: Operation." Until today, the Philippines, Sri Lanka, Pakistan, and Myanmar have already decided to establish "Platform on Water and Disasters" involving various government agencies. ICHARM has been actively supporting their decision by facilitating close communication between relevant organizations, both domestically and internationally.

2) IFI Activities

The IFI is promoting a worldwide effort to establish a Platform on Water and Disasters in each country to implement more effective disaster management. As its Visions, Platform envisions a future wherein decisions and actions for reducing water-related disaster risk are well supported by coordinated, comprehensive and sustained risk communication. To realize its Vision, Platform works to connect the demand for sound and timely decisions and actions taken by policy-makers and local communities with the supply of disaster risk information that is generated from integrated risk assessment and risk change identification based on well archived data and statistics. In doing so, Platform strengthens data integration and analysis functions by facilitating data and information accessibility and application to decisions and actions within and across many different stakeholders. Decisions and actions for reducing risk on water-related disasters, including floods, landslides and droughts, rely, and will continue to rely, on the ability of expert communities to collect and archive data from various sources and combine these with social and economic analyses. Platform strengthens experts' capability of data collection and archiving, integrated assessment and risk change identification and stakeholders' capacity for making maximum use of these data and information provided from the experts. Platform contributes to institutional and infrastructural design and investment including land use management and climate change adaptation (static approach) and to effective response and recovery (dynamic approach).

3) IFI in the Philippines

ICHARM has been supporting the Republic of the Philippines for establishing a Platform under the IFI by organizing a series of meetings. At the meeting on March 13, 2017, the framework of the Platform was agreed. On June 15, 2017, in Pasay City, Metro Manila, “Meeting for the Platform on Water-related Disasters,” was held to discuss specific activities to be conducted under the Platform, in which the representatives from the relevant governmental organizations participated, such as Department of Science and Technology (DOST) and Department of Public Works and Highways (DPWH), and from the universities. As data on water-related disasters are needed to conduct risk assessment in the river basin, the basic policy for data management to define collection, arrangement and utilization of data was discussed. As a result, it was agreed that the participating organizations will cooperate to prepare a list of data and upload it by using the Data Integration and Analysis System (DIAS). It is expected that archiving and integrating data on water-related disasters will be promoted and be accelerated by using the Platform of IFI.

4) IFI in Myanmar

The High-Level Consultation Meeting on IFI Coordination in Myanmar was held on May 9, 2017. The meeting was collaborated with the program, “Science and Technology Research Partnership for Sustainable Development” (SATREPS), which supports the “Development of a Comprehensive Disaster Resilience System and Collaboration Platform in Myanmar.” led by the University of Tokyo as the principal research organization. The meeting involved the relevant governmental organizations in Myanmar; Directorate of Water Resources and Improvement of River Systems, Ministry of Transportation and Communication (DWIR), Department of Meteorology and Hydrology (DMH), Relief and Resettlement Department (RRD), and Irrigation and Water Utilization Management Department (IWUMD). At the meeting, the basic structure and policy of the Platform was agreed. It was also confirmed that DWIR, DMH, RRD, and IWUMD will form the core of the Platform with the secretariats of National Water Resources Committee (NWRC) and National Disaster Management Committee (NDMC). Moreover, to demonstrate the functions of the Platform, test operations for the Bago River and the Sittang River was decided to start. The Platform will go ahead with preparation for risk assessment including data collection and database development, while discussing issues arising through the process.

5) Establishment of the Platform on Water and Disasters in Sri Lanka

Intensive rainfall started on May 24, 2017, and continued intermittently, resulting in a record daily maximum rainfall of over 550 mm in some parts of Sri Lanka. This heavy rainfall caused severe floods and landslides nationwide, especially in the Kalu River basin located in the south-western part of the country. More than 300 people were reported to be dead and missing, and more than 18,000 houses were reported to be damaged (as of June 3, 2017, by the Government of Sri Lanka). In response to this flood disaster, upon the request of the government of Sri Lanka, the government of Japan dispatched the Japan Disaster Relief (JDR) Expert Team to Sri Lanka to assist flood recovery efforts from June 2 to June 11, 2017. The Public Works Research Institute (PWRI) assisted by sending a senior researcher as its expert. Since Sri Lanka was in the middle of the rainy season, more flood disasters were anticipated, that might possibly cause further damages to human lives and property in the country. The situation was still critical, requiring latest information by maximizing Japan’s advanced science and technology for preventing recurring disasters and assisting the country in emergency response and post-disaster restoration.

In response to this disaster in Sri Lanka, Earth Observation Data Integration and Fusion Research Initiative, University of Tokyo (EDITORIA) and ICHARM have cooperated to provide the information for effective flood management by coupling outputs of meteorological and hydrological models through the DIAS. DIAS has already integrated ground and satellite precipitation data, rainfall forecasting data, results of flood inundation analysis and forecasting, and satellite observation data on cloud development, as well as ongoing floods and inundations. This information has been provided in real time for the related organizations of the Sri Lankan government since the dispatch of the JDR Expert Team, and will be provided continually. Hands-on-training and capacity development programs will be implemented for Sri Lankan experts to utilize these data and information provided through DIAS properly and practically. Through this support, Sri Lanka will be provided with various types of flood-related information based on the latest research findings. This information will enable the government organizations of Sri Lanka to disseminate effective flood forecasts and early evacuation alerts, which will lead to human damage reduction and efficient emergency response.

After this flood disaster, ICHARM has been planning to assist the country in flood management by using research outputs which have been achieved to date. In addition, as a secretariat of the IFI, ICHARM is supporting countries suffering from serious flood disasters in establishing a Platform on Water and Disasters. As part of this effort, the "Plenary Session for the Platform on Water and Disasters" was held on August 24, 2017, in Colombo, Sri Lanka, in volving all organizations relevant to flood management in Sri Lanka. More than 30 participants attended this session from Irrigation Department, Disaster Management Center, Department of Meteorology, Survey Department, and Ministry of Megapolis and Western Development. After the discussion among all the participants, a basic consensus was made on the concept of the Platform in Sri Lanka and other issues. Four target actions were agreed to implement, such as early warning, which will be implemented in three river basins. The secretariat role of these actions was assigned to individual Sri Lankan institutes.

RESULTS

After the "Implementation Planning Workshop on IFI in Asia-Pacific" held in Tokyo in January 2017. ICHARM has been supporting to establish a "Platform on Water and Disasters" by facilitating close communication between relevant organizations, both domestically and internationally. The progresses in the Asian countries, such as the Philippines, Myanmar, and Sri Lanka are significant; data management in the Philippines, start of test operation in the selected river basins in Myanmar, and implementation of target actions in the representative river basins in Sri Lanka.

CONCLUSION

ICHARM has actively been working as a secretariat of the IFI in collaboration with international organizations to improve flood management through supporting the establishment of the Platform on Water and Disasters through development of data management, implementation of test operation and target actions. While the establishment of the Platform is being promoted in some Asian countries, ICHARM will continue to extend the support for the other countries that suffer from damages due to frequent occurrences of flood disasters.

Keywords: *International Flood Initiative (IFI), Platform on water and disasters, Data Integration and Analysis System (DIAS), Asian countries*

Assessing Flood Risks Globally Using an Improved Country-Based Index

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INTRODUCTION

Water-related disasters, such as, floods, droughts and storm surges have been recently increasing globally. Damage caused by flood disasters in the Asia-Pacific countries is immense. In this study, we propose a country-based flood risk index, figuring in both natural and socio-economic factors, which contributes to mitigating flood damage.
The author and his team developed an indicator to assess flood risks in the Asia-Pacific countries, and the results were presented in the Asian Water Development Outlook (AWDO) published by the Asian Development Bank (ADB) in 2013. However, the method employed in AWDO 2013 has the following restrictions:

- The method was constrained by the availability of data sets in the Asia-Pacific countries, particularly in some developing countries.
- The method was applied only in the Asia-Pacific countries, although severe flood disasters have also occurred in other regions.

In this study,

1) We develop an improved flood risk index.
2) We apply the developed index globally and assess flood risks of the countries.

METHOD

We develop the following flood risk index.

$$\text{Flood Risk Index} = \frac{\text{Hazard} \times \text{Exposure} \times \text{Vulnerability}}{\text{Hard Coping Capacity} \times \text{Soft Coping Capacity}} \tag{1}$$

Table 1: Five Indicators

Hazard	Magnitude of natural phenomena that cause floods, such as monthly precipitation
Exposure	Scale of people or areas exposed, such as population growth
Vulnerability	Susceptibility to the damaging effects of floods, such as poverty rate
Hard Coping Capacity	Ability to manage flood disasters by structural measures, such as storage capacity of reservoirs
Soft Coping Capacity	Ability to manage flood disasters by non-structural measures, such as literacy rate

The five indicators in the right side are shown in the table 1. Each indicator is composed of two to five subindicators, which are normalized as shown in Eq. (2).

$$\text{Subindicator}(i) = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \qquad (2)$$

where x_i, $x_{\min}$ and $x_{\max}$ are the values of a subject country, the minimum country, and the maximum country, respectively. Each indicator is calculated by summing up subindicators as shown in Eq. (3):

$$\text{Indicator} = \sum_{i=1}^{n} \text{Subindicator}(i) \qquad (3)$$

We compute a flood risk index of each country according to Eq.(3).

RESULTS

To improve the flood risk index in AWDO 2013, we incorporate new sub-indicators and compute the flood risk indices of 33 Asia-Pacific countries (shown in Fig. 1). Both flood risk indices and numbers of fatalities of high income countries (shown in the green broken line), such as Japan, Australia and New Zealand, are small. Supported by economic capacities, these countries have invested in both structural and non-structural measures to reduce flood risks.

The low income countries (shown in the red broken line), such as India and Bangladesh, show high flood risk indices. In Nepal and Cambodia, massive floods occurred in 2015 and 2011 respectively and increased the numbers of fatalities significantly. The flood risks of these countries are high due to low 'Soft Coping Capacity.' High risk countries have potential to suffer serious damage when a catastrophic flood happens. Therefore, it is necessary to reduce their flood risks by increasing 'Coping Capacities' and decreasing 'Exposure' and 'Vulnerability.'

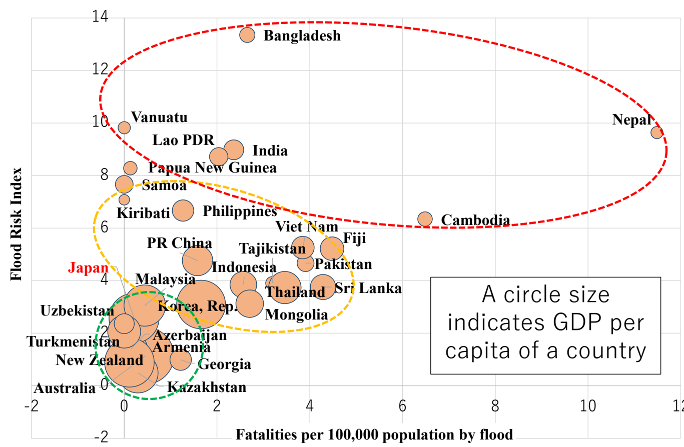

Figure 1: Number of fatalities per 100,000 people and flood risk index

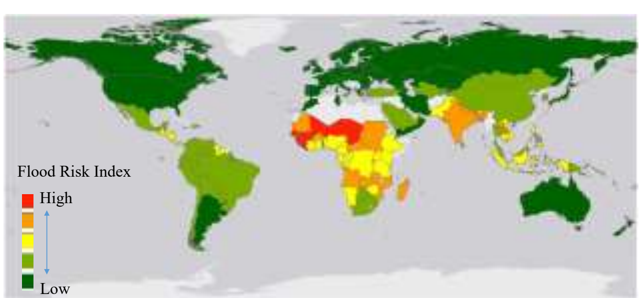

Figure 2: Flood risk map (146 countries)

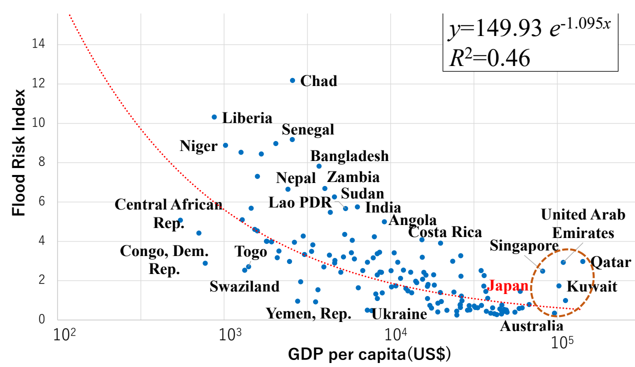

Figure 3: Gross domestic product (GDP) per capita and flood risk index

The results of computing the flood risk indices of 146 countries are shown in the figures 2 and 3.

The figure 2 shows that many African countries have high flood risks, and some other tropical countries have high to medium flood risks.

The figure 3 indicators that the smaller GDP per capita produces the higher flood risk. Gambia and Chad, the two highest flood risk countries, show very high ‘Hazard,’ due to their natural conditions. While oil-producing countries, such as Qatar, Kuwait and the United Arab Emirates, have high GDP per capita, their flood risk indices are not so low. It is because these countries are high urban population growth and deforestation rates. Therefore, it suggests that the countries should reform ‘Exposure’ and ‘Vulnerability.’

Figure 4 shows the five indicators by region. An area in a pentagon illustrates a flood risk of each region. Africa is the highest flood risk region due to high ‘Hazard,’ ‘Exposure,’ ‘Vulnerability’ and low ‘Soft Coping Capacity.’ The countries need to control explosive population growth and reform poor educational and living environments.

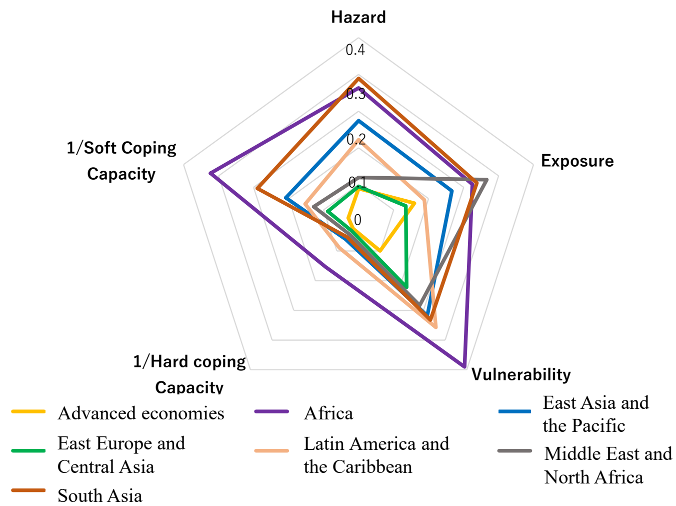

Figure 4: Five indicators by region (146 countries)

CONCLUSION

- We incorporate new sub-indicators and improve the country-based flood risk index, factoring in both natural and socio-economic conditions. The improved index articulates the causes of a flood risk of each country and indicates the way to mitigate future flood damage. The index is developed and improved to contribute to making better global, regional, and national policy and strategy.
- We apply the improved method to 33 Asia-Pacific countries, and the results suggest that the countries are divided into high, medium, and low flood risk countries, and economic development affects flood risk. The high flood risk countries should improve ‘Coping Capacity’ and ‘Vulnerability’ to prepare for a catastrophic flood.
- We also apply the method to 146 countries in the world. Many African countries have high flood risks, and some other tropical countries have high to medium flood risk. The African countries need to control explosive population growth and reform poor educational and living environments. Despite large GDP per capita, some oil-producing countries show slightly high flood risk because of high ‘Exposure’ and ‘Vulnerability.’

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Keywords: *Flood risk indicator, Country-based flood risk, Policy planning, Disaster reduction, Investment strategy*

Adaptive Strategies for Community Recovery and Identification of Pre-Disaster Activities: *A Case Study of Villages in Hinthada, Ayeyarwady Region, Myanmar*

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INTRODUCTION

The Association of Southeast Asia Nations (ASEAN) is exposed to high risks of hydrological natural hazards due to metrological and geological factors. German Watch (2017) points out that climate change risks have impacted these vulnerable regions. This is especially true of Myanmar, which is ranked as the second highest risk country in the world. They are anticipating increases of intensified disasters. Because Hinthada Township in Ayeyarwady Region has been affected by annual historical flooding, earthen dykes were constructed during the British colonial period, about 150 years ago. The dykes have been contributing to the protection of the urban area in Hinthada and transforming wetland into agricultural land However, villages located outside of the dyke have been designated as flood zones since then. Flood waters generated by consecutive heavy rains inundated the bamboo housing structures. As a result, the structures were damaged, though these houses were rebuilt in the same manner as before. Leik Chaung Village Tract in Hinthada Township, however, represents a distinctive example of adaptation and disaster mitigation strategies at the community level. The objective of this research is to identify the variety of recovery strategies used to respond to flooding and inundation within an administrative boundary and to suggest appropriate pre-disaster activities that can be adapted to local contexts.

METHODS

To identify the community recovery activities in the villages, semi-structured interviews were conducted at the household level. Four villages were selected, and a total of 80 household surveys were administered. Two villages were inside the dyke. These were Daw Na Kong Village, which is comprised of 57 households, for a total population of 296 people, and, South Leik Chaung Village, with 126 households (population = 572). The two villages located outside of the dyke are Na Be Kong Village, which contains 98 households (population = 419) and North Leik Chaung Village, with 146 households (population = 575).

RESULTS

The research reveals that recovery strategies among villages reflect different approaches: adaption to floods or dependence on protection measures (dykes). Unprotected villages have adaptation strategies that revolve around housing and livelihood. They are not willing to transfer or relocate, because their houses have been elevated in order to adapt to the annual event. A water-resistant plant, which benefits from the fertile soil brought by the floods, is a major contributor to livelihoods. On the other hand, houses in protected villages do not need to be elevated, but their main livelihoods, which include paddy rice and bethel leaves, are vulnerable to water inundation. The limitations of each strategy are also identified. Elevating the bamboo structure housing has limitations to its adaptation, because the strength of the bamboo pillar cannot endure above a certain point. As an alternate solution, timber houses have durability for higher elevation more than 2 feet. Therefore, some households have been retrofitted with elevated floors to cope with severe flooding. However, relatively poor households cannot use this option, because bamboo structured houses are more affordable than the timber ones. Thus, socio-economic background limits the recovery strategies in unprotected villages. The limitation for those inside the dyke is the capacity of the dyke itself. If the flood waters overflow, villagers may lose their houses as well as their livelihoods, regardless of socioeconomic status. Therefore, there is a high potential that the next flood event will have devastating consequences on the protected areas as well.

CONCLUSION

This research demonstrates that recovery strategies of villages inside and outside the dyke have been transformed by its construction. Over the course of 150 years, they have altered their patterns of disaster risk reduction by adapting their livelihoods and housing styles to the conditions created by the dyke. As a result, however, the vulnerability of those inside of the dyke is increasing due to lack of adaptive strategies.

Keywords: *Community Recovery, Adaptation, Mitigation, Transformation*

Development of Extreme Weather Monitoring and Information Sharing System in Metro Manila

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INTRODUCTION

The Philippines is an archipelago country which is located in the western side of tropical western Pacific. Nearly 20 tropical cyclones (TC) in a year approach Philippine area. When TC makes landfall it causes disasters of strong winds, heavy rain and storm surge. On the other hand, there are distinct summer monsoons (local name Habagat) on the western side of the Philippines and winter monsoons (local name Amihan) on the eastern side of the country associated with the seasonal shift of major wind direction. The climate in the Philippines is strongly influenced by TCs and monsoons. Metro Manila locates on the western side of the country and rainfall increases during the summer monsoon. Rainfall clouds tend to develop in a short time with a small scale, therefore it is hard to predict. Once heavy rainfall occurs in Metro Manila, damages spread widely in the mega city by floods, traffic confusion, etc. A project of Combination of Ulat (Clouds) and Kidlat (Lightning) of Science and Technology Research Partnership for Sustainable Development (ULAT/SATREPS) started from April 2017 to develop a methodology on short term forecast of extreme weather (torrential rainfall and lightning) and typhoon intensities in Metro Manila cooperating with Researchers of Advances Science and Technology Institute (ASTI) in the Philippines. At the first step, the factors producing heavy rainfall in the western Philippines including Metro Manila are investigated to understand the risk for disaster management.

METHODS

Station rainfall data are utilized to identify the summer monsoon onset and heavy rainfall in the western Philippines observed by PAGASA (Philippine Atmospheric Geophysical and Astronomical Services Administration). Criteria of summer monsoon onset is followed by PAGASA. The Japanese 55-year reanalysis dataset on a 1.25° grid was used to obtain three-dimensional atmospheric structures of wind and moisture. The TC best track data of TC location and intensity from the Joint Typhoon Warning Center (JTWC) and the Japan Meteorological Agency (JMA) are used.

RESULTS

We focused on the year 2013 to identify atmospheric structures that trigger Philippine summer monsoon onset. Summer monsoon started on June 9 by increasing rainfall in the western Philippines. Tropical cyclone (TC) Yagi traveled northward in the Philippine Sea (PS) and triggered the Philippine monsoon onset by intensifying moist low-level southwesterly wind in the southwestern Philippines and intensifying low-level southerly wind after the monsoon onset in the northwestern Philippines. The influence of TC was analyzed by the probability of the existence of TC in the PS and the South China Sea (SCS) since 1951. The probability of the existence of TC at the summer monsoon onset was found to be significantly correlated with the Philippine summer monsoon onset date (Fig. 1). After the mid-1990s, early monsoon onset was influenced by active TC formation in the PS and the SCS. However, the role of TC activity decreased during the late summer monsoon periods. In general, it was found that TC activity in the PS and the SCS plays a key role in initiating Philippine summer monsoon onset.

The combination of TCs and monsoons affected heavy rainfall in the Philippines. We started a new project called "ULAT/SATREPS" to improve the accuracy of short-term forecast of extreme weather (torrential rainfall and lightning) and typhoon intensities in Metro Manila and to disseminate the information to related agencies for use their disaster risk reduction and management activities such as issuing extreme weather alerts. We set four components to fulfill the project: 1. Quasi real time monitoring system (approx. 10 minutes intervals) for lightning and weather with dense and nation-wide observation networks is established (Fig. 2). 2. Quasi real time (approx. 10 minutes after the satellite data downlink) 3-D cloud monitoring system by satellite data is established. 3. Based on data obtained by dense and nationwide ground observation networks and satellite cloud imaging, methodology for short term forecast of extreme weather (torrential rainfall and lightning) and typhoon intensities in Metro Manila by extrapolation method is developed. 4. Software for sharing information on short term forecast of extreme weather (torrential rainfall and lightning) and typhoon intensities in Metro Manila by extrapolation method with concerned agencies in disaster risk reduction of Metro Manila is developed.

CONCLUSION

A Pilot study to develop a methodology on short term forecast of extreme weather (torrential rainfall and lightning) and typhoon intensities in Metro Manila has been investigated. TC triggered the Philippine monsoon onset by intensifying moist low-level southwesterly wind in the southwestern Philippines and intensifying low-level southerly wind after the monsoon onset in the northwestern Philippines including Metro Manila. A project of ULAT/SATREPS started from April 2017 cooperating with ASTI in the Philippines. We plan field observations under the project ULAT/SATREPS of airborne observation with dropsonde observations in 2018 and extra upper-air observations in Cebu/Mactan in 2019 to capture the atmospheric structure of thunderstorm clouds and tropical cyclones during the summer monsoon in the Philippines.

Keywords: *Heavy rainfall, Tropical cyclone, Lightning, Monsoon, Short term forecast*

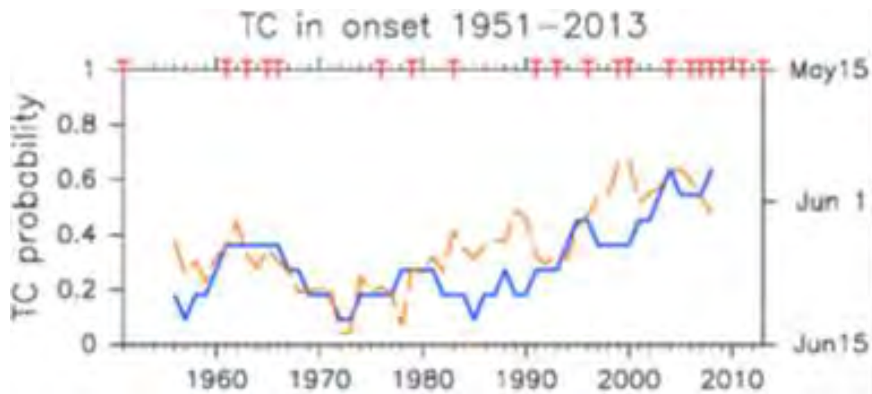

Fig. 1: The probability of TC existence during summer monsoon onset. Existence of TC at monsoon onset (red "T"), 11-year running average of the PTCe (blue line), and Philippine summer monsoon onset date (orange dashed line) are superimposed.

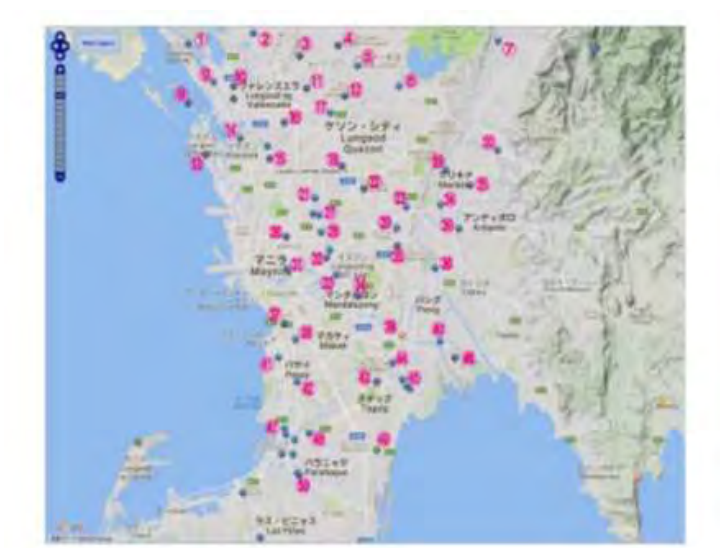

Fig. 2: Dense 50 weather and lightning observation candidate sites in Metro Manila.

Assessment of Disaster Waste Management in NCR

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INTRODUCTION

Disaster waste management in the country especially in Metro Manila has become a major problem in the past decades because of the inefficient waste collection and lack of temporary storage facilities that hinder the fast recovery. Following the 2009 Typhoon Ondoy (Ketsana) in Marikina, road blockages prevented access for motorists since the overwhelming volume of wastes collected after the typhoon were temporarily stored on the main road. Currently, the local government units (LGUs) are designated in the collection of wastes, and the cleaning and clearing operations where all of the post-disaster wastes collected are directly dispose to sanitary landfill. Assuming 50,000 cubic meters of wastes collected, it will be discharge to the sanitary landfill without any waste processing and treatment options. Hence, the space of the landfill will not be fully maximized. This study aimed to assess the disaster waste management practices in the National Capital Region (NCR) in order to prepare properly and to minimize the risks, impacts, and cost-effective process for the collection, transportation, storage, treatment and disposal of disaster wastes due to typhoons and floods.

METHODS

International and national documents such as UNEP-OCHA Disaster Waste Management Guidelines, Ecological Solid Waste Management Act of 2000, National Disaster Risk Reduction and Management Plan (NDRRMP) 2011-2028 and other documents were reviewed in order to assess the current disaster waste management practice of Metro Manila. Seven cities were selected based on their population, estimated waste generation and risk of flooding. Cities of Malabon, Manila, Marikina, Navotas, Pasig, Quezon and Taguig were visited for ocular inspection of their heavily flooded areas and their treatment facilities.

Representatives from seven LGUs' City Environment and Natural Resources Office (CENRO) and City Environmental Management Office (CEMO), and two government agencies, Metropolitan Manila Development Authority (MMDA) and National Solid Waste Management Commission (NSWMC), were visited and interviewed for data gathering. The representatives from the CENRO/CEMO were asked for information such as the ordinances being implemented in the city, latest waste analysis and characterization study (WACS), waste treatment options and disposal sites, other waste diversion programs, recorded disaster wastes, transfer stations and temporary storage facilities, number of MRFs, documentations during recovery phase and the cleaning and clearing operation after disaster. The representatives from the MMDA and NSWMRC were also asked for data such as list of MRFs, waste analysis and characterization surveys, footprint of sanitary landfills, documentations of solid waste management and disaster waste management activities and even the disaster waste management framework or plan of the study areas.

Survey form or questionnaire was developed and distributed to quantitatively analyze the perceptions of different stakeholders on disaster waste management. The perception survey was conducted on the most heavily flooded areas in each study site. A total of one hundred and forty respondents, or twenty respondents per city, were randomly asked and interviewed regarding the disaster waste management practices in their area and their attitude about it. The respondents were asked on the different ordinances they are aware of, the location of their disposal site, the most abundant type of waste collected and observed after a disaster, the waste processing and treatment options they've tried, on how long they've fully recovered on disaster wastes, on who should spearhead clean-up operations and etc.

Available data on the amount and types of disaster waves generated in the past and the results in the survey were gathered. Waste were characterized based on WACS standard composition (ex. Plastic, Paper, Kitchen Waste, Inorganic, Organic, Metal and etc.) and quantified based on the number of dump trucks.

Focus group discussions were done to present the output of the study and to solicit suggestions from stakeholders. Different government agencies were consulted regarding the existing policies related to disaster waste management to improve the scope and the conduct of the project. Existing disaster waste management, material flow and disposal practices were assessed based on the review of related literature, site visits and consultations.

Using the guidelines provided by the Swedish Civil Contingencies Agency and Joint UNEP/OCHA, the disaster waste management practices in selected sites in NCR were assessed. Mapping the location of the Materials Recovery Facility and Materials Recovery Systems and calculating the footprint of temporary storage for each city were also included. Several guidelines such as waste treatment options were recommended based on the findings.

RESULTS

Tabulated solid waste management and disaster waste management practices in the study areas were generated based on the data gathered through interviews and site visits.

It was observed that the waste generated (95,000 cubic meters per day) during 2009 Typhoon Ondoy (Ketsana) in Marikina is equivalent to its 50-day waste generation (1,903 cubic meters per day) and the waste generated (47,668 cubic meters per day) in Pasig during 2014 Typhoon Glenda (Rammasun) is equivalent to its 15-day waste generation (3,005 cubic meters per day). Lack of temporary storage facilities, documentation of recovery phase, waste analysis and characterization study and record of volume of disaster wastes collected are the factors observed that may hinder the effectiveness of the current disaster waste management practice in each study area.

The survey aimed to present the perception of the residents regarding the disaster waste management in their areas. Most of the respondents recalled the damage and disaster wastes produced after Typhoon Ondoy (Ketsana) in 2009 and Typhoon Pedring (Nesat) in 2011. The most abundant type of disaster wastes collected and observed based on their recalled experience is plastic. This data serves as a guide for the recommendations of waste treatment options. Furthermore, it is observed that some communities recovered fast within a day up to 4 weeks only, while others especially the residents in the cities of Marikina and Quezon have recovered for about 2-5 months after Typhoon Ondoy in 2009. Residents in these two cities were dissatisfied in the slow response and action by their local government unit.

Tools such as MRF/MRS map and calculated required footprint of temporary storage facility for the study areas were generated. MRF/MRS maps are created to provide guidance and assistance to the residents for the disposal of their wastes especially the collected disaster waste in the selected cities in NCR. The list of the MRF and MRS in every city in Metro Manila is provided by the NSWMC and few of the MRF and MRS listed is not located due to unspecified location. On the other hand, the calculated required footprint of temporary storage facility for each city was created using the design ratio by UNEP-OCHA of 400,000 square meters of land for every 1,000,000 cubic meters of debris. The estimated amount of debris was based on the highest recorded volume of disaster waste obtained from each city.

Using the guidelines provided by the United Nations Environmental Protection and Office for the Coordination of Humanitarian Affairs (UNEP-OCHA), disaster waste management of the selected study sites were assessed. In the pre-recovery phase, all of the cities were able to identify the waste issues and to prioritize action especially in the clearing of roads, but failed to characterize, map and assess the disaster wastes collected. Some LGUs except Manila, Navotas, Quezon and Taguig City have already established the temporary storage facility in their recovery phase which are commonly in open spaces due to the limited space available in their vicinity. It can be observed that all cities failed to assess their disaster waste management facilities during the recovery phase. For post-recovery and contingency phase, LGUs failed to accomplish activities such as having communications plan with key stakeholders and handover of disaster waste management systems into normalized and improved solid waste management systems.

Below are the recommendations after assessing the disaster waste management of the study areas.

1. A Disaster Waste Management Plan should be established in order to minimize the risk on human health and environment. Included in this plan are the temporary storage sites, and useful tools such as waste map, waste hazard ranking tool, waste handling matrix, etc.

2. Government coordination between the national and local government is important in order to designate specific responsibilities of barangay level up to the national government and concerned agencies. It is recommended that the barangay should spearhead clean-up operations due to their close proximity and awareness to the condition of the

affected community. If it can no longer be handled by the local government, the national government should provide assistance.

3. An inventory of available resources such as manpower, materials and equipment should be generated. If insufficient, procurement of necessary equipment and materials or pre-negotiation of agreements with other municipalities or agencies should be considered.

4. The WACS report submitted by each city should comply with the standard provided by the NSWMC. This could aid in identifying appropriate waste treatment options.

5. Based on the perception survey and each city's WACS, biodegradables and recyclables are the most abundant solid waste and disaster waste collected. In order to conserve the capacity of the Sanitary Landfills within Metro Manila especially the Quezon City Sanitary Landfill, diversion strategies and appropriate processing and treatment of these wastes should be considered such as waste-to-energy methods. Some examples are Refuse Derived Fuel (RDF), pyrolysis, gasification and anaerobic digestion.

6. The MRF/MRS map will increase the awareness of residents of the different locations of MRF/MRS in their city. This tool will be useful to residents especially in times of disasters in disposing their wastes and diverting them from being disposed directly to sanitary landfill. In this manner, residents could drop-off their segregated or mixed waste in nearby MRF for it to be segregated further and processed properly either via recycling, composting or any waste-to-energy methods.

7. The destructive effect and frequency of typhoons and floods especially in the wet season can overwhelm the existing solid waste management system and facilities. In order to be able to manage the massive amount of waste that will be generated during this season the establishment of a temporary storage facility is a part of the solution especially for Marikina and Pasig City.

CONCLUSION

Existing policies in the country and abroad were critically analyzed and reviewed. It has been observed that the guidelines provided by the RA 9003 for solid waste management were also practiced by the local government units for their disaster waste management. Information such as Waste Analysis and Characterization Study (WACS) and documentations regarding the solid waste management and disaster waste management in the selected cities of NCR were gathered from the City Environment and Natural Resources Office (CENRO) and City Environmental Management Office (CEMO). In addition, the perception and evaluation of the residents regarding the solid waste management and disaster waste management were obtained through survey forms. The quantification of disaster wastes are based on the recorded volume of disaster wastes collected by each LGU while the characterization of the disaster wastes are based on the results of the perception survey. A focus group discussion was held in order to gather further information and clarifications regarding the information and initial results of the study.

MRF and MRS map which provides specific location for each city were generated. This tool is provided in order to increase the awareness of the residents and to promote waste diversion through MRF and MRS. Furthermore, a general design guideline and required footprint in the establishment of temporary storage facility for each city is also included in order to give guidance to the different local government units.

Currently, there is no established Disaster Waste Management Plan in the Philippines, independently or incorporated in any environmental law. With the aid of the Disaster Waste Management Guidelines of UNEP-OCHA as a standard for assessment, the researchers observed that not all the guidelines were accomplished by the selected LGUs especially in the activities in the Post-recovery and Contingency Phase. For an efficient and effective disaster waste management in Metro Manila, several guidelines were recommended.

Keywords: *Disaster waste management, NCR, Typhoons, Waste, WACS*

A Conceptual Framework of Economic Valuation Towards Flood

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INTRODUCTION

The purpose of this paper is to inform a conceptual framework of economic valuation towards floods disaster. The existing pattern, themes and issues associated with economic of valuation towards flooding were identified and used to inform the conceptual framework.

METHODS

Literature review is performed to identify the factor in economic valuation towards flooding. The review approach was based on related literature contributing to identify themes and sub themes summarized as “floods mapping” and “property value”. The synthesized literature is then utilized in developing the conceptual map which further paved the way towards designing the conceptual framework.

RESULTS

The generic conceptual framework presented explores the interaction between different internal and external factors affecting the economic value of properties. An extensive review of previous studies in economic valuation of property for different floods disaster studies considered to be main restrictive factor resulting in lack of empirical studies in this field.

CONCLUSION

This study brings together two existing research domains of floods and property value. Practitioners and researchers will find this study useful in developing an improved understanding of the economic valuation to flooding. The conceptual framework is important outcome of the research which will encourage further research in this area of study.

Keywords: *Conceptual framework, Floods, Economic Valuation, Property value*

Flood Control and Channel Development in the Middle and Lower Yangtze River

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INTRODUCTION

During the past few decades the middle and lower Yangtze River have experienced an increasing frequency of severe floods affected both by abnormal monsoon rainfall and high intensity human activity that include river sedimentation caused by extensive deforestation, and shrinking lakes after reclamation and large scale shoreline utilization project reduced areas available for floodwater storage. The Three Gorges Reservoir (TGR), located at the entrance to the middle and lower reaches of Yangtze River, was constructed as the key project for flood control of Jingjiang reach and the area surrounding Dongting Lake. Since its high water level for normal operation reached to 175m from 2010, the safety discharge was limited to 45000 m^3/s in flood season, which was called as flood peak reduction. Here comes two questions, can the discharge flow below 45000 m^3/s meet the requirements of river channel development, and will there be new flood control problem if the river shrinkage occurs? These issues have been widely concerned, but few answered. To examine the new flood control situation of the middle and lower Yangtze River, the stage-discharge relationship was analyzed by using the series data for 1954–2017 at 4 stations. As downstream erosion has been observed since the operation of TGR, it will be possible and necessary to demonstrate the scouring degree and channel evolution by employing a large number of river channel topography and cross section observation data. Possible problems, maybe developed by increasing the safety discharge to 50000 m^3/s, 55000 m^3/s or even larger, was also be revealed, including the levee safety, bank collapse, and washout of river training works.

METHODS

Both hydrological method and mathematical statistic method were used to analyze the influence of the impoundment of the TGR on the flow and sediment at the middle and lower Yangtze River. The flow and sediment changes after the impoundment (2003–2016) compared to before the impoundment (1956–2002) were focused on.

Measured data of discharge and water level in 1954, 1998, 2010 and 2017 respectively at 4 stations (Yichang, Shashi, Luoshan and Hankou) will be selected to draw stage-discharge curves. By analyzing these curves, the changes of flood level in the middle and lower Yangtze River during the past few decades can be revealed.

The cross section method is usually used for river channel erosion and deposition calculation. The flow profile used in the cross section method included 3 water levels of low water level, bank-full stage and high water level based on the water level-flow relation and topographic conditions at the major hydrologic stations in the section. The discharge areas of $A_i(z_i)$ and $A_{i+1}(z_i)$ of the upper and lower cross sections, respectively for corresponding water level conditions were calculated, and the river channel storage volume between two cross sections for the corresponding water level was calculated using the truncated cone formula:

$$V_i(z_i) = \frac{1}{3}(A_i + A_{i+1} + \sqrt{A_i A_{i+1}})\, L_i$$

where L_i is the cross section spacing. River channel storage volume of a river section for the corresponding water level is the sum of those between two cross sections, $V = \sum V_i$. Difference in river channel storage volume between any two measurement times is the erosion /deposition quantity between cross sections, or $\Delta V=V_1-V_2$.

All of the original measured data was provided by the Yangtze River Water Conservancy Committee, Ministry of Water Resources of China.

RESULTS

As the primary task of TGR is flood control, it will play the role of flood retention when the discharge coming from upstream area exceeds the flood control capacity of the middle and lower reaches (Fig.1). In 2010, the largest flow discharge coming into the TGR reached to 70000 m^3/s, but the dam only released 40000 m^3/s to insure the safety of flood control in the downstream area. Besides, the dam can also reduce flood pressure of reaches downstream from the intersection of the Yangtze River and Dongting Lake when the Lake experiences excessive flood by controlling the discharge water within an appropriate range. July 4th, 2017, runoff from the Dongting Lake was 49200 m^3/s which is a new record peak flood, meanwhile the TGR reduced the discharge flow by almost 18000 m^3/s.

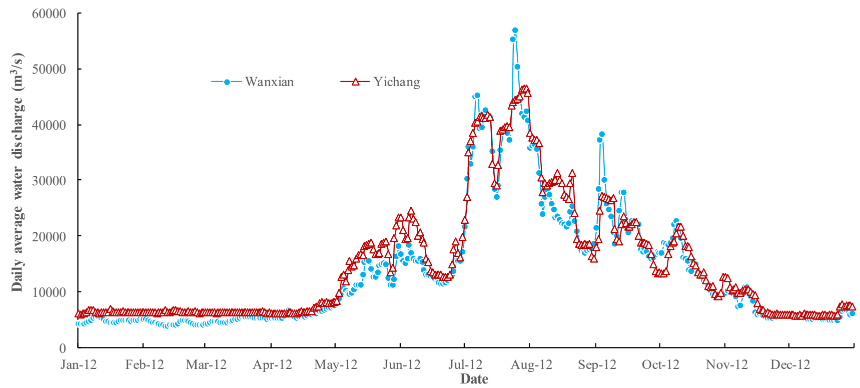

Figure 1 Daily average water discharge at Wanxian and Yichang stations in 2012

To examine the flood control situation of middle and lower Yangtze River, measured flow and water level data was employed to draw stage-discharge curves (Fig.2). In 1954 and 1998, the Yangtze River suffered the largest and second flood respectively, and the highest water level on records of Luoshan station was 34.95 in August 2th, 1998. The water level of same discharge at Luoshan staion has risen from 1954 to 1998 caused by shrinking of Dongting Lake and deposition of river channel in reach downstream from Chenglingji. Since the operation of TGR, as the storage capacity of Dongting Lake kept stable and remarkable downstream channel degradation has been found, the flood level in 2010 and 2017 changed slightly compared to 1998. Which means firstly the flood control situation in the middle and lower Yangtze River is still grim, and secondly channel development has not yet affected by the flood regulation of TGR.

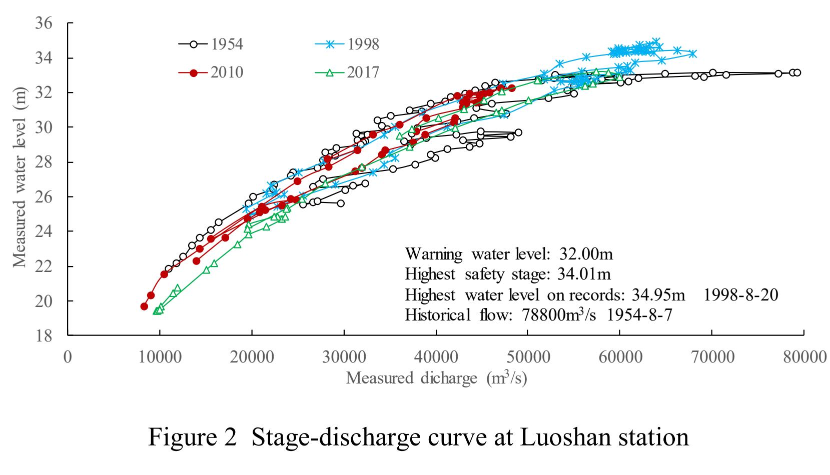

Figure 2 Stage-discharge curve at Luoshan station

After the impoundment of the TGR, over 70% of the incoming sediment was intercepted by the reservoir, causing further decrease in the sediment discharge to the sections downstream the dam and obvious erosion in the mainstream of the middle and lower reaches of the Yangtze River especially in the Yichang-Hukou section. From Oct. 2002 to Nov. 2016, the total bankfull channel erosion volume in the Yichang-Hukou section was 20.9×10^8 m^3 with an annual average amount of 1.45×10^8 m^3 (Fig. 3). Longitudinally, 52.6% and 47.4% of the total erosion occurred in the Yichang-Chenglingji and Chenglingji-Hukou sections, respectively. Riverbed erosion mainly occurred in low water level channels where 91.6% of the total amount was generated. Apparently the erosion degree of downstream channel has not yet affected by the flood peak reduction of TGR since 2010. Particularly in 2016, runoff from Dongting Lake was abundant, and the bankfull channel evolution volume of Chenglingji to Hankou reach from Nov. 2015 to Nov. 2016 was up to 2.19×10^8 m^3 that is sevenfold of annual average amount from Oct. 2002 to Nov. 2016.

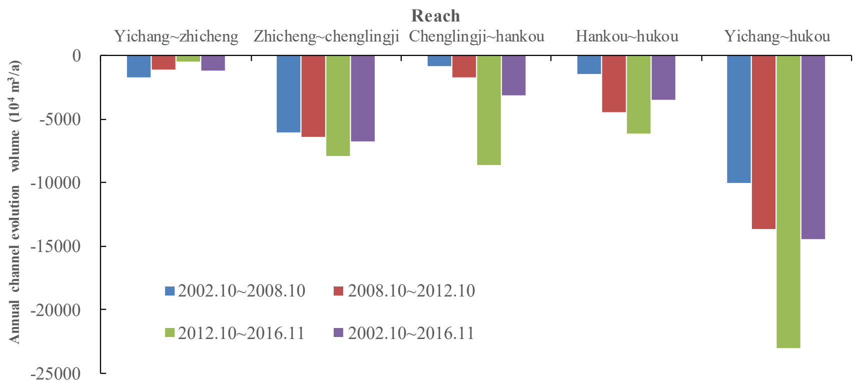

Figure 3 Annual bankfull channel evolution volume in the middle and lower Yangtze River from 2002 to 2016

CONCLUSION

The flow and sediment entering the middle and lower Yangtze River has been significantly altered owing to the operation of TGR. Especially, the frequency of large flow discharge has decreased and the sediment discharge in the study reach reduced drastically, leading to a considerable degradation of river channel. However, the flood level of same discharge has only been slightly changed since 1998, which means that the flood control situation will be still grim and river channel shrinkage has not yet turned up. Ever since the Yangtze River suffered the second largest flood in 1998, a large number of river and waterway regulation works had been constructed including bank revetment, river bottom and flood-plain protection. Besides there are also a lot of beach development and utilization projects in cities along the middle and lower Yangtze River. The purpose of limiting the largest discharge of reservoir to 45000 m^3/s was not only to ensure the flood control safety, but also to protect these projects from washout by flood.

Keywords: *The middle and lower Yangtze River, flood control, channel development, Three Gorges Reservoir, River regulation works*

Alternative Flood Mitigation Plans for Cagayan De Oro River

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INTRODUCTION

In June 2011, JICA funded a Master Plan and Feasibility Study for Flood Risk Management Project for Cagayan de Oro City (FRIMP-CDOR). Then in December 2011, in response to the devastation of CDOR brought by Typhoon Sendong, JICA funded another study in March 2014 to review and update the previous flood masterplan for CDOR Basin. However, the March 2014 updated flood mitigation plan has encountered some resistance by concerned parties that include Paseo Del Rio and Torre de Oro, both being land developers and the former with an ongoing commercial/residential project complex along the Cagayan de Oro River. In response to this, the Department of Public Works and Highways (DPWH) commissioned the National Hydraulic Research Center of the University of the Philippines (UP-NHRC) to serve as third party to conduct a review and value engineering study of the flood risk management project for Cagayan de Oro City. An important task of UP-NHRC is to engage the stakeholders such DPWH's UPMO-FCMC Office, the City Mayor's Office, Mindanao Development Authority, PDR, TDO, among others to meetings and consultations so that these stakeholders are informed and their inputs properly solicited in the course of this study. Specifically, this study evaluates the hydraulic performance and level of protection that can be provided by the alternative flood mitigation plans for FRIMP-CDOR through hydraulic simulation studies.

METHODS

As shown in Fig. 1, the portion with the finite element mesh is modeled using a 2-d flood hydraulic model based on the finite volume method (FVM) formulation of the mass conservation equation of water-sediment mixture and the momentum conservation equations in the x- and y-directions. The inflows to the 2-d model were computed from a continuous-time, distributed model where the soil-moisture accounting model is the Sacramento model with watershed modeled area shown in Fig 2. Note that the area modeled by the 2-d hydraulic is also shown in Fig. 2 located at the top of the figure. Flood inundation simulation studies were conducted to evaluate the alternative flood mitigation plans.

RESULTS

Based on meetings with DPWH engineers, JICA experts and a series of public consultations held in Cagayan de Oro City, 7 alternative flood mitigation schemes were developed namely: 1) existing condition (present flood control structures); 2) existing and urgent-ongoing flood control projects; 3) DPWH-JICA proposed long-term flood mitigation project; 4) same as Case 3 but with realigned dike at Paseo del Rio-Torre de Oro area; 5) same as Case 4 but with one additional retarding basin upstream of the realigned dike; 6) same as Case 4 but with two additional retarding basins; and, 7) same as Case 6river flood storage with notched, overflow weirs downstream of Pelaez Bridge. Note that Case 3 above is the original flood mitigation plan developed in the March 2014 JICA study. The results of the flood simulations are too long to show here but one useful output is to display

CONCLUSION

Generally, the flood analyses and model simulations show that there are only slight differences among the different flood plans/configurations. In particular, however, Cases 4 and 5 and especially Case 7 result in smaller flood inundation levels compared to Case 3 especially at higher rainfall amounts. A cost analysis was also conducted but too long to show here, and it can be concluded that Cases 3 and 4 are equally competitive based on flood level reductions and project costs. However, Case 7 results in the best flood level reduction but it costs higher and in the long term due to maintenance dredging costs.

Keywords: *Alternative flood mitigation plans, stakeholder consultation, flood inundation, 2-d hydraulic model simulation.*

Figure 1. 2-d finite volume mesh of modeled area.

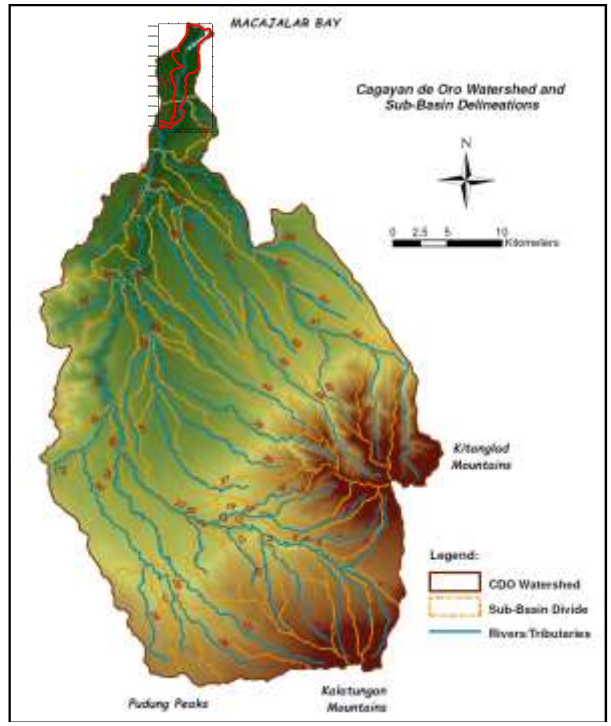

Figure 2. Cagayan de Oro River watershed area.

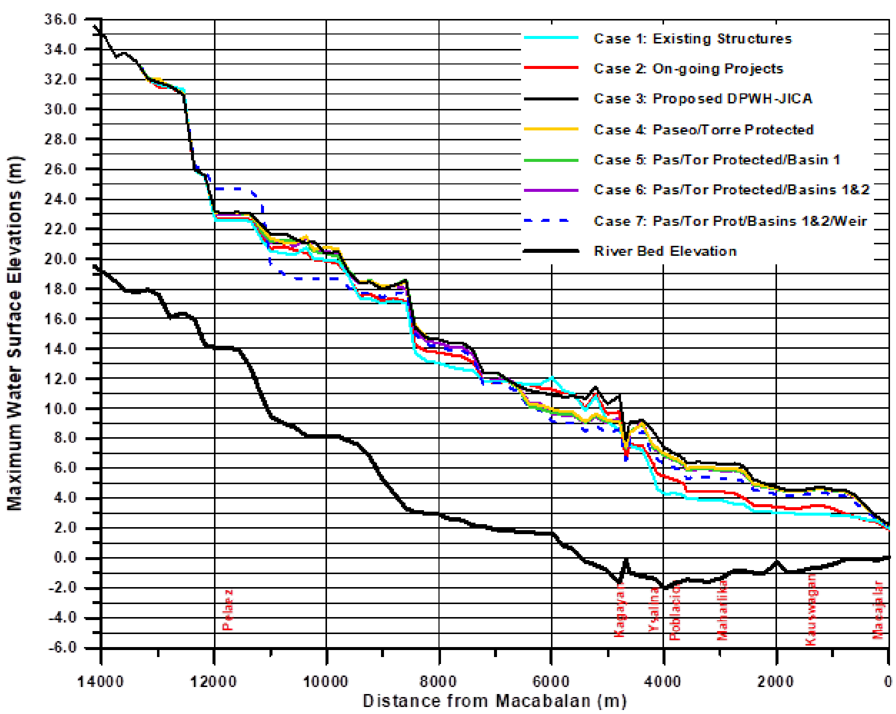

Figure 3. Resulting water surface profile of the 7 alternative flood mitigation plans.

Mekong River Inundation Simulation Using K-Super Computer

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INTRODUCTION

Mekong River is the largest river in Southeast Asia. The river experienced large-scale flooding in the past such as in 2000 and 2011. The flooding in Mekong River is crossing several countries, thus we need to model large area (several hundred km × several hundred km) to reproduce the inundation. With a relatively coarse resolution and sophisticated model, it can be modelled by a single PC. However, it may be better modelled with finer resolution if a super-computer is used. Therefore, in the paper, we present the result of Mekong River inundation simulation using K-supercomputer in Kobe, Japan.

METHODS

A shallow water equation is used for the inundation simulation. The modelled area is shown in Figure 1. The area is approx. 378.2km x 380.0km (1,891 x 1,900=3,592,900 computational nodes) with a 200m resolution. The simulation duration is from May 1st 2000 to October 31st 2000. The elevation data is obtained from ALOS World 3D - 30m (AW3D30), JAXA. The observed water level at Kratie is given to the X in Figure 1 for half year.

RESULTS

The simulated result is shown in the left panel of Figure 2. A MODIS satellite image of the inundated area is shown in the right panel of Figure 2. The simulated result shows good agreement with the MODIS image, at least, from birds-eye view. The computational time was 23 hr. 18 min. 26 sec. for the half year simulation using 960 CPUs of K-supercomputer.

CONCLUSION

The results indicated that relatively large area of Mekong River can be modelled with relatively fine resolution (i.e. 200m). Likewise, the computational time became acceptable with the use of K-supercomputer. In reality, the effectiveness of K-supercomputer may become more prominent if the modelled area becomes larger. On the other hand, the simulation model with a shallow water equation can be replaced with any faster models, which result in the faster computation for the same problem setting with K-supercomputer. The author would like to find a good collaboration partner who has deep knowledge about Mekong River.

Keywords: *Mekong river, shallow water equation, inundation simulation, K-supercomputer*

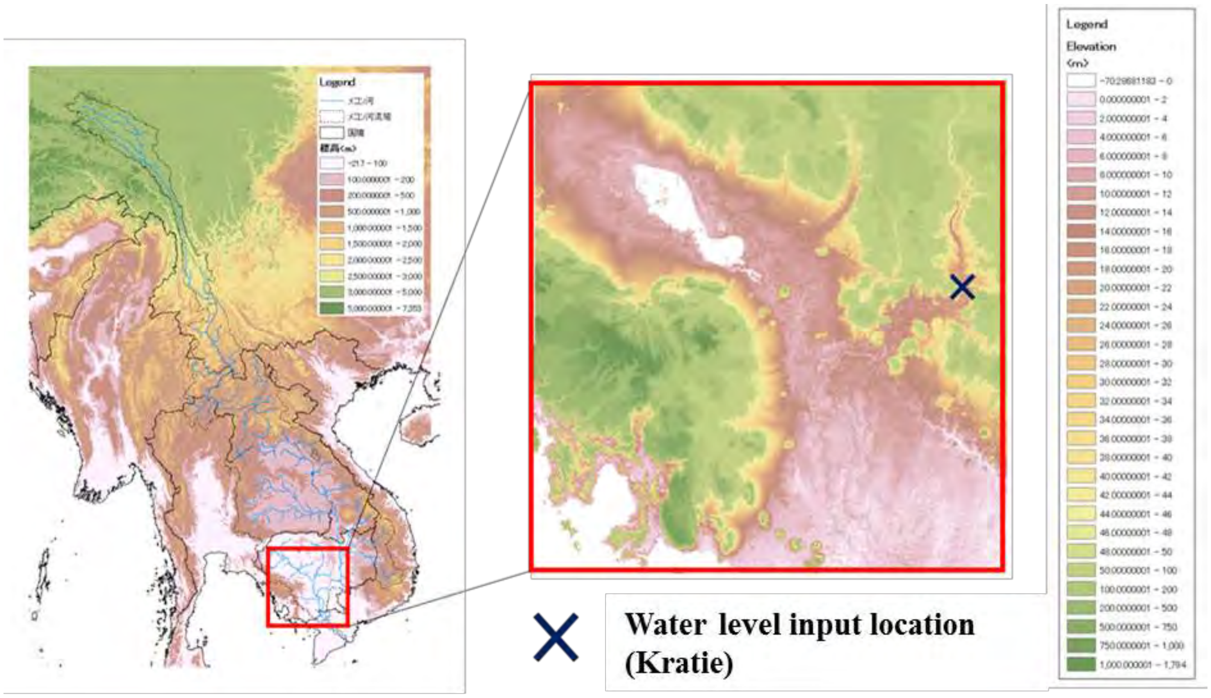

Figure 1. Modelled area

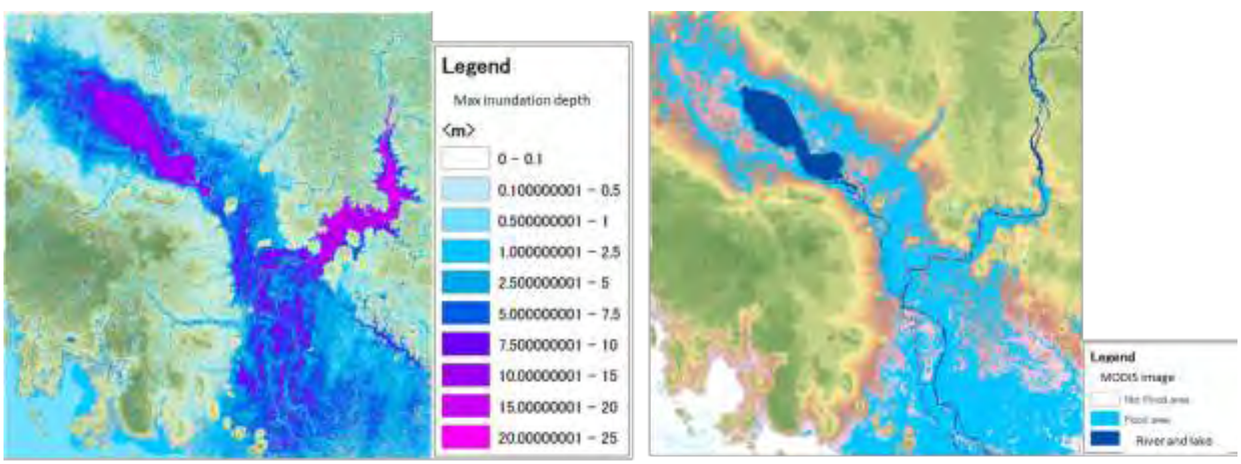

Figure 2. Simulated maximum inundation depth (left) and MODIS image of the inundation (right)

Rainfall-Runoff-Inundation Simulation for Basin-wide Flood Hazard Mapping at the Batanghari River in Sumatra, Indonesia

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INTRODUCTION

In Sumatra in Indonesia, large-scale plantations of palm and acacia trees have caused 50 % reduction of natural forests in the 25 years between 1985 to 2009. Deforestation of natural forest might have changed water cycle in the area including runoff and evapotranspiration, which may lead to possible changes in flood and drought conditions. Downstream parts of river basins in Sumatra spreads wetlands with rich ecosystems, though such environment have degraded due to land use changes over the last few decades to agricultural areas. Drying the wetlands by drainage for rice cropping and other agricultures caused various issues including peatland fire and haze problem in surrounding regions. Hydrologic process understandings and their representations by simulation models are therefore important scientific steps for achieving adequate water management. Among various hydrologic processes, rainfall-runoff processes in tropical climate conditions characterized also by deep weathered soil layers have been poorly understood. Based on field investigations and modeling, this study attempts to simulate rainfall-runoff and flood inundation processes at the river basin scale, especially to develop a flood hazard map in the Batanghari River basin in Sumatra, Indonesia.

METHODS

This study uses the Rainfall-Runoff-Inundation (RRI) Model applied to the Batanghari River Basin (42,960 km^2). The topographic data used in this study is based on HydroSHEDS with 30 arc-seconds. The model simulates for both rainfall-runoff and flood inundation processes simultaneously at the river basin scale by considering the effects of subsurface flow and evapotranspiration etc. For better representations of subsurface flow processes, this study also conducts field monitoring near Muara Bungo in the central part of the Batanghari River basin to continuously monitor hillslope groundwater dynamics. By reflecting field conditions within the RRI model, it conducts a long-term rainfall-runoff-inundation simulation in the area to estimate the high potential regions of flooding. In addition to the modeling, we used also a remote sensing technique to detect land cover changes from 1990 to 2015.

RESULTS

Based on the remote sensing analysis, the changes in land cover conditions have been well identified from forest to agriculture or agroforestry. Field measurements of soil infiltration suggested that different land covers result in different infiltration rates. In general, settlement and bare land show smaller infiltration rates compared to, for example, forest or rubber plantation. With the basic understanding the effects of land covers on hydrologic characteristics, the model is set suitable for the basin. Then it indicates wide spread flood inundation areas along the Batanghari River as well as some parts along tributaries. Although further detailed modeling should be conducted in future by reflecting on-going field monitoring, the present results with a preliminary flood hazard map can identify the high potential areas of flooding over the Batanghari River basin.

Keywords: *Tropical climate, RRI Model, Flood hazard map, Batanghari River Basin in Sumatra*

Impact of Climate on Stream Flows in Hunza River Basin

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INTRODUCTION

Pakistan being a semi-arid country largely depends upon water supplies on melt water coming from glacier and snow in the northern mountains. The Indus river originates from northern parts and replenishes the domestic demands, irrigation and industry. The snow and glaciers which supply water to the Indus at its origin are quite vulnerable to temperature and precipitation changes. This study incorporates a temperature-index hydrologic model to quantify the impacts of future temperature and precipitation on the river flows of basin.

The present study is undertaken in the Hunza River watershed (drainage area, 13659 km^2). The elevation range of the basin is 7722-1420 meters, approximately 7500 km^2 of basin area is above an elevation of 4500 m.

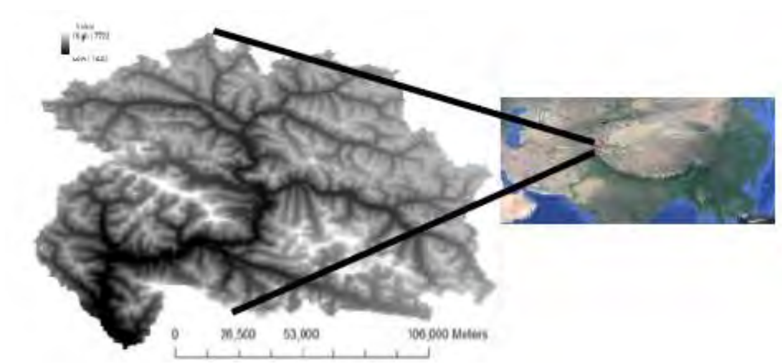

Figure 1: The Hunza Basin

METHODOLOGY

HBV Model: Since the study area is located in a data scare region, the model with less data requirements was preferred. Snow Runoff model has been tested quite effectively along with Hydrologiska Byråns Vattenbalansavdelning (HBV-Light) in the region. HBV-Light was given priority because it has a glacier routine. It is a semi-distributed conceptual model. The HBV model simulates daily discharge using daily precipitation, mean-temperature and potential evaporation as input parameters. Precipitation is simulated to be either snow or rainfall depending on the temperature, if it is below or above a threshold temperature, TT [°C]. If the temperature is bellow TT, all the precipitation is simulated to be snow, is multiplied by a snowfall correction factor, SFCF. Snowmelt is calculated with the degree-day method.

Climate change Scenarios: The HBV model was used to quantify the impact of changing climate on the river flows following the calibration (2000-02) and validation (2003-04). Different scenarios for precipitation and temperature used in this study are adopted from (Su, et al., 2016), they used ensemble of GCM’s and three Representative Concentration Pathways (RCPs) to generate future projections, which are given in (Table 1):

Table 1: Summary of climate scenarios used in the study Future

	RCP scenario	mid-century (2046-2065)	Late-century (2081-2100)
temperature	2.6	1.21 °C	1.1 °C
precipitation		3.20 %	5.60 %
temperature	4.5	1.93 °C	2.49 °C
precipitation		0.10 %	4.00 %
temperature	8.5	2.71 °C	5.19 °C
precipitation		6.20 %	7.80 %

RESULTS

The calibration results (Figure 2) show that the HBV-Light has efficiently simulated the discharge of the river

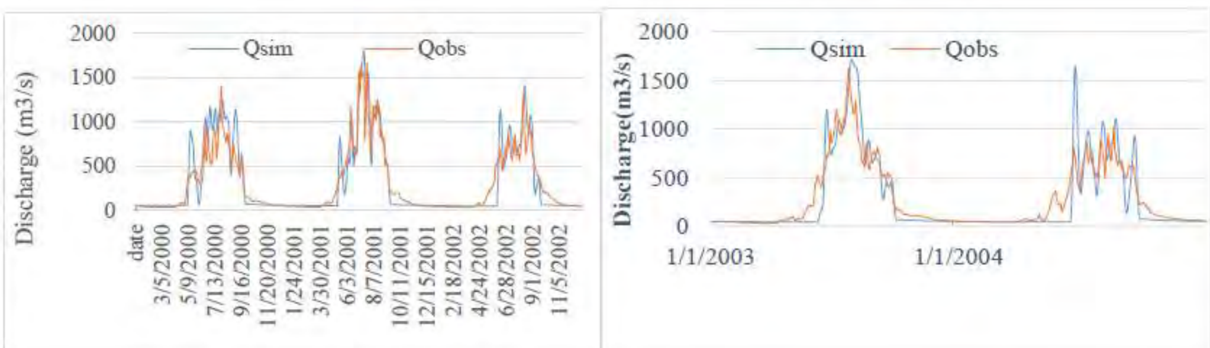

Figure 2: Calibration (2000-02) and Validation (2003-04) results

Future Run-off Simulation:

The mean monthly runoff is shown in (Figure 3) for all scenarios. All the scenarios have shown increase in the quantity of flows.

The simulated discharge for the period of 20002004 was used as a reference to measure the change in the discharge as a result of change in climate. The flows from November-March are omitted because of their low and stabilized values. The discharge will increase in every scenario with different rates with the greatest in 8.5 in late century. Future climate would ensue alteration in the river flow trend because it largely depends upon precipitation and melting snow and glaciers. Temperature rise of 1 °C rise in temperature in the middle century would add 13 m3/s, 36 m3/s and 50 m3/s in the annual average discharges under RCP 2.6, 4.5 and 8.5 respectively. While in the end of century these additions to would jump 8 m3/s, 47 m3/s and 70 m3/s.

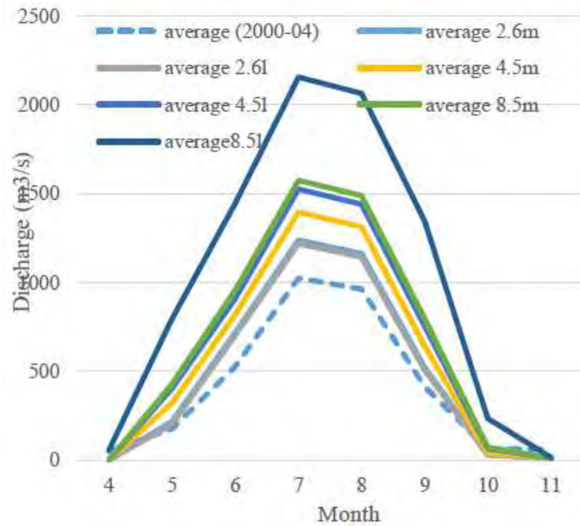

Figure 3: Present and average annual discharges of Hunza River. Letters m and l represent middle and late century respectively

CONCLUSION

Several sets of climate scenarios were used and each scenario is found to be altering hydrologic cycle of the river basin. The average annual river flow in coming decades would increase under different temperature and precipitation scenarios. However, increase in temperature is found to be the main driver of change in river flows. The higher flows stress the significance of water conservation in the form of reservoirs/dams. A part from conservation measures, demand management side should be addressed various approaches including legislation and public awareness.

Key words: *Hunza River, climate change, stream flows, Karakoram mountain range*

Future Change Analysis of Extreme Floods at the IndoChinese Peninsula Using Large Ensemble Climate Simulation Data

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INTRODUCTION

Flood predictions are classified into three categories: the flood magnitude prediction in terms of the flood frequency such as an annual maximum 100-year flood, the largest-class flood prediction such as a probable maximum flood (PMF), and the real-time flood prediction. To improve these flood prediction techniques under climate change is a key engineering issue to cope with flood disasters. In this study, future changes of probability distributions of extreme floods are analyzed at the river basins in the Indochinese Peninsula using "Database for Policy Decision-Making for Future Climate Change, d4PDF" having large ensemble climate simulations for the historical experiment with 60-years 100 ensemble members and the four-degree increase climate experiment with 60-years 90 ensemble members. The motivating question behind this study is how to increase the trustworthiness of the probabilistic analysis of the future changes in river discharge by combining results of plausible datasets. Relying only on a large amount of data may prove insufficient because future climate projection data from multiple physics and boundary conditions might not originate from an identical population and could also have a different prior distribution. The first objective of this research is to examine the dependence of the different future SST (sea surface temperature) scenarios adopted in d4PDF future projection on the differences of the shape and tails of the future empirical probability distributions of the annual maximum discharge in the Indochinese Peninsula. For this purpose, the differences of the distributions among combinations of SST scenarios of the d4PDF are investigated statistically.

METHODS

The d4PDF is a database which includes large ensemble members of climate simulations with a 60km atmospheric general circulation model developed by Meteorological Research Institute in Japan to analyze probabilistic characteristics of low-frequency future projections. The d4PDF has two sets of experiments: the historical climate experiment (1951-2010) with 100 perturbed ensemble members with the observed SST as a boundary condition and the four-degrees increase climate experiment (2051-2110) with 90 perturbed ensemble members from six different SST patterns (6x15=90), which were determined from the coupled six GCMs.

The simulated time series of runoff generation data in d4PDF was given as forcing data to a distributed river routing model, 1K-FRM, with 10km spatial resolution. 1K-FRM is a physically-based one-dimensional hydraulic model based on watershed topography data. The topographic information used for 1K-FRM was generated from processing of the scale-free global streamflow network, with a spatial resolution of 5 arc minute. The flow direction is defined using the 8-direction method, which assumes the flow direction to the steepest downward slope to an immediate neighboring cell. The forcing data, runoff generation intensity in d4PDF were then routed by the kinematic wave equations at each flow element in accordance with the flow direction.

The non-parametric methods were employed to analyze the statistical discrepancies among the empirical probability distributions of the annual maximum river discharge simulated from the different six future SST patterns. The possible pairs of the distributions which consist of the 15 cases from the 6 SST patterns were examined. The two-sample Kolmogorov-Smirnov test (KS-test) and Anderson-Darling test (AD-test) were used to investigate the differences between the shape and tails of the empirical probability distributions6). The null hypothesis for the statistical tests was defined as no difference between two empirical distributions of the future annual maximum discharge. Subsequently, the statistical significance of the changes of the annual maximum river discharge was assessed in terms of the mean value by comparing the future distribution with respect to the present using the Mann-Whitney U-test7) statistics. A significance level of 5% (or 95% confidence level) was selected.

RESULTS

To fully utilize the multi-initial and boundary condition datasets, the differences between each couple of the empirical distributions of the future annual maximum river discharge produced by different groups of SST patterns were investigated firstly using the non-parametric two-sample KS-test and AD-tests. The analysis results indicated that the differences in the distributions were significant for much of the study area except parts of the Mekong delta and southern Indochina region. Thus, the total number of samples was limited within the same SST pattern, which is equivalent to 900-year period data. Then, the changes of river discharge in the future period for each SST pattern and its statistical significance were assessed using the Mann-Whitney U-test. These changes primarily showed a similar trend regardless of SST patterns. The strongly positive signals were found at Mekong Delta and southern Indochinese Peninsula with the ratio of 1.5-2.0 and 2.5-3.0 for all of the d4PDF SST scenarios. The subtler yet increasing trend were found at Mekong, Irrawaddy, Salween, and the Red River Basin with the ratio up to 1.10 in 4 of 6 SST patterns of the future climate in d4PDF. The changes in mean of the annual maximum discharge were projected as statistically significant at 95% confidence level in the Mekong Delta, the southern Indochinese Peninsula, and the mouth of the Red River Basin in Vietnam for all of the SST patterns of the future climate in d4PDF. On the contrary, the significance of changes in river discharge along the Irrawaddy River, the Chao Phraya River, and the Salween River basin are not projected to be significant for future climate.

CONCLUSION

This study compared the empirical probability distributions of the future annual maximum river discharge simulated from the six future SST patterns. The analysis results indicated that the differences in the distributions were significant for much of the study area. Then, future change of river discharge projections was examined with respect to the present situation for each SST pattern in terms of the statistical significance. These changes essentially showed a similar trend notwithstanding of SST patterns. The strong positive signals were found at Mekong Delta and southern Indochinese Peninsula for all of the d4PDF SST scenarios. The changes in mean of the annual maximum discharge were statistically significant at 95% confidence level in the Mekong Delta, the southern Indochinese Peninsula, and the mouth of the Red River basin for all of the SST patterns. Based on the overall simulated results and the past studies, we can conclude that there is a clear and increasing risk of future floods at the Indochinese Peninsula, especially at the low-lying Mekong Delta and the Southern Indochina regions.

ACKONWLEDGEMENTS

This research was supported by the grant-in-aid for scientific research (A) 17H01294, the SOUSEI and TOUGOU programs. This study utilized the database for Policy Decision making for Future climate change (d4PDF), which was produced under the SOUSEI program. Keywords: climate change, d4PDF, Indochinese Peninsula, river discharge, non-parametric test.

Strengthening the resilience by reducing risk from sediment-related disasters

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INTRODUCTION

The sediment-related disasters in term of landslide, flood, debris flow, occur in different topographic and geologic setting and causes great socio-economies losses. It may increase apparently due to the human development expands into unstable hill-slope areas under the pressures of increasing populations. The sediment-related disasters mitigation efforts may be carried out both structurally and non-structurally. The implementation of mitigation measure for sediment-related disaster usually focuses on avoiding the mass movement, diverting the moving mass away from vulnerable elements or building reinforcement to protect the threatened elements. However, the importance of monitoring and early warning system can rise when the mass movement mitigation works is considered expensive. This paper describes the current progress of mitigation effort in term of the implementation of monitoring and warning system against sediment-related disasters in Indonesia.

Monitoring and early warning system against sediment-related disaster

An adaptive and sustained landslide and debris flow monitoring and early warning system (MEWS) has been implemented in several hazard prone areas in Indonesia, including the establishment of collaboration among the university, private sector, and the disaster management community. The main purpose of the effort is to establish a strategic approach for disaster risk reduction through the implementation of information flow and order/command system (Fathani et al., 2016; Fathani and Karnawati, 2014). The technical system to support sediment-related disaster risk reduction was developed by Fathani and Karnawati (2012), consisting of several technical components such as the instruments for landslide and debris flow early warning system recommended by Fathani et al. (2008) and also Fathani and Karnawati (2010), supported by the smart-grid for landslide hazard communication, monitoring and early warning developed by Karnawati et al. (2012). Up to now, the real-time landslide and debris flow monitoring and early warning was developed and installed at 28 provinces in Indonesia by Universitas Gadjah Mada in cooperation with the Indonesian National Authority for Disaster Management (BNPB). The system comprises several sensors namely digital extensometer, wireless tiltmeter, inclinometer, Automatic Rainfall Recorder, Ultrasonic water level sensor and IP Camera, and can be added with other sensors such as pore water pressure and inclinometer sensors. The collected data is sent point to point in a wireless network. The data is received by a field server, which functions are to receive, store, analyze and resend data to the central server, and decide when to inform early warning. Figures 1-3 show the installed monitoring sensors in the the field. The recorded data from extensometer, tiltmeter, and ultrasonic sensor are shown in Figure 4. Figure 5 shows the network diagram of telemetric system for real-time sediment-related disaster monitoring and early warning.

Fig. 1 Extensometer with underground invar wire

Fig. 2 The installation of wireless tiltmeter

Fig. 3 Ultrasonic water level sensor installed at the upstream

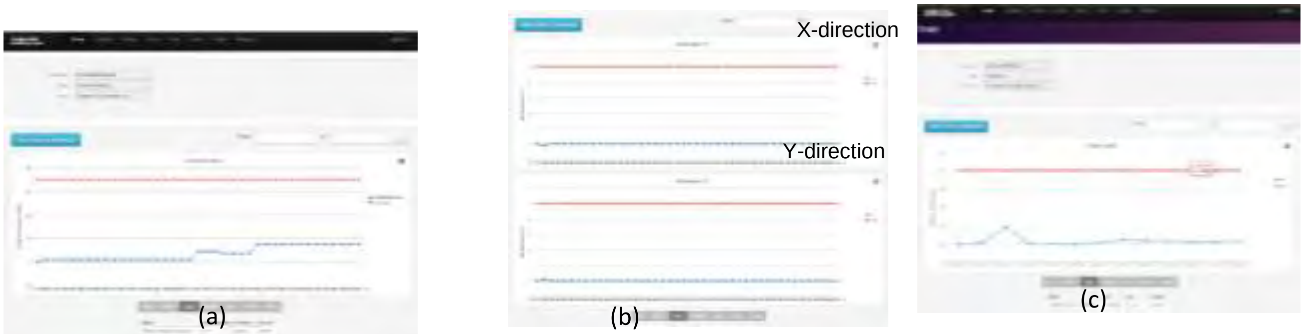

Fig. 4 Recorded data from the monitoring sensor: (a) extensometer; (b) tiltmeter; and (c) ultrasonic water level sensor

Fig. 5 Network diagram of telemetric system for real-time monitoring and early warning

DISCUSSION

In order to guarantee the effectiveness of the sediment-related disaster early warning system, the developed system should be simple to operate and appropriately installed in the most suitable sites. Consequently, this system should include the incorporating technical and social approaches. The determination of early warning criteria is considered one of several involvements in technical approach (Fathani et al., 2011, Fathani and Karnawati, 2010). The understanding on the cause and sediment disaster triggering mechanism is very crucial to establish an appropriate concept and method for monitoring and determining warning criteria for hazard prediction and risk assessment at the region.

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Evaluation of the Impacts of Hydropower Development on Salinity Intrusion Into Vietnamese Mekong Delta

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INTRODUCTION

There are more than 56 completed dams along the Mekong River and its tributaries up to 2016, among them, the cascade system of six hydropower dams located in the mainstream of China were completely built in 2014. The total active capacity of these dams accounts for more than 50% capacity of total flow volume in dry season in the mainstream. In the last 20 years, the fresh water demand for agriculture and aquaculture has increased significantly in Vietnamese Mekong Delta (VMD). The unbalance of water supply-demand in combination with low flat terrain and sea level rise due to climate change, about 3mm/year during the last 30 years, that makes salinity intrusion more severe during the dry season here. The year 2016 also witnessed the new record of the drought and salinity intrusion in the VMD.

Taken into account all the concerns mentioned above, the objectives of this study are to (1) assess the current status and causes of the drought and salinity intrusion in 2016, (2) determine the correlation between the flow right downstream of six dams with the inflow to the VMD and (3) elucidate the impacts of flow change on the salinity concentration and intrusion length by numerical simulations.

METHODS

Based on analyzing the data series of water level and salinity collected in many years and numerical simulation, the impacts of changes of flow and salinity concentration in the post cascade dam period are elucidated.

RESULTS

Recent extreme salinity condition 2016

Fig.1 shows the evolution of the salinity at Cau Quan station for four highest salinity years with a repetition period of 5-6 years. It can be seen that the salinity concentration is much higher in 2016. The maximum salinity concentration (S_{max}) in January almost equals to the peaks of other years even though January is not the highest salinity month. In addition, different from the other years, the peak in 2016 shifts from March or April to February. Thus, it can be stated that salinity intrusion comes 1 -2 months earlier this year.

Changes of flow and salinity concentration in the post cascade dam period

The largest hydropower dam of the cascade system Nuozhadu started storing water since September 2012. Its active storage capacity together with the second largest Xiaowan dam accounts for $22.2x10^9m^3$, about 75% and 25% of the average total dry flow at ChaingSaen and Kratie, respectively. The operational schedule of cascade hydropower dams therefore strongly influences on the flow volume downstream. With very large capacity of reservoir, it will take longer time to fill up the reservoir. Noticeably, there are two abnormal peaks appearing in period of 2013-2014 and 2015-2016 (Fig.2). Both occurred at the transition from flood to dry season. The time for the flow to move from ChaingSaen to Kratie is about 15-17 days. At this stage, water is supposed to store fully in the reservoir and any unexpected extra water source which might be from Tibetan avalanche could threaten dam safety and therefore water releasing must be implemented quickly. This should be the reason causing the abnormal peak. After the unexpected releasing, the cascade dams have to store water again. However, the year 2016 is extremely dry that makes the water storing process become too long and causes the situation of lack of water worse downstream.

Numerical simulation

The MIKE 11 model was used to simulate flow by hydrodynamic module and salinity intrusion in river and channel network by advection-dispersion (AD) module. The computational scheme consists of five hourly discharge boundaries in the upstream and 59 downstream boundaries using hourly water levels and hourly salinity concentrations. One hundred and fourty-five (145) cross sections describing the geometry of Tien River from Tan Chau to My Thuan are updated to 2014 whereas cross sections measured in 2010 are applied elsewhere. The baseline is run for real condition of dry season 2016. The scenario is built as there was no abnormal peak in Kratie station (lasted about 15 days) in order to see how the water releasing from hydropower dam affects salinity intrusion in Vietnamese Mekong Delta. The result shows that salinity downstream increases sharply by 4.1 to 5.8g/l at Co Chien and Tran De estuaries. The salinity also intrudes 8 to 13km further inland that adversely affects agricultural and aqua-cultural activities. The salinity contours of 4g/l for base-line and scenario 1, i.e. no sudden water release, are plotted as can be seen in Fig. 3.

CONCLUSION

Based on data analysis, it can be clearly seen that the cascade hydropower dams with their operational schedule strongly affect water supply downstream. Especially, during the dry year, this impact becomes more obvious. Upon the fact that more hydropower dam will be built along the mainstream of Mekong river as well as its tributaries, it is utmost important regarding information of water releasing and sharing among the countries in the Mekong River Basin. When the upstream reservoirs have open operation procedures, the downstream countries can be proactive to propose appropriate water use plans.

Keywords: *Salinity intrusion, hydropower, Vietnamese Mekong Delta, salinity contour.*

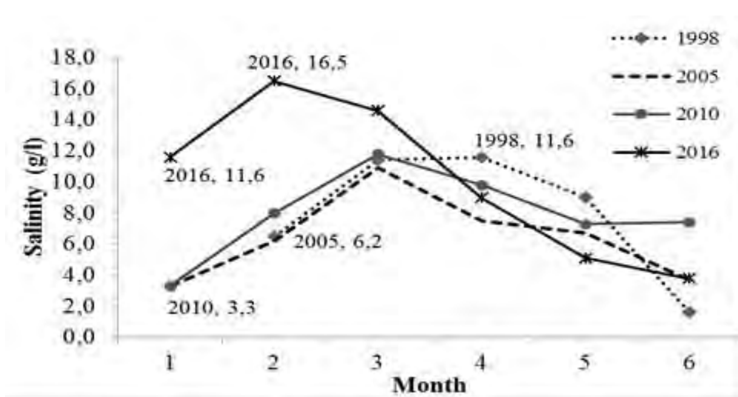

Fig.1 The maximum monthly salinity concentration of 4 high salinity years at CauQuan station in Hau River during 26 years

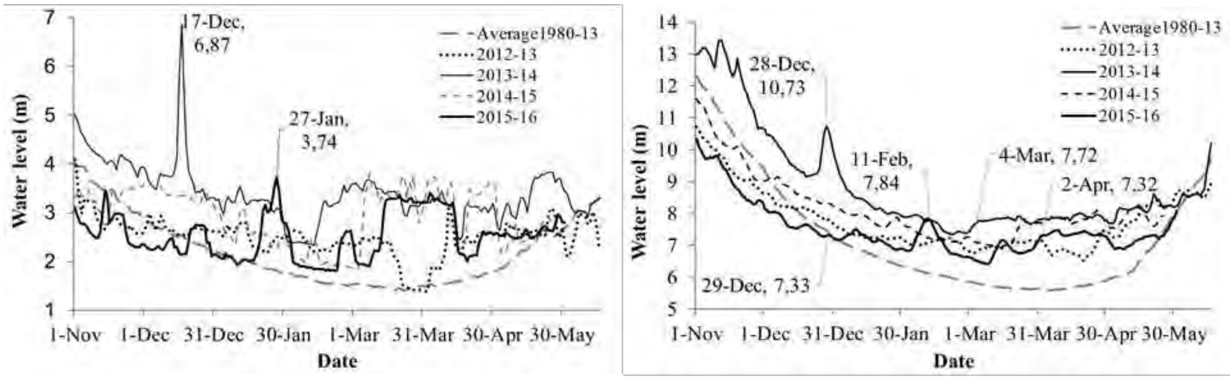

Fig.2 Water level change in the Mekong River measured at the Chaing Saen (a) and Kratie (b) station during dry seasons

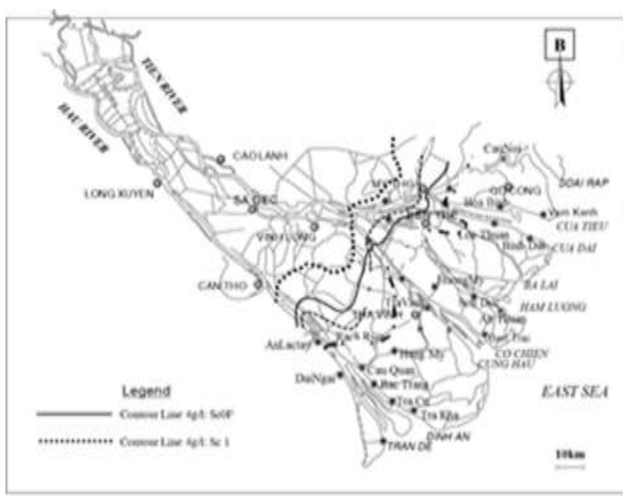

Fig.3 The contour line of maximum monthly salinity for base-line and scenario 1

An Integrated Model Simulating the Initiation and Motion of Earthquake and Rain Induced Landslide in Pakistan

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INTRODUCTION

In Pakistan, during monsoon season majority of the landslides occur along the highways, built in the mountainous terrain. These landslides cause human and economic loss, disruption to traffic and reduce the tourist activities in these areas. Kashmir earthquake on Oct 8,2005 triggered thousands of mass movements in the affected region of Pakistan. The Panjgran landslide in the Neelum Valley area, close to the epicenter is one that obstructed the Neelum Valley communication system for many days even after the earthquake. This landslide travelled 650m in the direction of north towards the Neelum river and caused severe damage to the Neelum road. Some authors have worked on the study area but they made susceptibility maps or analyzed the area by empirical approach. Therefore, detailed field and laboratory methods were still indispensable and there was a dire need to model and study the landslides sub-surface structure and behaviour. The landslide disaster emphasis the necessity of a detailed geotechnical study for disaster risk preparedness which simulates initiation and motion. This paper presents a new computer simulation integrating the initiation process triggered by rainfall and earthquake and very well simulate the process of motion of landslide to progressive failure and development to a rapid landslide. The field investigation and the undrained dynamic loading ring shear tests on the Panjgran landslide suggested that this landslide was triggered by the combined effect of pore water pressure due to rain and 2005 Kashmir earthquake. The application of LS-Rapid simulation model could well reproduce the initiation and the rapid long runout motion of the Panjgran landslide.

METHODS

The 2005 Kashmir earthquake of the magnitude Mw. 7.6 occurred on October 8, 2005 at 18km in the northeast of Muzaffarabad with its epicentre (34.493, 73.629) and a focal depth of 26km. The catastrophic earthquake was the destructive mountain disaster in the 100year history of Kashmir. According to the official sources, 86,000 people were killed, injured 75,000 people and left homeless 2.8 million people by the earthquake. Furthermore, several landslides were triggered throughout the area which was affected by 2005 Kashmir earthquake. The seismically reactivated Panjgran landslide near the 2005 earthquake epicentre in the Neelum Valley area is an example. This landslide is the largest one, having volume of 6.75 million m3 around the epicentre which caused severe damage to landscape and buried 300-400m of Neelum road. Consequently, the Neelum road remained blocked for 60 days after the 2005 Kashmir earthquake. The study area is located in the Neelum Valley and lies in the NE of Muzaffarabad city, capital of the state of Azad Jammu and Kashmir, between the coordinates 34°21′ to 34°28′ N and 73°27′ to 73°41′ E. It is categorized as rugged topographic characteristics and steep slopes. Topographically, the study area is mountainous with valleys and stretches of plains and is very prone to landslides because of the long and persistent rainstorms and frequent earthquakes. It is the part of “Sub-Himalaya” a morphotectonostratigraphic division of Himalaya. Himalayan orogeny is the world's youngest active continental to continental collision. Two active faults Kashmir Boundary Thrust (KBT) and Kawai Fault (KF) are running through the area. KBT was responsible for the devastating 2005 Kashmir Earthquake. KF joins the Indo Kohistan Seismic Zone (IKSZ) which extends up to the Moho. These interformational (KBT) and intraformational (KF) faults have affected the physical and mechanical properties of the rocks present in the immediate vicinity forming a 200m or sometimes thicker deformed zone. The rocks present in these fault zones are highly sheared, folded, weathered and in most parts, are badly crushed to fine material. An engineering approach was adopted focusing on quantifiable outputs for physical aspects of Panjgran landslide (Table 1). For this purpose, intensive field investigation was carried out and In-situ samples were collected. Digital elevation models and topographic sheets were collected from relevant authorities and photographs were taken. Ring shear tests were performed on the collected samples from the field by using landslide Ring shear simulator and the parameters obtained from laboratory testing will be used in LS-Rapid software to simulate the landslide initiation and motion.

Table :1 Geometric characteristics of the Panjgran landslide

Table :1 Geometric characteristics of the Panjgran landslide

Location Name	Crown elevation (m)	Length (m)	Maximum Width (m)	Estimated depth (m)	Height (m)	Total surface area (m^2)	Deposit area (m^2)	Estimated volume (10^6m^3)
Panjgran	1460	950	650	25	600	390,000	278,000	6.75

RESULTS

There were four tests performed on the sample collected from the Panjgran landslide site to investigate the initiation and motion of landslide. i.e. pore water pressure control test, rubber edge friction test, undrained stress control test and seismic loading test. Pore water pressure control test was the first basic test for this landslide to study landslide failure by increasing only pore water pressure. At first, the sample was saturated (BD value, 0.85), then consolidated to 1.2MPa normal stress and 0.7MPa shear stress in a drained condition. This preparatory stage was to reproduce the initial stress in the slope and is shown as a black line in Fig. 1. This initial stress corresponds to a slope or arctan (0.7/1.2) =30.1°. This is the slope of the landslide. Then in order to simulate the pore pressure induced landslide process, the pore water pressure was gradually increased at a rate of 1kPa/sec. Failure occurred at a pore water pressure of 0.375MPa (a pore water pressure ratio ru = 0.375/1.2 = 0.3). This is the critical pore water pressure ratio which can trigger the landslide without earthquake. The friction angle at failure was 40^0.

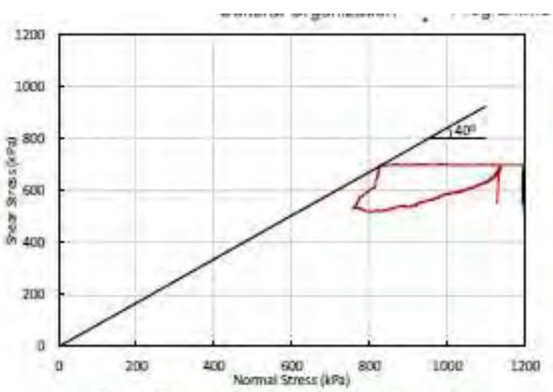

Fig.1 Pore pressure control test results

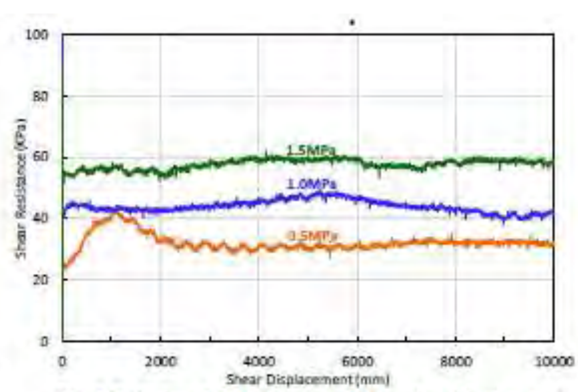

Fig.2 Relationship between rubber edge friction and shear displacement

In Rubber edge friction test the shear stress mobilized on the sliding surface is equal to the measured value of the shear load cell minus the rubber edge friction. When a normal stress is loaded on the sample in the shear box, a lateral pressure acts on the rubber edge. The rubber edge is compressed by the lateral pressure, but due to an arch action of the rigid stainless-steel shear box, less pressure will act on the soft rubber edge. The shear box will be filled with water and consecutively loaded normal stresses of 0.5,1.0 and 1.5MPa and sheared water in a speed control test. Fig. 2 shows the measured shear resistance of the rubber edge at 0.5,1.0 and 1.5MPa. The 0.5MPa test result was unstable, whereas 1.0 and 1.5MPa tests were stable. Rubber edge friction value varied with shear displacement. The most important value is the steady state resistance after a large shear displacement, it was found to be 42kPa at 1.0MPa and 58kPa at 1.5MPa.

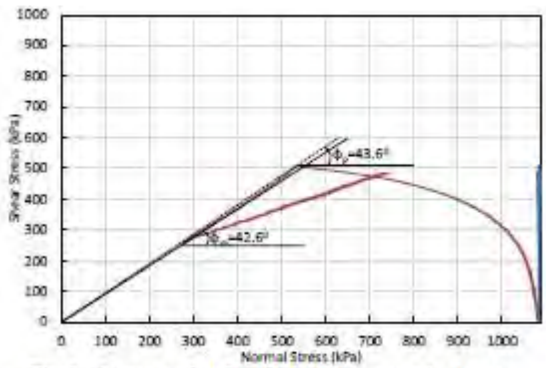

Fig.3a Stress path of undrained monotonic stress control test

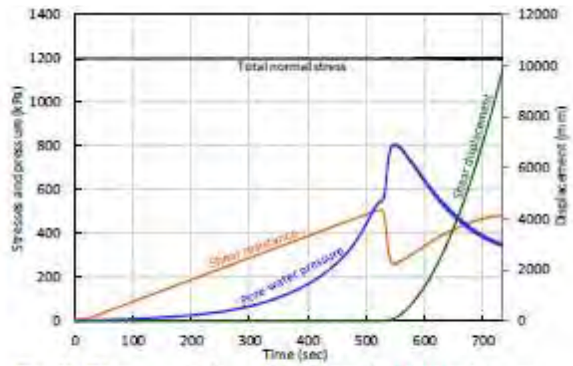

Fig.3b Time series data of undrained monotonic stress control test

Undrained monotonic stress control test can provide the appropriate shear stresses under rainfall, earthquake or undrained loading in the moving landslide mass to simulate the landslide phenomena. For test, normal stress was first loaded in the drained condition to close to the planned normal stress (1.2MPa). The shear box was then changed to the undrained condition, and shear stress was loaded gradually at a rate of $\Delta\tau$=1kPa/sec. When the effective stress path reached the failure line, it began to decrease due to pore pressure generation along the failure line (this is the phenomena of sliding surface liquefaction). Shearing was continued until 10m of shear displacement. The stress path and time series data for undrained stress control test are shown in Fig.3a & 3b. Shear behaviour at 1200kPa normal stress was contractive and stress path at the normal stress reached the failure line (43.6 o) then went down until 250kPa shear stress and shows a dilative behaviour and increased to touch the failure line again. A positive pore pressure was generated until failure and then negative pore pressure was measured just before failure. After failure, the pore pressure decreased during shear displacement. Dilation of the sample near failure caused negative pore pressure and grain crushing occurred in the shear zone. The resulting volume reduction together with the accumulating post failure shear displacement, generated negative pore pressure in the sample.

CONCLUSION

The Panjgran landslide was first activated in 1988 and 1992 floods and was reactivated during the 2005 Kashmir earthquake in northern Pakistan causing many causalities and blocked the Neelum valley road for 60 days. The factors controlling the landside activity includes steep slope, presence of clayey material, construction of the Neelum road and river under cutting. • The pore pressure control test for simulating the source area of the landslide suggested that a pore pressure ratio of 0.3 could have caused the landslide without an earthquake. • This study can not only help in reducing the casualties but also in saving millions of dollars of nation by detailed analysis of the active landslide in landslide prone areas including geological, geotechnical, hydrological, and topographical data essential for the assessment of landslides. This research can provide a strong and practical base for the evaluation of risk and vulnerability assessment of the active landslides and slope failures in study area, and for the secured and cost-effective buildings and sustainable infrastructure in landslide prone areas. • Seismic loading test results and simulation on LS-Rapid software are under study and their data will be published later. • By this Project, the author will find an opportunity for long term international collaboration between Disaster Prevention Research Institute, Kyoto University and University of Engineering and Technology, Lahore Pakistan which will be beneficial for both countries.

Keywords: *2005 Kashmir earthquake, Disaster risk preparedness, Neelum valley, Panjgran landslide, Landslide ring shear simulator*

A Study of Liquefaction Potential in Chiang Rai Province, Northern Thailand

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INTRODUCTION

On March 24, 2011, the 6.8 M_w earthquake ruptured in Tarlay (Myanmar) hit the border of Thailand-Myanmar. The earthquake, which was later known as Tarlay Earthquake, had resulted in the destructive damage to the Chiang Rai Province (the northernmost province in Thailand). The earthquake had not only destructed the buildings, housing, and lifelines facilities but also triggered the ground failure, which was known as liquefaction, in Chiang Rai Province, especially in Mae Sai District located at the border of Thailand-Myanmar. This liquefaction event was recorded as the first eyewitness case in Thailand.

This study is focused on the one-dimensional ground response analysis of the soil sites in the Northern Thailand, especially in Chiang Rai Province. Three site investigation data in Chiang Rai, were collected. Furthermore, the ground motion was applied at the bottom of boring for wave propagation analysis. The soil behaviours including the excess pore pressure ratio, shear stress-shear strain, and effective stress path were observed. In general, this study is aimed to provide a deeper understanding of soil liquefaction in the Northern Thailand and as a recommendation to the local engineers to consider the liquefaction problem as well as its countermeasure to the soil-structure problem in the Northern Thailand, especially in Chiang Rai Province.

METHOD

Three locations in Chiang Rai Province were studied. The first one was Mae Sai District, the closest district to the epicentre of the Tarlay Earthquake. The second location was Mueang District, where mostly economy and social activities in Chiang Rai Province were centralised. The last one was Wiang Pa Pao District, the southern district, which was bordered with Chiang Mai Province and Phayao Province and as the southern gate to Chiang Rai Province from other provinces in Thailand. In those locations, the site investigation data, such as boring logs and seismic downhole results were collected. The maximum ground motion of Tarlay Earthquake recorded in Mae Sai Station was also collected. This study was initiated by interpreting the soil resistance of soils and determining the soil parameters for simulation, such as SPT-N values, fines content (FC), and soil density to estimate soil effective stress. These parameters were also used to estimate other parameters, such as shear modulus (G), bulk modulus (K), etc. In this study, the one-dimensional site response analysis using effective stress model was performed to model non-linear behaviour of soils under dynamic load. The ground motion collected at Mae Sai Station (the closest station to the epicentre of Tarlay Earthquake), which had peak ground acceleration (PGA) of 0.206 g was applied at the soil column. Since there was information of the depth of engineering bedrock; therefore, the bottom of each borehole was assumed as the engineering bedrock with the shear wave velocity of 760 m/s. Furthermore, the ground motion recorded at Mae Sai Station was applied at the bottom of borehole to perform one-dimensional seismic response analysis. The soil behaviours including excess pore water pressure ratio-time history, shear stress-shear strain curve (hysteresis loop), and effective stress path were observed in this study. The liquefaction was indicated by the minimum values of excess pore water pressure ratio about 0.95. In addition, the prediction of liquefaction duration and pore pressure and settlement after liquefaction were also observed in this study.

RESULTS

The site investigation results informed that the investigated locations were dominated by sandy soils, with low soil resistance and in fully saturated condition (low ground water level). However, the thin clay layers were also found at certain depth on several locations, such as Wiang Pa Pao District (from ground surface to 2 m below) and Mueang District (from 31 to 32 m deep). In general, the results showed that liquefaction could occur at the investigated sites, especially at the first and second sand layers on each investigated site dominated by Silty Sand (SM) and Poorly Graded Sand (SP) according to Unified Soil Classification System (USCS). The thickness of these layers was about 3 to 12 m deep. These layers also had low soil resistance $(N_1)_{60}$ less than 15 blows/ft. The excess pore pressure ratio at those first and second sand layers were more than 0.95. The maximum settlements of the first and second sand layers were about 5 cm, especially after 10 seconds after the seismic wave propagation completed. The pore pressure at the sand layers were not easily dissipated, which was confirmed by the observation of excess pore water pressure after simulation, where there was no significant dissipation of pore pressure after excitation. The liquefaction was also indicated by the reduction of shear modulus (G) due to the excess pore water pressure built up. The hysteresis loop (shear stress-shear strain curve) inclined to be flat due to the soil elements started to liquefy and it was almost horizontal after liquefaction. The flat hysteresis loop on the first and second sand layers on each site investigation showed that the soil failure occurred, which in this case was liquefaction. Meanwhile, due to the seismic wave propagation through to soil layers, excess pore pressure built up and decreased the effective confining pressure of soil layers. For the first sand and second layers of each investigated site, the effective confining pressure decreased up to zero due to the excess pore pressure build up. The liquefiable layers were generally starting to liquefy at 10 to 17th second, whereas the dissipated of pore water pressure was generally stating at 50 to 60th second. The liquefaction starting time and the dissipated time of pore pressure were further analysed to estimate the liquefaction. Based on the calculation, the duration of liquefaction on the investigated sites were about 35 to 50 seconds. In term of the impacted depth, Mueang District could be the most vulnerable location to undergo liquefaction. Due to seismic wave propagation, total of 11.3 m thickness of soil layer could be liquefied in Mueang District, which was followed by Mae Sai District with total impacted layer of 9.84 m, and Wiang Pa Pao District with the total of 2.54 m sand layer thickness The liquefaction also would have probably happened at the deeper sand layers (especially below the depth of 16 m), if the stronger earthquake with the higher magnitude and peak ground acceleration had happened in the future; since the present excess pore water pressure resulted due to maximum ground motion of Tarlay Earthquake were about 0.8 t 0.9 (very close to the liquefaction threshold i.e. 0.95). Therefore, the necessary further investigation by considering the stronger earthquake could be performed in the future.

CONCLUSION

A liquefaction study based on one-dimensional ground response analysis through the horizontally layered soils was performed to investigate the liquefaction potential in the Northern Thailand, especially during the strong earthquake event of Tarlay on March 24, 2011. This study concluded that the liquefaction could occur at the first and second layers on each investigated location. The soil behaviours at those layers showed there were the liquefaction indication, which were signed by the excess pore water pressure ratio more than 0.95, the significant degradation of shear modulus, and the effectives stress reduction due to pore water pressure built up. In general, the results could help to make an awareness to the people in the Northern Thailand to reconsider the impact of the earthquake and liquefaction in structure design.

Keywords: *Liquefaction, Earthquake, Northern Thailand, Sandy Soils*

Geohazard Risk Assessment in a Tectonically Active Region in Malaysia

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INTRODUCTION

Geological hazards and risk poses significant threats to future development planning in a tectonically active region yet very difficult to quantitatively predict. Despite remarkable efforts of mapping and assessing geological processes at regional and local scales in Malaysia, the understanding of disaster risk remains elusive. Although Malaysia is in a relatively low seismic hazard zone, an increasing seismotectonic activity coupling with extreme climate triggered a series of fundamental study to better understanding of geohazard process and activities and later assessing disaster risk objectively. This study provides a regional framework for assessing geohazard risk in a tectonically active region.

METHODS

A collaborative disaster-geospatial environment for mapping, assessing and understanding disaster risk in a seismically active region in Malaysia was established. This promotes a transdisciplinary approach for building social resilience to disaster. An inventory of the 245 earthquakes that have occurred in Sabah between 1897 and 2015 was made. A recent earthquake on June 2015 with a 6.0 magnitude, 10 km depth and more than 200 aftershocks were cited. 2015 Sabah earthquake with its epicentre recorded near to the Mount Kinabalu, the UNESCO World Heritage Site resulted in 18 casualties and reported economic losses of up to USD 25 million, with several cascading hazards due to extreme and intense precipitation, and anthropogenic activity.

RESULTS

Several causal and triggering factors have been incorporated into the statistical spatiotemporal based probability model. A list of element-at-risk and vulnerability has been collaboratively extracted and analysed for supporting risk assessment. This study has supported the National Slope Master Plan 2009-2023 and also ASEAN Vision 2025. An evidence-based decision, as a result of wide range of geospatial and temporal scales, is essential for assessing disaster risk and supporting future development by mainstreaming DRR. It is also crucial to highlight the land-use-land-cover changes in relation to temporal and spatial pattern of co-seismic landslides. Also, it is important to assess, model and incorporate the changes into the sustainable risk management.

CONCLUSION

This integrated research has contributed significantly to improve the regional hazard and risk assessment in the tropics, which later beneficial in providing a critical input for making vulnerable cities more resilient and sustainable in a complex environment.

Keywords: *Transdisciplinary disaster risk, Quantitative Risk Assessment, Space based technology, Sabah*

Looking Through Disaster Management of Thailand: A Focus on Earthquake and Tsunami

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INTRODUCTION

Thailand is located in Southeast Asia. The possible natural disasters in the region include tropical cyclones, earthquakes, floods, thunderstorms, tsunamis, landslides, storm surges, forest fires, droughts, etc. (Thai Meteorological Department, n.d.). Mainly, disaster management consists of four phases: disaster preparedness, disaster response, disaster recovery, and disaster mitigation. This study picks some interesting issues from those four phases to present in terms of earthquakes and tsunamis.

WARNING SYSTEM

After the 2004 Indian Ocean tsunami, the warning systems, along with the establishment of the National Disaster Warning Center and other related organizations, have been implemented (Leelawat et al., 2015). In present, this center is under the Ministry of Interior as the official warning agency of the country. The center does not focus on only earthquakes and tsunamis, but also other natural disasters.

EVACUATION: AN OVERSEAS EXPERIENCE

Not only disaster management in Thailand, we also look at the evacuation process of Thai citizens and Thai organization in Japan. In April 2016, the Kumamoto earthquakes in Japan killed 50 people. Due to an overseas primary tourist destination for Thai citizens, many Thai people were visiting Japan when these earthquakes occurred. The study focused on the evacuation process for Thai citizens mainly conducted by the Royal Thai Embassy, Tokyo, which was successfully completed within a few days (Leelawat et al., 2017).

DISASTER EDUCATION

Many academic and research institutes in Thailand have paid attention to topics related to disaster management. Currently, some universities in Thailand provide a degree program in disaster management. Those programs are in either Faculty of Engineering, Faculty of Science, or a specific individual program. In 2018, Chulalongkorn University is going to accept students to the new Master's program, so-called Master of Science in Risk and Disaster Management. Also, there are many established international research collaborations for disasters between Japan and Thailand, and Japan and ASEAN countries.

DISASTER AWARENESS

Northern part of Thailand experienced many earthquakes recently. We conducted surveys seeking disaster awareness in elementary schools students. We found that students in the affected areas considered disaster education and disaster drill exercise as one of the important to-do lists in their education activities.

CONCLUSION

Recent work of Suppasri et al. (2017) found various improvements of tsunami disaster mitigation, especially for non-structural countermeasure. For example, evacuation drill and disaster education in the disaster-experienced areas. Disaster education is among the necessary activities which can reduce the disaster risk as it provides the foundation as the soft countermeasure for citizens. Therefore, it is necessary to enhance the role of education for disaster management. While there are still less than ten academic institutes in Thailand include a university-level curriculum on disaster management (Department of Industrial Engineering, 2017), many educational institutes have started to consider such related curriculum and courses.

Keywords: *Disaster risk reduction, disaster education, earthquakes, Thailand, tsunamis*

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Investigation of Tide Data Processing and Utilization by NAMRIA-Application to Astronomic Tide Synthesis of South Harbor Port Manila

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INTRODUCTION

Water level is an important consideration in both disaster mitigation and coastal structure design. National Mapping and Resources Information Authority (NAMRIA) is the government agency that collects, process and synthesize water level data along its 18 tide stations in the coastal areas of the Philippines. NAMRIA tide data is composed of tide time series and tidal datums. Tide time series is used to analyze historical stormS by separation of the non-tidal component to water level time series. The remaining tidal component is the astronomic tide which can be predicted by harmonic analysis. Long term trends in the tide time series, which corresponds to the sea level rise of the local study area, affects the results of harmonic analysis so a thorough study of the trends should be done prior to predicting the astronomic tide. Tidal datums are composed of tide extremes and tide normals. Tide extremes (Highest and lowest tide) are used to determine design water levels of coastal structures while tide normals (MLLW, MLW, MSL, MHW, MHHW) are used as input parameter in wave climate simulations (i.e. through REF/DIF software) to obtain the wave height distribution and wave direction in the study area. Although they can be classified through their uses, tide data are interrelated and each contributes to other's applications. Astronomic tide is long-period wave that oscillate through oceans due to the gravitational pull of the moon and sun to the earth while storm surge is the unusual rise of water level generated mainly by strong winds during a typhoon. Hence, astronomic tide is periodic and predictable through harmonic analysis. While astronomy dictates the tide constituents' angular frequencies, it is the basin hydrodynamics that controls their amplitudes and phase lags. Therefore, tide time series record is needed in Harmonic analysis. The length of tide data needed is 19 years which is also the National Tidal Datum Epoch (NTDE). A specific 19-year is selected because it is closest full year to the 18.6-year nodal cycle, the time required for the regression of the moon's node to a complete revolution. It is also long enough to averages out all the local meteorological effects on tide data. The NTDE also allows one to define a certain phase of tide for tidal datum establishment. Tidal datums are standard elevations on which local water level measurements are reckoned. Since hydrodynamics controls the behavior of tides in oceans and connected bays, it introduces different type of tides (diurnal, semi-diurnal, mixed). Manila Bay has a semi-diurnal type of tide, hence it experiences two high tides and two low tides in a tidal day. When there is significant difference in the heights of the two high tides and the two low tides, the type of tide is mixed. The diurnal type of tide has one high tide and one low tide in a tidal day. When the type of tide is diurnal, then there are no mean higher high water (MHHW) and mean lower low water (MLLW) in the list of tidal datums.

METHODS

The specific objectives of this research is to assess the tide data suitability to storm surge analysis and wave climate studies. Since tide data varies with different locations, this study chose a specific site where the hazard of storm surge is considerably high and mitigating solutions such as coastal structures are needed. Hence, this research specified South Harbor tide station as the study area because of its location in Manila Bay. The first objective is consist of the assessment of sea level rise and analysis of historical storms. To assess the sea level rise, least square linear solution method was utilized in the 1901-2015 monthly mean sea level. The monthly mean data was grouped based on calendar months. The y-intercept of the plot of each group is determined to be the Average Seasonal Cycle (ASC) of each calendar months. The ASC was removed in the original monthly mean data and the linear trend of the resulting plot is computed. The computed linear trend is used to de-trend the 1969-2015 hourly tide data in the analysis of historical storms. Harmonic analysis is done piecewise annually in the hourly tide data to hindcast the astronomic tide. The hindcast astronomic tide is subtracted from the original hourly tide data to extract the storm surge values of historical typhoons tracked within Manila Bay (study area). For the second objective, the NAMRIA-specified monthly tidal datum values was compared to the computed values through individual wave analysis (zero-crossing method). Zero-crossing method defines each individual waves by dividing the hourly tide time series into periods based on zero-crossing points. The higher high water (HHW) and high water (HW), and the lower low water(LLW) and low water (LW) are then identified from each individual wave. Their averages (MHHW, MHW,MLW,MLLW) are computed and compared to the NAMRIA-specified monthly tidal datum values.

RESULTS

The results in the assessment of sea level rise shows that the sea level trends are rapidly increasing over time since a varying trend for 1901-1968 (1.76mm/year) and 1969-2015 (13.6mm/year) was obtained. The plot of computed ASC of each calendar month for both periods (1901-1968 and 1969-2015) has a bell-shaped curve with increasing values from the month of March to August and a decreasing trend from September to December. By definition, average seasonal cycle (ASC) in coastal waters are combination of the effects of air pressure, wind, water temperature, salinity, ocean currents and river discharge. Therefore, the increasing values from March to May (Summer months) is due to increase in water level because of thermal expansion. The continuous increase in values of the ASC plot is attributed to the Pasig River discharge because of intense and frequent rainfall for this months. The decreasing trend for September to December (Cold months) is due to decrease in water level due to contraction of water. In the analysis of historical storms, the methodology of extracting the storm surge values from the tide time series by synthesizing the astronomic tide is validated. The results are storm surge values of 47 historical typhoons tracked within Manila Bay from 1969-2015. The highest historical typhoons based on storm tide level are Typhoon Nesat (Pedring) and Typhoon Faye (Norming). The highest based on storm surge values are Typhoon Nesat (Pedring) and Typhoon Saola. For the second objective, the NAMRIA-specified tidal datum values varies significantly with the computed values through zero-crossing. The large variation is due to the difference in the selection of wave period on which the individual waves are to be defined. NAMRIA uses a uniform wave period equivalent to a tidal day (24.84 hours) to define individual waves while zero-crossing method has wave periods ranging from 12 to 275 hours although the mode of values is close to 24.84 hours.

CONCLUSION

In the assessment of tide data suitability to storm surge analysis, it was concluded that least-square linear solution method is not suitable to assess the sea level rise for longer period of observation since rapidly increasing sea level trends are observed. Using least-square linear solution method of longer period of observation will underestimate the relative sea level rise of local study area. For the second part of the first specific objective, the methodology to extract storm surge values in the water level time series by predicting the astronomic tide was validated. The accuracy of the extracted storm surge values is not guaranteed since the gaps in the tide record and the varying sea level trend are introducing errors in the hindcast astronomic tide. For assessment of tide data suitability to wave climate studies, it was concluded that the selection of wave period on which the individual waves are to be defined causes large variations in the compared tidal datum values (NAMRIA-specified versus computed through zero-crossing). Since Manila Bay is categorized to be mixed-mainly semidiurnal type of tide, it experiences two high tides and two low tides in a tidal day. To represent this variation on the heights of tide, the researcher recommends the use of uniform wave period equivalent to a tidal day (24.84 hours) for tidal datum computations.

Keywords: *Astronomic tide, sea level rise, NAMRIA, tidal datums, storm surge, Manila Bay*

Disaster Mitigation Implications of Study of Manila Coastal Flooding Due to Recent Typhoons

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INTRODUCTION

Out of the 20 average typhoons that pass the Philippines' area of responsibility, about 8 to 9 make landfall along its more than 36,000 km of archipelagic coastlines. In recent years, several severe typhoons made landfall along the Manila Bay coastline, generating historical storm tides and high waves that caused overtopping of an important seawall that protects the national road Roxas Boulevard and inundating the built-up urban areas of Manila just behind the wall. Numerical analyses indicated that storm surge-uplifted sea level overtopped the 1.34-km-long existing RB seawall by 37 cm during typhoon Ramassun 2014 and by 10 cm during typhoon Xangsane 2006. Adding the seawall runup and other wave effects, the required minimum non-overtopping elevation of the seawall crest is +4.68m which is significantly higher than the existing crest elevation of +2.01m. One of the mitigating solutions recommended is the raising of the seawall by at least 2.2 m to contain the historical +4.68 m. In order to assess the economic cost of such intervention, a do-nothing scenario where the existing seawall is overtopped is studied. This paper presents a limited summary of such a scenario in order to assess the implications to disaster mitigation plans of Manila when such historical typhoons recur.

METHODOLOGY

Numerical model ADCIRC is used to compute the storm tide levels (STL) induced by these recent typhoons. The mesh, terrain elevation and tracks of the recent strong typhoons are shown in Figure 1. A quadratic formulation for bottom friction is used with Manning's roughness coefficient *n* set according to the depth variation which ranges from 0.017 to 0.040 on sea elements, and is 0.05 on inundation elements. The *n* value decreases with depth. This is in contrast with the pure storm surge simulations where the coefficient is set uniformly to 0.0025. Overtopping of the seawall's crest by storm tides is modeled as an overflow weir with a discharge coefficient of 1.0, i.e. maximum theoretical discharge. The flowrate on an overtopped land element is modeled as a broad-crested weir with a discharge coefficient of 1.0, or equal to the theoretical maximum flowrate.

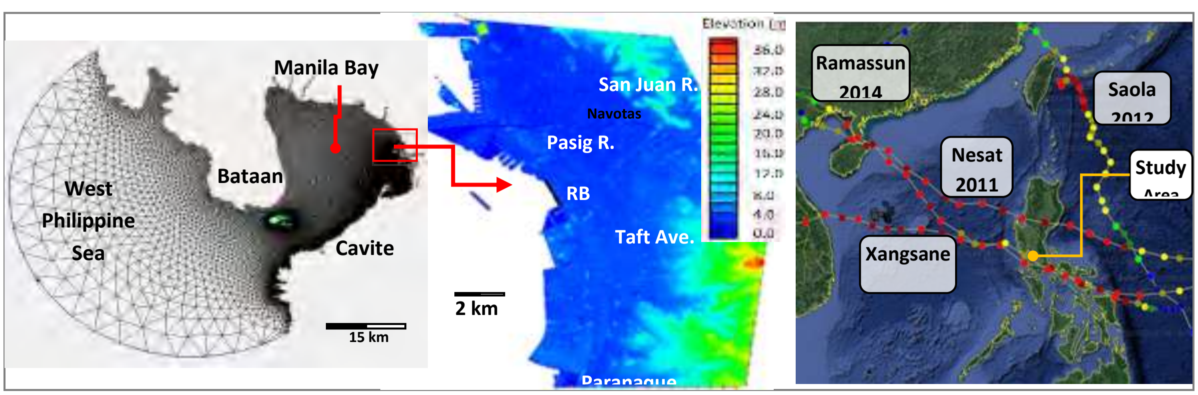

Figure 3. Model mesh, digital terrain elevation data, tracks of recent strong typhoons

RESULTS

Figure 2 shows the computed envelopes of peak storm tides in the nearshore as well as in Pasig River due to typhoons Ramassun 2014 and Xangsane 2006. The results are valid if the seawall and river banks were high enough to prevent inland inundation. In this case, the maximum storm tide reached +2.36 m at the seawall, and as high as +0.5 m along Pasig River at a channel distance of 7 km upstream of the outfall during Ramassun.

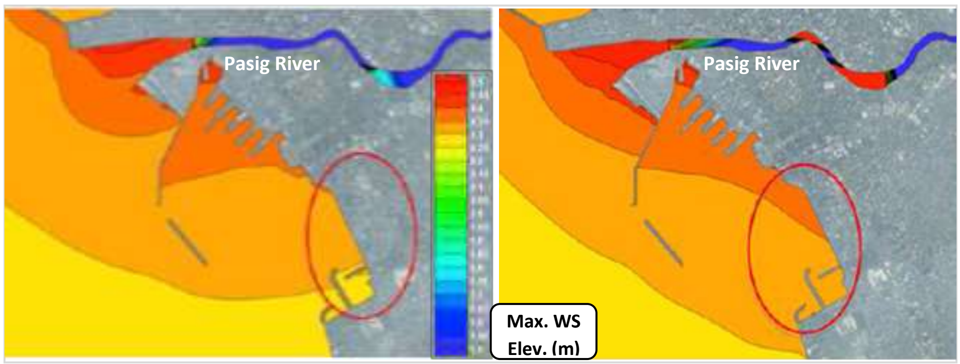

Figure 4. Maximum envelope of water surface due to typhoons Ramassun 2014 (left) and Xangsane 2006 (right)

Figure 3 indicates the extent of inundation due to storm tide overtopping (note: the sea is uniformly colored to highlight the coastal flooding only). It is clear that the rear of the seawall experiences a rapid variation of inundation depth that it has decreased to 0.45 m just a few tens of meters from it. Also, the inundation occurs most inwardly along the alignment of Pasig River with the wetting front reaching as far as 3 km inland from its outfall. This result has been reported by other studies of storm surge propagation in estuaries. A rapid change of inundation depth behind the seawall is seen, the wetting front has advanced more inland both behind the seawall and along the waterway Pasig River. The extent of inundation is seen to be extensive, particularly along Pasig River. It should be noted that the above plots involve inundation *envelopes*, not snapshots of inundation, hence, the results should be taken as inundation *potential*, not actual inundated areas.

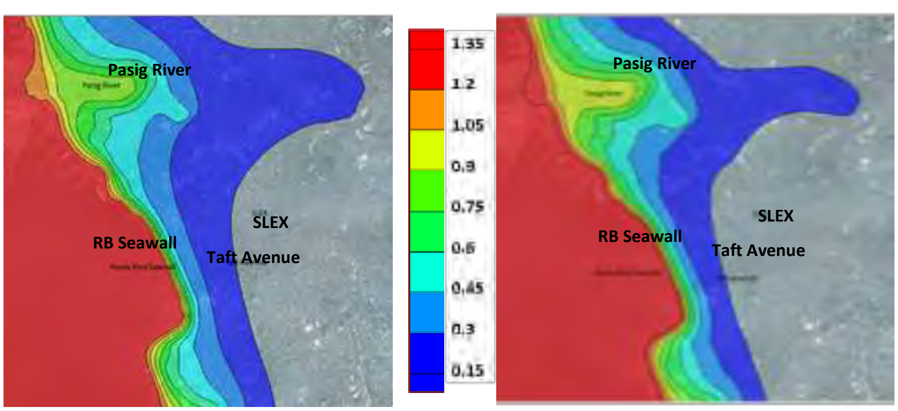

Figure 5. Simulated maximum inundation depths due to Ramassun 2014(left) and Xangsane 2008 (right)

CONCLUSIONS

Table 1 summarizes under existing conditions the peak depths of inundation at various inland distances from the seawall based on the synthesis of the 5 historical typhoons that impacted Manila's coastal flooding. The depths in front and behind the seawall are also summarized.

Table 2. Peak inundation depths behind RB Seawall due to 5 critical typhoons under a "do nothing" scenario

Case	Typhoon/Local name	near Seawall (40m to sea)	near Seawall (20m inland)	Taft Ave (1km inland)	Osmeña Ave (1.85km inland)
1	Rammasun/Glenda 2014	1.489	1.380	0.189	0.102
2	Xangsane/Milenyo 2006	1.489	1.380	0.122	0.054
3	Fengshen/ Frank 2008	1.364	1.309	**0.374**	**0.285**
4	Saola/ Gener 2012	1.453	0.863	0.179	0.081
5	Nesat/ Pedring 2011	1.450	0.855	0.170	0.077

The largest inundated area was induced by typhoon Fengshen 2008 with a peak depth of 0.37 m at Taft Avenue and 0.29 m at South Luzon Expressway (SLEX, Osmeña Ave.). This vast horizontal extent and high inundation depths due to Fengshen appear to be consistent with its peculiar track, which was east then north of the seawall, with closest distance of 26.4 km northeast from the seawall. Typhoon Ramassun 2014, which tracked 25 km at the closest distance southwest of the seawall and caused the highest storm tide level, generated a much lower inundation depth of 0.19 m at Taft Avenue.

These results consistently indicate that the coastal flooding of Manila resulting from the overtopping of the RB seawall highly depends on the meteorological characteristics of the historical typhoons. In addition, the spatial extent of the resulting inundation depends on the freeboard of the overtopping storm tide above the seawall crest. For some cases of historical typhoons, coastal flooding can be exacerbated by the propagation of inundation via the tide-open Pasig River. A storm tide gate across the river's outfall in conjunction with the raising of the seawall crest may provide a more effective mitigation against coastal flooding of Manila behind the seawall.

Keywords: *Disaster mitigation, coastal flooding, storm surge, seawall, Roxas Boulevard*

Storm Surge Simulation of Typhoon Haiyan (2013) and Typhoon Agnes (1984) in San Pedro Bay Using the Advanced Circulation (ADCIRC) Model

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INTRODUCTION

Coastal flooding associated with storm surges is one of the main causes of extensive damages and loss of lives. On November 8, 2013, Typhoon Haiyan (local name Yolanda), which is considered as one of the most intense typhoons on record, struck and devastated the Philippines, specifically the Visayas Region. The typhoon caused catastrophic destruction in Visayas, in which a total of 6,300 individuals were reported dead, 28,688 injured and 1,062 are still missing. With the estimated 215 kph wind strength and gustiness of 250 kph, Typhoon Haiyan generated around 5-7 meters of storm surge in Samar and Leyte. In Tacloban, most of the 2,678 of the total number of fatalities have been killed by the storm surge. A post-assessment report done by NDRRMC in 2014 found that early warnings on storm surges were not understood by the communities. Moreover, published storm surge hazard maps only indicated inundation up to 4 meters, which is mostly located in Tacloban. In the past, however, there were already storm surge accounts in San Pedro Bay, which include the 1897 Typhoon and 1984 Typhoon Agnes (local name Undang). The 1897 Typhoon have generated 3-5 meters of maximum water levels in San Pedro Bay while Typhoon Agnes generated storm surge in Basey which killed 895 people (NDRRMC, 2015).

San Pedro Bay has a shallow bathymetry which is less than 25 meters deep at the mouth of the bay and decreases towards San Juanico Strait. Located in Leyte Gulf which faces the Pacific Ocean in the East, the bay has a frequency of one typhoon per year. With its shallow bathymetry and funneling coastline, the bay is regarded as susceptible to storm surges. At the inner part of San Pedro Bay, where the bathymetry is shallowest, are the coastal towns of Tacloban in Leyte and Basey in Samar. In view of disaster mitigation and preparedness, improved understanding and accurate predictions of storm surges along the coast will help in the reduction of the negative impacts of coastal disasters. Nowadays, numerical ocean models are considered an important tool to predict the rise of sea water levels generated by typhoons for hazard assessment and for design of coastal structures, minimizing damage loss and casualties.

This study investigates the storm surge generation in San Pedro bay caused by Typhoon Haiyan (2013) and Typhoon Agnes (1984) using the Advanced Circulation (ADCIRC) model. The results show that the model can predict the peak surge and storm tide along the coasts of Basey in Samar, and Tacloban in Leyte, which are located at the inner bay. The results of this study can be used to further understand the storm surge generated by Typhoon Haiyan (2013) and Typhoon Agnes (1984) through the use of numerical modelling for disaster prevention management, and preliminary planning and design of coastal structures for disaster mitigation.

METHODS

The pressure and wind distribution profile of Typhoon Haiyan (2013) and Typhoon Agnes (1984) are developed using the Holland 1980 typhoon model. Typhoon parameters required for the Holland 1980 typhoon model are the maximum wind speed, central pressure, and radius of maximum windspeed. For Typhoon Haiyan, the typhoon parameters are obtained from the Joint Typhoon Warning Center (JTWC) data. For Typhoon Agnes, the typhoon track and windspeed are obtained from JTWC. Since JTWC has no central pressure and radius of maximum windspeed information for typhoons that occurred before 2001, the central pressure data for Typhoon Agnes are gathered from Japan Meteorological Agency (JMA) and the radius of maximum windspeed is estimated using the Vickery and Wadhera (2008) method. Several methods for estimating the radius of maximum windspeed are explored by comparing the estimated radius of maximum winds to the JTWC data of typhoons that occurred from 2001-present. These methods include Quiring et al. (2011), Japan National Institute for Land and Infrastructure Management (2005), Japan Weather

Association (2002), Takagi and Wu (2016), and Vickery and Wadhera (2008). It is found that the methods used in Japan overestimate the radius of maximum windspeed for typhoons that passed San Pedro Bay. The method of Quiring et al (2011), which is based on the maximum wind speed, also overestimates the radius of maximum windspeed. The Vickery and Wadhera (2008) method estimates the radius of maximum windspeed in the lower range of 10-20 km for central pressure range of 920 to 980 hPa. In the validation of the Holland 1980 typhoon model, the model overestimates the windspeed at larger radii of the typhoon. Applying the Vickery and Wadhera (2008) method provides lower values for radius of maximum winds which gives higher simulated windspeeds near the eye of the typhoon and lower windspeed at larger radii using the Holland 1980 typhoon model.

The hydrodynamic model used in this study is the 2DDI Advanced Circulation (ADCIRC) model, which is a continuous Galerkin, finite element model based on the depth-integrated equations of mass and momentum equations. The model domain has open ocean boundaries in the Pacific Ocean and portion of the Bohol Sea in the West. The boundary at San Juanico Strait extends just after the San Juanico Bridge and is treated as a mainland boundary. The nearshore bathymetric data is obtained from digitized bathymetric maps of the National Mapping Resource and Information Authority (NAMRIA) while the deep shore bathymetry is gathered from the General Bathymetric Chart of the Oceans (GEBCO) which has a spatial resolution of 30 arc seconds. The modeled bathymetry of the bay shows that the inner part of San Pedro Bay is very shallow with a depth below 10 meters. A depth-adaptive triangular mesh is generated with the smallest grid size of 100 m near the coast and around 12 km grid size at the Philippine Trench. The model mesh has 110,264 elements, 57,736 vertices, minimum elevation of 0.3 m and maximum elevation of 9,887.72 m. A time step of 5 seconds is used in the simulation. The tidal elevations for the Pacific Ocean boundary are determined from the LeProvost tidal database while the tidal constituents for the Bohol Sea boundary are derived from harmonic analysis of WXTide tide at Nasipit Harbor and Maasin stations. The tidal constituents used are M2, S2, K1, O1, P1 and Q1. Tide data were available at Tacloban tide gaging station located at the inner bay before Typhoon Haiyan destroyed the gaging station. The simulated tide at Tacloban tide gaging station is compared with the actual tide data. Using a manning's roughness of 0.025, the computed RMSE of the simulated and actual tide is 0.1468. The simulated tides are in phase with the actual tide and the differences in the amplitude of the simulated tide and actual tide are attributed to the closing of the San Juanico Strait. Observed water level data for both Typhoon Haiyan and Typhoon Agnes are not available.

RESULTS

Typhoon Haiyan (2013) crossed the Leyte Gulf and made landfalls at Guiuan, Samar at 0440 PHT and at Tolosa, Leyte at 0720 PHT on November 8, 2013. The maximum sustained windspeed at landfall over Tolosa is estimated from satellites at 85 mps and the estimated forward speed of the typhoon is 41 kph. The results of the storm surge simulation for Typhoon Haiyan are evaluated using the observed timing of peaks and high-water marks. According to the interviewed residents, storm surge inundation around Tacloban port started after 0730 PHT. In downtown Tacloban, the peak surge occurred around 0800 PHT. From the generated storm surge time series, the simulated peak storm tide at Tacloban occurred around 0810 PHT and the simulated storm tide is around 2.25 m, which already depicts possible coastal flooding. Respondents in Tanauan, Leyte indicated that the high-water level held for about 30-40 minutes and the clock stopped at 0720 PHT. The simulated storm tide in Tanauan is already at 1.9 meters at 0720 PHT which may indicate start of inundation and the duration of storm surge above 2.4 meters is around 40 minutes. The simulated maximum water surface elevations for Typhoon Haiyan along the coasts of San Pedro Bay are compared with the reported measured high-water inundation marks by Tajima et al (2014). As expected, the observed water levels are higher than the simulated water levels because the model does not incorporate the effects of waves. The simulated water levels decrease from the inner part towards the mouth of San Pedro Bay. It appears that the simulated results, though underestimated, agree well with the observed values inside the bay. However, large discrepancies are observed at the mouth of the bay. The simulated peak storm tide at the airport is around 4 meters and 4-5 meters at downtown Tacloban. At Palo, the simulated water surface elevation reached up to 3 meters in height. The simulated rise of storm surge from the minimum is estimated at 1 hour. The duration of inundation above 4 meters in Tacloban is estimated to be 40 minutes.

Typhoon Agnes (1984) passed San Pedro Bay on November 4-5, 1984 (UTC), with a pressure of 940 hPa and a 10-min maximum sustained winds of 105 kts (195 kph). The typhoon had a forward speed of approximately 31 kph and the track of the typhoon based on JTWC data crossed the San Juanico Strait just north of San Pedro Bay. The maximum simulated storm tide at Poblacion Basey is around 2.5 meters, which is consistent with the accounts of the local residents in Basey in which the storm surge rose around 2-m in height (NDRRMC, 2015). From the maximum simulated water surface profile and distribution, the storm surge is concentrated along the coasts of Basey. The simulated storm surge time series plots show a negative surge occurred before the peak surge, especially at areas along the northern coasts of San Pedro Bay. This negative surge is attributed to the direction of windspeed, which is towards the coast as the typhoon approaches. The duration of rise to peak of water level is estimated as 2 hours. The maximum simulated water surface profile indicates 2-3 meters of storm tide inside the bay.

CONCLUSION

The Advanced Circulation (ADCIRC) Model is applied to San Pedro Bay for simulating the storm surges of Typhoon Haiyan (2013) and Typhoon Agnes (1984). The triangular finite element mesh model of the ADCIRC model can represent the irregularity of the shoreline of San Pedro Bay. Since the model domain for San Pedro Bay uses two open ocean boundaries, it is recognized that the tidal elevations extracted from LeProvost tidal database should be validated. For this study, the Bohol open ocean boundary tidal constituents are derived using harmonic analysis. Data for Typhoon Haiyan is obtained primarily from JTWC. Determining the typhoon parameters for Typhoon Agnes that occurred before 2001 requires central pressure data from JMA and estimation of the radius of maximum windspeed. Though validation of the Holland 1980 typhoon model presents that the typhoon model overestimates the windspeed at larger radii of the typhoon, the results of the simulation using the ADCIRC model show that it is capable of predicting the storm surge in San Pedro Bay. The discrepancy in the observed and simulated values of Typhoon Haiyan (2013) may be attributed to the effects of waves, especially at the mouth of the bay where wave-like fluctuations are observed by witnesses. Further study on the nearshore wave generation in San Pedro Bay should be done to validate the discrepancy of the simulated results to the observed values of storm surge high-water marks generated by Typhoon Haiyan.

Numerical modelling using ADCIRC can be an important tool in disaster management, specifically for coastal flooding due to storm surges. Typhoon Haiyan (2013) and Typhoon Agnes (1984) are two historical events which produced significant storm surges in San Pedro Bay in the past. Typhoon Haiyan and Typhoon Agnes have different storm characteristics. The track, high windspeed and forward speed of Typhoon Haiyan have generated high storm surges of about 4-6 meters inside the bay. Typhoon Agnes with a track above San Pedro Bay, a relatively lower windspeed and forward speed than Typhoon Haiyan, have also generated significant storm surges of 2-3 meters inside the bay. The results of this study can be used in the improvement on the knowledge of local storm surge hazard which could be used for information and education campaigns, and planning for storm surge disaster management of the local government along the coasts of San Pedro Bay.

Keywords: *ADCIRC, storm surge, Typhoon Haiyan, Typhoon Agnes, San Pedro Bay, disaster mitigation*

Comparative Analysis of Parametric Cyclone Models for Surface Wind and Sea Level Pressure Modeling for Storm Surge Simulations

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INTRODUCTION

A parametric cyclone model describes the spatial characteristics of the surface winds and sea level pressures, and is particularly used as boundary conditions for numerical simulations of storm surges. It typically consists of an assumed radial pressure distribution, and a wind field obtained by substituting the pressure distribution to the gradient wind relation. There are several existing parametric models developed, but their accuracy in modeling intense typhoons that form in the Western North Pacific particularly for storm surge numerical simulations is yet to be verified.

METHODS

Commonly used parametric cyclone models in storm surge modeling were reviewed, together with two commonly used relations for radius of maximum winds. The wind and pressure profiles generated by models of Fujita (1952), Holland (1980), Young and Sobey (1981), Holland et al. (2010) and the modified Rankine Vortex Model were compared versus observations from several atmospheric monitoring stations in the Philippines. The wind and pressure profiles were developed using the radius of maximum wind relations given by Gross et al. (2004) and Vickery and Wadhera (2008).

Three typhoons that made landfall in the Philippines were considered in the study: the 1978 Typhoon Rita that hit the southeastern Luzon, the 2013 Typhoon Haiyan that hit eastern Visayas, and the 2016 Typhoon Meranti that hit the Northern group of islands of the Philippines. All three typhoons have reported minimum sea level pressure of at least 895 hPa, and maximum winds of at least 120 knots. Observations were gathered for three sites near the track of 1978 Typhoon Rita, four sites near the track of 2013 Typhoon Haiyan, and two sites near the track of 2016 Typhoon Meranti.

The wind and pressure profiles by Fujita (1952), Holland (1980) and Holland et al. (2010) were generated with the aid of the MatLab-based tool Delft Dashboard (Nederhoff, 2016). The wind and pressure profiles by Young and Sobey (1981) and the modified Rankine Vortex model were generated with the aid of the Cyclone Toolbox from the Mike21 by DHI software (DHI, 2014). The typhoon model characteristics were based on the best track archive of JMA. The gradient winds were transformed to surface winds by applying a factor of 0.7. Over-land wind observations were converted to over-water winds following CEM (2005). The ambient atmospheric pressure was set to 1010 hPa. The time history of modelled surface winds and sea level pressures 24 hours before and after the peak of the typhoon was recorded, and compared with a time history of observations. The level of agreement between modeled and observed surface winds and sea level pressure were measured by computing the R2 value, bias, and root-mean-square-error.

RESULTS

The surface wind profiles given by the various models were greatly varied. The model by Holland et al. (2010) significantly improved the modeled surface winds by Holland (1980), and best represented the surface wind observations. The surface winds given by Holland (1980) greatly overestimated the observations, sometimes even reaching a factor of 2. The surface winds given by Fujita (1952) and Young and Sobey (1981) consistently provided good estimation of the observations. The wind profile given by the modified Rankine Vortex Model was consistently milder than the steep wind profiles commonly observed for typhoons landfalling in the Philippines.

All models provided very similar pressure profiles. In a general sense, the pressure profile given by Fujita (1952) best represented the observations.

Based on comparison plots for all observation stations, the relation of Gross et al. (2004) tend to significantly overestimate the radius of maximum winds. The relation by Vickery and Wadhera (2008) provided a better correlation between the modeled values and observations.

The modeled surface winds and sea level pressures were more accurate for the small remote islands in the Northern part of the Philippines, whereas effects of topography on the land masses of eastern Visayas and southeastern Luzon caused significant differences in the modeled surface winds and sea level pressures versus the observations.

CONCLUSION

The parametric cyclone models provided very different surface wind profiles, but the wind field given by Holland et al. (2010) best described the observed surface winds. All models provided similar pressure profiles, but the observations were best matched by the Fujita (1952) radial pressure distribution. The empirical relation derived by Vickery and Wadhera (2008) provided a better correlation between modeled and observed surface winds and sea level pressures, comparted to the relation given by Gross et al. (2004).

For particular applications for storm surge numerical modeling, it is noted that the storm surge height can be either highly affected of the wind speeds or highly dependent on the sea level pressure. It is known that for coastlines with shallow and wide continental shelves, the storm surge height is highly attributed to the surface winds, whereas for small islands located in deep bathymetry, the storm surge height is primarily due to the negative ambient pressure. Therefore, it is recommended consider the accuracy of the parametric cyclone model for use as boundary conditions to a storm surge model. Effects of the accuracy of the atmospheric boundary conditions on the modeled wave conditions, which also affect the storm surge height should also be considered.

Keywords: *Tropical cyclone modeling, Surface winds, Sea level pressures, Radius of maximum winds, Storm surge*

Modeling of wind flow around tree for CFD simulation: Preliminary investigation by wind tunnel experiment with tree model

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INTRODUCTION

Evaluation of wind speed acting on exposures is a prerequisite for wind risk assessment of built environment. In the context of wind risk assessment, wind speed is first evaluated by means of so-called typhoon simulation or other means at a reference height under standard surface condition, e.g. at 10-meter height from the ground surface and under nominal roughness category. Then, the wind speed is converted by considering the actual heights of exposures and the actual roughness conditions where exposures are located. This approach is commonly used in probabilistic wind risk assessment and useful especially for the assessment of risks of large number of exposures. However, this does not explicitly take into account the micro wind environments that surround the individual exposures. In countries of southeast Asia, exposures are often surrounded by trees; sometimes those trees are intentionally planted for the purpose of wind breaking. Thus, in order to consider the effects of trees on wind acting on exposures in the risk assessment for those countries, it is important that the model used can reasonably capture such effects. Such a model is also useful to quantify the usefulness of trees to protect exposures from strong wind. The objective of this study is to develop a model that can describes the wind flow around tree. The development of the model takes its basis in the Navier-Stokes equation. Specifically, the model development focuses on the modeling of forces acting on air flow as a reaction to the wind pressure on objects. Such modeling techniques and corresponding models have been developed for different types of objects and widely used in numerical simulations. However, most of these are for solid and rigid objects; hence, cannot be directly applied to tree, which are of porous and deform. The model will be eventually developed in terms of a component used in computational fluid dynamic simulation. As its first step, this presentation presents preliminary results of wind tunnel experiment with a tree model. It investigates the effects of a single tree on wind flow behind tree with a focus on the dependence of wind speed, which reflects the deformation of the tree subjected to wind.

METHODS

In this study, the wind flow affected by tree is modeled as the flow through porous-like object. Technically, by applying a spatial filter to the Navier-Stokes equation, the effects on the flow around tree is found to be characterized by three parameters; i.e., ratio of void over a unit volume, projected surface area of objects over a unit volume, and drag coefficient. In theory, these parameter values could be determined by full-scale measurement of tree subjected to wind. However, full-scale measurement is practically not feasible. Therefore, this study works with a tree model and its surrounding wind flow in wind tunnel. In this way the abovementioned three parameters as well as wind speeds at various locations around the tree can be readily measured; therefore, the wind flow can be fully analyzed. Once the effects of tree on wind flow was clarified using these results from the wind tunnel experiment and the wind flow could be reproduced with CFD simulation, the challenge would be reduced to find optimal parameters in CFD simulation that simulate the actual wind flow around tree. The procedure for the investigation in this study is as follows: (1) The tree model is developed: It consists of model parts of a trunk, branches and leaves. Whereas the trunk and the branches are made respectively with wood solid pole and acryl tube that are hard to deform, leaves are made with plastic film and are connected to branches with silicon tube that is easy to deform, see Figure 1. Leaves can be attached/detached from the rest of the model so that it enables us to investigate the effects of tree on wind flow under different conditions regarding the positions and density of leaves. Here, the tree model is divided into three horizontal layers and leaves are installed at one or all of these layers in order to check whether the wind flow around the tree can be approximately modeled with the separate flows at the respective horizontal flows. (2) The tree model is set on aerodynamic balance and placed in wind tunnel: It enable us to measure the drag force acting on the tree model. (3) The wind flow around the tree model as well as the drag force are measured for the reference approaching wind speeds of 2, 4 and 8 [m/s] for different conditions on leaves, see Figure 2. The uniform flow is simulated as the approach flow in wind tunnel. (4) At the same time, the motion of the tree model – especially focusing on the motion of the leaves – is recorded, see Figure 3. (5) The degree of wind speed reduction due to the presence of the tree model is quantified as a function of wind speed and the different conditions on leaves. Also, the drag force acting on the tree model is measured for the three different wind speeds. (6) The relationship between the wind speed reduction and the drag force is investigated from the viewpoint of the equation of momentum.

RESULTS

The record and visual inspection of the motion of the tree model show that the tree shape changes when subjected to wind. These changes differ for different wind speeds. The apparent changes are due to the deformation of the shapes of the leaves themselves and the connections between the leaves and the branches. The deformations of the branches and trunk are of minor. It is believed in this study that these changes are sufficient to investigate the wind-speed dependency of the projected leaf surface area density and the drag coefficient; hence, wind flow behind tree. The measurement of the drag force acting on the tree model shows that the drag force without leaves (i.e. consists of only trunk and branches) is approximately proportional to the square of wind speed, indicating that the projected surface area of objects and the drag coefficient are not changed. On the other hand, the drag force with leaves is not proportional to the square of wind speed, which is considered due to the deformation of the leaves and the connections between the leaves and the branches; i.e. the projected surface area of objects and the drag coefficient are changed. This result confirms that the two of the abovementioned three parameters are wind-speed dependent and these must be appropriately considered in CFD simulation. The degrees of the wind speed reduction behind the tree model are found to differ for different wind speeds. This is interpreted due to the non-proportionality of the drag forces. However, the estimated drag force by using the equation of momentum with the measured wind speeds in front and behind the tree model show a moderate deviation from the measured drag force. The causes of this deviation have yet to be clarified.

CONCLUSION

The tree model developed in this study is found to be useful to analyze (a) the wind flow around tree, (b) wind-speed dependency of the drag force, and (c) the relationship between the wind speed reduction and the drag force. The wind tunnel experiment result indicates the wind-speed dependency of the projected surface area of objects as well as drag coefficient. However, the preliminary results fail to fully explain the relationship between the drag force acting on the tree model and wind speed reduction behind the tree model, which is related through the equation of momentum. The change of the projected surface area of leaves as a function of wind speed is currently confirmed only in a qualitative manner. A technique to estimate (alias of) the projected surface area of leaves based on the record must be developed to quantitatively estimate its value. The reproducibility of the wind flow based on the measured/estimated values of the three parameters (i.e. ratio of void over a unit volume, projected surface area of objects over a unit volume, and drag coefficient) is addressed as one of the next steps.

Figure 1. Tree model.

Figure 3. Deformed tree model subjected to wind (wind flow from left to right)

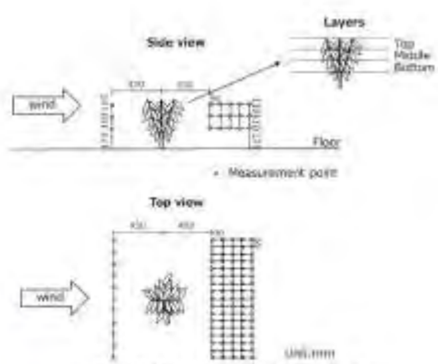

Figure 2. Measurement point of wind speed.

KEYWORDS: *Wind breaking effect, wind tunnel, computational fluid dynamics.*

Flood Vulnerability Assessment of Public School Buildings In Metro Manila, Philippines

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INTRODUCTION

Vulnerability analysis had always been an integral part of disaster risk assessment. Vulnerability pertains to the inherent quality of elements at risk to incur damage upon exposure to a particular hazard. Although the Philippines is frequented by floods, there are little to no recorded information of the actual damages brought to public schools. This paper aims to provide a comprehensive flood vulnerability assessment of public school buildings in the country's capital. The main objective is to estimate the physical damages as a function of inundation depth by gathering actual damage data and analyzing how the community reacts to flood events. The results of this study can be used in developing the insurance mechanism for incentivizing public school buildings. Similarly, this research can give valuable information for the government to decide the specific disaster risk management strategy that must be adopted to public schools, whether to focus in mitigation or towards resiliency.

METHODS

Flood vulnerability assessment was carried out by developing vulnerability curves. A vulnerability curve shows the relationship between inundation depth and damage index. The damage index in the case of physical damage to structures is the ratio of building damage cost and total construction cost of a structure. Building damage cost includes all expenses related to damages in load and non-load-bearing components, building finishes, fixtures, and fixed equipment.

Four (4) public school buildings according to the Department of Public Works and Highways (DPWH) standards were analyzed in this study. The building models are as follows:

- Standard one-storey school buildings (4 class rooms)
- Standard two-storey school buildings (12 class rooms)
- Standard three-storey school buildings (15 class rooms)
- Standard four-storey school buildings (20 class rooms)

In addition to the available building plans, construction data were obtained by visiting some public schools with on-going constructions. The field reconnaissance provided an opportunity to see how the buildings are actually constructed. Similarly, by interviewing teachers and other school personnel, the flood damage response of the school was documented and became the basis for damage cost estimation. The damage cost depends on how people react to the damages brought about by flood, whether an exposed element will be cleaned, repaired or replaced. Site visits were done among different schools within Metro Manila, particularly in the flood-prone areas of Manila, Marikina City and Quezon City. There are also some schools visited that do not frequently experience floods but their school personnel nevertheless had personal accounts of flooding from some other schools. All in all, twenty (20) schools were visited and one hundred (100) people were interviewed.

RESULTS

As a public infrastructure, every flood-damaged school building is being restored to its original state for the general public to use according to its intended functions. Although the timing of restoration is different for each school due to availability of funds and mobilization of the community and local government, total restoration is still achieved in the long run. Table 1 summarizes the damage response of schools based from interviews.

In general, the load-bearing structures of a building are not compromised considering the inundation depth of floods. For concrete surfaces, the normal mode of restoration is through cleaning and repainting. For wooden components exposed to flood, they are either repaired or replaced immediately. As for any electrical element, once the flood reach it, replacement is the preferred course of action.

Table 3. Summary of flood damage response in public school buildings

Attribute	Damage Response
Floor	Clean
Interior Wall	Clean (d=0.1m) / Repaint (d≥0.5m)
Exterior Wall	Clean (d=0.1m) / Repaint (d≥0.5m)
Door	Clean (d=0.1m) / Repair (d=0.5m) / Replace (d≥1m)
Window	Clean and Repair
Blackboard	Replace
Ceiling	Replace (Wood) / Repaint (Concrete)
Electrical Outlets	Replace
Electrical Switch	Replace
Other Electrical Fixtures	Replace
Lighting Fixtures	Replace
Fire Alarm System	Repair
Septic Tank	Maintenance
Roof	Clean

The flood vulnerability curves of Figure 1 describe the over-all physical vulnerability of public school buildings in Metro Manila. For the same inundation depth, buildings of lower heights have higher damage indices. This is because the construction cost increases (the denominator of damage index) as building height increases, with the building damages more or less similar. There are no reported structural damages associated with flood inundation. Total building damage can go up to about 23% of total building construction cost for flood depth of 10 m. For low-height floods, i.e., less than 0.5m, the damage indices range from 4.14% to 1.47% for one-storey to 4-storey schools respectively. This translates to $4,500 to $10,000 of funding needed to restore a public school building in its pre-flooding state. This cost is mainly for wall finishes since the whole wall per floor needs to be repainted, not only the portions exposed to flood. For higher inundation depths, the replacement of electrical components and doors also contribute to the increasing damage cost.

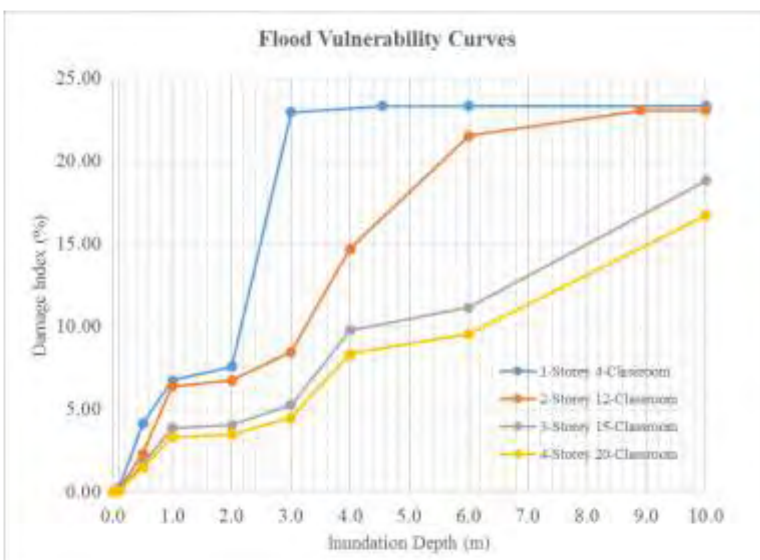

Figure 6. Flood vulnerability curves of public school buildings in Metro Manila

It must be noted that public schools have generally poor flood-coping mechanism as compared to residential buildings. In the event of flooding, the easily damaged contents like personal computers, photocopying machines, LCD projectors and other electrical appliances as well as books, wooden cabinets and chairs are easily exposed to water, unlike in residential houses where there are some measures that can be done to save these things.

CONCLUSION

The physical vulnerability of public school buildings in Metro Manila against floods can be fully described by the vulnerability curves of Figure 1. Based from historical account in the sample population, any inundation depth does not cause structural damages to schools. The damage costs are mainly attributed to cleaning and repairs of exposed elements and replacement of electrical fixtures.

To assess the total vulnerability of public schools, it is recommended to extend this study to other elements at risk, building contents in particular are more vulnerable due to limited flood-response mechanism of public schools.

KEYWORDS: *Flood vulnerability assessment, school buildings, Metro Manila*

Tools for Effective Response: Space Design for Emergency Operation

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INTRODUCTION

“Emergency Architecture” is architecture used at the time of emergency. Universitat Internacional de Catalunya organize the master course program titled “International Cooperation Sustainable Emergency Architecture” (http://masteremergencyarchitecture.com/). This program’s goal is “prepares architects to develop and rebuild communities affected by rapid urbanization, poverty, conflict and natural disasters.” This paper discusses about emergency architecture for effective emergency response.

METHODS

We would like to discuss about how space design for emergency operation tasks such as emergency operation center, shelter, volunteer coordination could work for effective emergency management reflecting the cased in the 2017 Kumamoto earthquake. Field survey were conducted to collect information about emergency architecture.

RESULTS

When we are talking about emergency architecture, main interests of architects are shelter for victims. There are many proposals of shelters and temporary housings after disasters by architects. But emergency architecture have broader sense, and should include all the architecture used for emergency response. The self-defense force deployed the emergency medical clinic and public bath. These are also emergency architecture. There are variety of an emergency architecture such as emergency operation center, temporary medical facilities, logistics center for victims support, shelter, public bath, volunteer coordination center, temporary housing, temporary shop and factory.

From the view point of deployment method, there are two types of emergency architecture style. One is the newly deployed buildings such as an emergency medical clinic of the self-defense force and temporary shelters. Sometimes, a movable architecture is used for these types of emergency architecture. The other style is a conversion of existing buildings. In Japan, a gymnasium of school and a public facility is used a shelter. And usual large meeting rooms are used for emergency operation centers, and open spaces will be used for volunteer coordination spaces or logistic centers. Many emergency architectures are the conversion of existing buildings in Japan. Emergency architectures in Japan, which works for effective emergency response, will be introduced in following chapters by spotlighting to the conversion types.

After the 2017 Kumamoto Earthquake, Emergency Operation Centers were set up in various organizations. At the EOC of Kumamoto prefecture, Self-defense force, fire fighters, Disaster Medical Assistance Team (DMAT), Disaster Psychiatric Assistance Team (DPAT), civil engineers from national government, and prefectural government staffs worked together in the same room. Space for national government field office, assisting prefectural government staff, and executive conference rooms joining all the responding organizations were also set up in the prefecture government building. All the organization responding to the 2017 Kumamoto earthquake could work together in the prefecture building, and it supported a coordinated response to the event.

Volunteer workers play an important role in relief and recovery phase. Volunteer workers helps shelter operation such as food preparation, relief goods delivery, shelter clearing, child care, and administration works in a shelter. In the recovery phase, house clean up, support of moving, temporary roof repair using blue sheet, light mental health care will be done by volunteers. To manage volunteer work, bridging between victims needs and volunteer workers is necessary. Management of volunteer workers are also necessary. And volunteer coordination center is set up in the impacted area. Large scale temporary volunteer coordination center, where volunteer workers get together and getting victims need information, is set up in the impacted area. In case of the 2017 Kumamoto earthquake, the volunteer coordination center is set up in the park in downtown. Effective matching is done based on the well-designed space layout. Workflow of the matching is 1) Volunteer works registration, 2) Orientation, 3) Job selection, 4) Grouping, 5) Work preparation, 6) Work at the site, and 7) reporting. Space layout was decided based on the volunteer coordination process starting from 1) registration and orientation, 2) Job selection, 3) Grouping. And Management space is also deployed. Those effective space layout to manage mass volunteer workers coordination has been developed from various experiences after the 1995 Kobe earthquake disaster.

CONCLUSION

This short essay introduced various emergency architectures used in the 2017 Kumamoto earthquake. Effective space layout make the effective emergency response possible. However, it is essential to understand the goal of each operation and the workflow for the space design. So having a standardized operation procedure, SOP, is very important. And SOP is not only for the space layout. It would work to make manuals, report formats, and ICT systems. Good space layout is only ONE output of the well-designed SOP. It is important to analyze the operations of emergency management and set up SOP is very important for effective emergency management.

Reference

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