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Climate Change Impact and Adaptation in Agriculture:
Examples from Climate-Water-Crop Modelling and Field Studies

ABSTRACT AND PROGRAM

SECOND WORLD IRRIGATION FORUM

8 November, 2016

Chiang Mai, Thailand

Organized by:

Asian Institute of Technology (AIT)
Food and Agriculture Organization (FAO)
Hydro and Agro Informatics Institute (HAII)

BACKGROUND

Agriculture is one of the most severely affected sectors due to climate change. Extreme weather conditions caused by climate change in the past decades have disrupted global food production and increased risk to food security. New studies reported that extreme heat waves and droughts have reduced global cereal harvests such as maize, wheat and rice by 10 percent in a span of 50 years. World Bank estimated that climate change could cut crop yields by more than 25% by 2050. Climate change along with non-climatic factors poses significant threat to agricultural production if no adaptation measures are taken. Understanding and quantifying the impact of climate change in agriculture at different spatial (basin to farm level) and temporal (seasonal to decadal) scale is key to formulate adaptation strategies.

Responding to changes in water availability, improving resiliency and adaptive capacity, responding to floods and droughts, responding to increased irrigation requirements, responding to deterioration of soil and water quality are some of the adaptation measures that can offsets the potential negative impacts of climate change in agricultural production. However, these adaption measures must be evaluated before recommending to policy makers, practitioners, and farmers for adoption. Uncertainty in climate change impact quantification, availability of data, models and qualified/skilful personnel are major challenges to realize the opportunities for adaption.

OBJECTIVE

The objectives of this side event are:

- To understand the broad overview of climate change impact on agriculture sector
- To understand the impact of climate change in irrigation water requirements and crop production in selected basins
- To explore the adaptation measures (modelling and field based studies) to offset the negative impact of climate change on crop production
- To discuss the challenges and opportunities in adapting agriculture to climate change.

ORGANIZING INSTITUTES

Asian Institute of Technology (AIT), Thailand

AIT is the leading multicultural regional hub of educational and research in Asia (www.ait.asia). It has been promoting technological change and sustainable development in the Asian-Pacific region through higher education, research and outreach. Established in Bangkok in 1959, AIT has become a leading regional postgraduate institution and is actively working with public and private sector partners throughout the region and with some of the top universities in the world. AIT has expanded network of partnerships with industry and educational institutions and promoted development, transfer and adaptation of educational and research inputs from global sources to the region and spread local knowledge to the rest of the world. AIT has educated more than 20,000 students and 29,000 short-term trainees from more than 90 countries.

Food and Agriculture Organization of the United Nations

Food and Agriculture Organization (FAO) of the United Nations is an agency of the United Nations (UN) with 194 Member Nations, two associate members and one-member organization, the European Union. FAO's main mission is to achieve food security for all by making sure that people have regular access to enough high-quality food to lead active, healthy lives. FAO is committed to achieve for strategic objectives comprising: 1) help eliminate hunger, food insecurity and malnutrition; 2) make agriculture, forestry and fisheries more productive and sustainable; 3) reduce rural poverty; and 4) enable inclusive and efficient agricultural and food systems; 5) increase the resilience of livelihoods to threats and crises. In addition, FAO also works towards sustainable management and utilization of natural resources, including land, water, air, climate and genetic resources for the benefit of present and future generations.

Hydro and Agro Informatics Institute (HAII), Thailand

Hydro and Agro Informatics Institute (HAII) is a public organization under the Ministry of Science and Technology, Thailand with main responsibilities in developing and applying science and technology to better support agricultural and water resource management from local to international levels.

SECTION I: PROGRAM SCHEDULE

AGENDA

Date : Tuesday, 8 November, 2016 (Duration- 4 hours)
Time: 9:00 – 13:00
Venue : Room B9

09:00-11:00	**Session I**
09.00-09.15	Welcome, Introduction and Objective by Sangam Shrestha
09.15-09.45	Keynote speech: Overview of adapting agriculture to climate change by Mukand S. Babel
09.45-10.00	Climate change, water and food security: an Asian perspective by Puspa R. Khanal
10.00-10.15	Perceiving of Farmers' Agricultural Adaptation in Communities Water Resources Management Scale by Sutat Weesakul
10.15-10.30	Assessment of Agricultural Water Demand in Thailand under Climate Change Impact by Winai Chaowiwat & Kanoksri Sarinnapakorn
10.30-10:45	Case Study: Climate and Drought Trends and their relationships with rice production in the Mun river basin, Thailand by Saowanit Prabnakorn
10:45-11:00	Discussion
11:00-11:15	Health Break

11:15-13:15	**Session II**
11:30-11:45	Climate Change Impact on Water Resources and Crop Yield in the West Seti River Basin, Nepal by Aakanchya Budathoki
11:45-12:00	Climate change impact assessment on rice yield and water footprint in Nam on Irrigation Project, Thailand by Ranju Chapagain
12:00-12:15	Adaptation Strategies for Rice Cultivation Under Climate Change Scenarios in Gujranwala District of Punjab, Pakistan by Sangam Shrestha
12:15:12:30	Groundwater irrigation for climate-proof agriculture in Lao PDR: How the country could benefit from international experiences? by Binaya R. Shivakoti
12:30-13:15	Panel Discussion, Recommendations and Way Forward
13:15-14:00	Lunch Break

Coordinator : Dr. Sangam Shrestha, Asian Institute of Technology (sangam@ait.asia)

SECTION II: ABSTRACTS

Overview of Adapting Agriculture to Climate Change: Cases from Asian Countries

Mukand S. Babel
Professor, Water Engineering and Management (WEM)
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Abstract
Climate change is expected to have multiple impacts on water sector through alteration in climatic variables, sea level rise, hydrologic cycle, water availability, and its spatial and temporal distribution, water demand/use for various economic activities, frequency of extreme hydrologic events, water quality affecting its uses, and ecosystems as a whole.

This presentation highlights global and regional perspective as well as local insight of climate change impacts on hydrology and water resources including erosion and sediment, and on water use sectors, namely municipal, agriculture and irrigation, hydropower etc. It also covers evaluation of various adaptation measures to combat adverse impact on crop yields. The studies at basin level used downscaled climate data from multiple GCM/RCM for different IPCC emission scenarios, and various tools to assess the impacts and adaptation in Asian countries. These research projects include:

- Assessment of future climate and its impact on
  - (a) Hydrology and water resources in Kabul Basin, Afghanistan; Nam Ou Basin, Lao PDR; Bagmati, Tamakoshi and Koshi Basins, Nepal; Upper Indus Basin, Pakistan; Ping, Mae Klong and Pak Phanang Basins, Thailand; and Ba River Basin and South Central Coast, Vietnam;
  - (b) Snow cover in Tamakoshi Basin, Nepal;
  - (c) Urban flooding in Bangkok, Thailand;
  - (d) Water quality in Saigon River System, Vietnam;
  - (e) Soil erosion and sediment in Nam Ou Basin, Lao PDR; and Upper Nan Watershed, Thailand.
- Assessment of impact on future municipal water demand in Bangkok, Thailand.
- Assessment of impact on rice yield in Chi-Mun Basin, Thailand; maize yield in Sikkim, India; and maize yield in wet and dry agro-ecological zones, Uganda.
- Assessment on irrigation water demand in Citarum Basin, Indonesia; Upper Indus Basin, Pakistan and in Mae Klong River Basin, Thailand.
- Assessment of impacts on hydropower in Wangchu Basin, Bhutan; Dudhkoshi Basin, Nepal; Jhelum Basin, Pakistan; and Mae Klong Basin, Thailand.

The key challenges from research and application/policy perspectives are also presented for discussion.

Keywords: Agriculture, Climate change, Hydrology, Water resources, Impacts, Water use sectors

Climate Change, Water and Food security: An Asian Perspective

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Abstract

Asia has made impressive economic growth and rapid rural transformation in the past decades. Millions of rural mass has come out of poverty and starvation through opportunities offered by new economic environment. Water has played a central role in this transformation supporting agricultural change and economic growth while also providing foundation for rural livelihood. While the impressive growth has been possible through higher degree of economic water security, the situation in environmental water security and water related disasters have been poor: much of Asian economic growth has been therefore achieved at the cost of environmental degradation. Asia now faces a dilemma that in one hand, it must continue to increase its economic water security supporting structural transformation and growth of the national economies to ensure poverty reduction and food security. On the other hand, it should move towards greener growth and improve its environmental water security and reduce vulnerability against the water induced disasters.

Managing this dual transitional challenge remains the most pressing issue in Asia today, as they do not necessary complement each other and often they conflict with each other. The existing challenges will be further complicated by the climate change impacts. This presentation centers on this dual transitional challenge facing Asia today and looks at how climate change is expected to add new dimensions in the pre-existing water challenges. It analyzes options to improve water security in major food production systems in Asia under the expected climate change scenario. It argues that future water security must be situated within the broader context of Asian transition and climate change impacts. It concludes recommending water management measures that help facilitate successful transitions towards sustainable growth in the changing Asian context.

Keywords: water and food security, Asian transition, climate change

Perceiving of Farmers' Agricultural Adaptation in Communities

Water Resources Management Scale

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Abstract

Climate change has become a challenge globally specially in developing countries and it has become an essential component for food production and sustainable development. Agriculture is an important sector in Thailand employing 23 million people or 37% of total population, covering 46% of country area. Farmers can cope with climate change by necessitating adaptation. The objectives of study are to analyze farmers' perception on climate change, selecting choices of adaptations, determination of factors and barriers affecting agricultural adaption and evaluation level of satisfaction. Bottom-up approach is used in this research to obtain the first hand information by conducting a survey at household level from the farmers. The data from questionnaires are collected in 2015 to 16 at farm level for 208 households with 95 percent confident levels consisting of the farmer's households belonging to two sub districts i.e Bung Cham Aor and Sala Kru sub districts, Nong Sua district, Pathumthani, Thailand.

The study investigated the farmer's perception towards climate change and examines that how farmers perceived trends in climatic parameters recorded at meteorological stations. Average temperature is increased with increased number of hot days and reduced number of cold days with 66% to 76 % respondents. Annual rainfall, rainfall duration and its frequency are decreased with 69% respondents while length of dry period is extended with 75 % respondents. It shows that short memory in recent severe climate which strongly affect their productivity has influenced their perception for long term climate change. Farmers prefer agricultural adaption as the most selected choice with 69 % compared to financial, technology and external adaptations. This study also identified the major agricultural adaptations used by the farmers. Changing in sowing and planting date, use of fertilizer and pest management practice, and change in cropping pattern are the most fours adaptations that local farmers practically used in the field. Independent factors affecting the choice of agricultural adaptations and barriers to adaptation are identified. A multivariate probit model for discrete choice was used to determine the main factors that affects the choice of adaptation strategies at farm level. It is confirmed from the results that age, income, household size, distance from market and farming experience are the five important ascending factors affecting the farmers choice to farm-level adaptation. It can be analyzed that age of head of farmers are the main factors to capture farming experience and use it for their adaptation. Income represents wealth which is normal hypothesized to adopt agricultural technologies requiring sufficient

financial support. Household's size indicates higher labor endowment and can accomplish various agricultural tasks including implementing traditional pest management which is laboriously required in their farm.

In summary, community water resources management at Bung Cham Aor can plan and use effectively available water to get high selling price for their productivity at the peak demand time. Using science and technology approach with strong participation from community, farmers can learn to use data and develop their own system for water management for climate adaptation.

Keywords: Farmer perception, agricultural adaptation, multivariate probit mode, community water resources management

Assessment of Agricultural Water Demand in Thailand under Climate Change Impact

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Abstract
Global climate change has induced extreme rainfall, in terms of frequency, duration, pattern and intensity, in many countries including Thailand. Thailand has faced more flooding events and higher drought frequencies in the last few years, and is currently experiencing severe drought conditions and water shortages. The main consumers of water in Thailand are in the agricultural sector, where climate change has caused damages to cultivated areas during both wet and dry seasons. In particular, in 2015 and into 2016 Thailand has experienced drought phenomena. The Thai government has attempted to solve the drought problem by encouraging farmers to stop cultivating paddy rice in dry season and change the type of crop to less water consuming plants. It is, therefore, proved necessary to adapt water management policies and practices to ensure water demand side can be met by the water supply side, especially when the current water storage is limited, as in the current drought situation. The purpose of our study was to assess the impact of climate change on rainfall, temperature, and water demand in the main river basin in Thailand. The future climate model adopted in this study is focused on 7 general circulation model datasets with Representative Concentration Pathways (RCPs) 4.5 and 8.5 scenarios. The results show that the changing climate will result in about a %15 increase in water demand in both scenarios. The high risk water deficit areas include the Ping, Yom, Nan, Chi and Mun River Basins due to increasing water demand and decreasing rainfall. The Salween River Basin has the highest risk of a water deficit with the greatest increase in water demand of .%32.6

Keywords – climate change, water demand, general circulation model, statistical bias correction, evapotranspiration

Climate and drought trends and their relationships with rice production in the mun river basin, thailand

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Abstract
The variability in climate regime is an important factor contributing to rice yield variations in Thailand because nearly 80% of total rice cultivation is rain-fed. Here we investigated the past weather conditions using a drought index (SPEI) and examined correlations of rice yield with SPEI and with other climatic variables (precipitation and temperatures) in the Mun River Basin, Thailand. The results show that the basin experienced both wet (leading to floods) and dry (leading to droughts) climatic conditions in recent years. During rice cultivation, over the past 30 years, the months with wet conditions was slightly higher than the dry one. Quick variations of weather conditions, i.e. from severe drought in a month turned to extreme wet in the next month etc. were observed more frequently since year 2000. Additionally, the 3-month SPEI exhibited that the dry conditions were prominent during the period of 1986-1999, whereas the wet conditions were prominent afterwards. The alternate occurrences of floods and droughts were also noticed, for example the flood in 2011 were followed by the drought in 2012. For the correlations of rice yield with the climatic variables and with the SPEIs, we found that increasing minimum and maximum temperatures generally suppressed rice yield. In contrast, precipitation and 1-month SPEI had positive correlations with the yield, except in September. We also found that i) the yield presented better associations with temperatures than precipitation, ii) maximum temperature showed slightly stronger correlations with the yield than minimum and mean temperatures, iii) the yield was more correlated with 1-month SPEI than with precipitation and SPEI with other timescales. Therefore, the 1-month SPEI should be used to monitor soil moisture and crop stress in rice. In addition, we observed that rainfall in the basin is much less than the water requirements for rice and that makes average rice yield in Thailand is one of the least among the major rice producing countries in Asia. Therefore, irrigation and drainage systems supplemented by alternative sources of water in combination with innovative method of rice cultivation and efficient water management techniques should be introduced to enhance the rice yield. Our findings form a basis to quantify impacts of climate variability and change on rice production.

Keywords: Climate, Drought index, Rice yield, Mun River Basin, Thailand.

Climate Change Impact on Water Resources in the West Seti River Basin, Nepal

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Abstract
West-Seti River Basin, situated in far-western region of Nepal, is one of the most exposed basins in regards to the potential impacts of climate change. In this context, this research evaluated the impacts of climate change on water resources and crop yield in this basin. The first stage included bias correction of observed temperature and precipitation data for the historical period taken from the Department of Hydrology and Meteorology. Future climate data was downscaled from three RCMs, namely ACCESS, GFDL and MPI, and projections were made for RCPs 4.5 and 8.5. The predicted temperature in the basin showed considerable rise in both maximum and minimum temperature. The rise in temperature was steep for RCP 8.5 compared to RCP 4.5, while increase in minimum temperature is more than the maximum temperature. Both seasonal as well as annual precipitation is expected to increase slightly higher for RCP 8.5 than RCP 4.5 although there is no substantial difference between them. Further, SWAT model was used for calculation of components of water balance and crop yield. The model assessed both the hydrologic processes as well as crop growth well up to an acceptable level. The lower part (Hills) of the basin is expected to have 15% increase in precipitation and 25% increase in water yield, but the actual ET is higher in the upper part (Middle Mountains and High Mountains) of the basin with an increase of 23% in High Mountains and 14% in Middle Mountains. An increase in crop yield is estimated for summer (corn, rice) and winter crops (barley, wheat) but with relatively less increase in rice yield. A strong correlation was found between crop yield and average temperature. The result indicates the possibility of further increasing the crop yield, especially for barley, by advancing the crop calendar by one month. In order to avail such opportunities of increasing crop yield under future climate, the agricultural extension services should focus on enhancing the awareness of local people. In addition, low flows in the basin are expected to decrease and high flows are expected to increase which indicates that water resources development can be explored as an option. The ministries and departments responsible for planning and management of water resources in Nepal should consider the expected increase in temperature and future flows as an opportunity for further water resources development in the basin. Future research may consider land use changes and detailed analysis of crop growth using specific growth models.

Keywords: Climate change, RCM, West Seti basin, SWAT, water resources, streamflow, crop yield

Climate change impact assessment on rice yield and water footprint in Nam on Irrigation Project, Thailand

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Abstract
Quantification of potential climate change impact on rice yield and its corresponding water footprint was carried out using CERES-Rice crop growth model for Nam Oon Irrigation Project of Thailand. Crop phenology data were obtained from field experiments and were used to set up and validate CERES-Rice model. The present water footprint (green, blue and grey) of rice, defined as amount of water evaporated during growing period or rice, was then calculated for irrigation area. The outputs of three regional climate models (ACCESS-CSIRO-CCAM, CNRM-CM5-CSIRO-CCAM and MPI-ESM-LR-CSIRO-CCAM) for scenarios RCP 4.5 and RCP 8.5 were downscaled using quantile-mapping. Simulation results from CERES-Rice shows considerably high declination in yield of KDML-105 and RD-6 rice varieties ranging from 32.9 to 37.2 % and 10.7 to 12.8% respectively in future under RCP 4.5 and 34.7 to 38.2% and 11.4 to 17.5% respectively under RCP 8.5 relative to simulated baseline yield for period of 1976-2005. ChaiNat-1 variety, on contrary shows an increase of 78.46% to 59.35% in projected future yield. As for projected future water footprint, water footprint for KDML 105and RD6 increase between 56.5 to 76.4 % and 27.55 to 37.61% respectively and a decline ranging between 42.2 to 31.7% can be observed in water footprint of ChaiNat variety. The results also indicate increase in future blue water footprint will be very huge which consequently will cause high increment in amount of irrigation water requirement in order to meet plant's evaporation demand. The outcomes of the research highlights importance of looking for proper adaptation strategies in order to reduce or maintain acceptable water footprint under future climate.

Keywords: Climate Change, Food Security, Rice Production, Water Footprint

Adaptation Strategies for Rice Cultivation Under Climate Change Scenarios in Gujranwala District of Punjab, Pakistan

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Abstract
Climate Change poses an alarming threat to agriculture and global food security. Rice production in Pakistan holds an extremely important position in agriculture and the national economy. Since District Gujranwala has the largest production of rice in Punjab, Pakistan therefore it is need of the hour to assess the impact of climate change on productivity of rice and lessen its impact by use of agricultural adaptation measures in Gujranwala District. This study focuses on assessing impact of future climate on rice production and the evaluation of different agricultural adaptation measures suggested by farmers themselves to minimize the impacts of climate change using DSSAT Model. Future climate scenarios under outputs of RCP 4.5 and RCP 8.5 for the periods 2016-2040, 2041-2070 and 2071-2099 were developed using three GCMs CCSM4, MIROC5 and MPI-ESM-MR and downscaled using Quantile Mapping Bias Correction Technique. The minimum and maximum temperature of the district is projected to increase by 0.975 to 3.625°C and 0.65 to 3.2°C respectively in future. Similarly, the annual precipitation is expected to decrease by 6% to 12%. The model DSSAT was used to simulate the impact of future climates on yield. Results show that climate change will reduce yield from 1.09 to 26% for both scenarios and all time periods, relative to baseline yield. This decrease of yield can be offset by opting for various agricultural adaptation measures. On the basis of famer survey it was found that the practised agricultural adaptation measures of proper management of nutrients, irrigation, use of alternate rice variety and shifting the planting dates have been helpful in mitigating the impact of climate change. Late transplanting of rice increases the yield by 9.9% to 22.2% in future. Increasing the fertilizer application rate enhances the yield from 3.73% to 26.96% under future climate. Delaying the time of application of fertilizer increases the yield from 4.33% to 13.04% in future. Shifting to alternate varieties also increases the yield in future. Deficit Irrigation increases the yield from 2.51% to 22.2% for the future. Therefore, based on these findings change in planting date, deficit irrigation, proper nutrient management and adopting to alternate rice cultivars can be beneficial for the adaption of rice cultivation under climate change scenarios in Gujranwala District of Punjab, Pakistan.

Keywords: Adaptation, climate change, rice, Pakistan

Groundwater irrigation for climate-proof agriculture in Lao PDR: How the country could benefit from international experiences?

Binaya Raj Shivakoti, Hiromasa Hamada, Anousith Keophoxay, Paul Pavelic, Corentin Clement

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Abstract

Agricultural groundwater use is being viewed as a reliable alternative in Lao PDR due to increasing uncertainty over water availability. Although the country receives plentiful rainfall and hosts a network of rivers, new drivers such as climate change, commercial agriculture, and competition for hydro-power, ecosystem and urbanisation are shifting demand-supply pattern. Groundwater could become a viable alternative either as a supplement or a main source of irrigation. Before the expansion of agricultural groundwater could become a norm, Lao PDR should have appropriate governance mechanisms in place so that "tragedy of groundwater commons" due to unplanned and uncontrolled resource exploitation, as observed in other Asian countries, such as China and Indo-Gangetic plains were not repeated in the first place. This paper examines the challenges of establishing vibrant institutions at different levels for promoting sustainable groundwater use. Lessons were drawn from existing mechanisms of groundwater governance in Asia, including the Lower Mekong countries, to assess necessary management requirements to ensure that resource sustainability is not compromised.

Review of groundwater governance cases across Asia reveals that management interventions, if any, are only considered at the latter stage of groundwater development when problems such as groundwater table depletion are visible. Proper incentives and access to information about groundwater resources could be the binding factor for promoting groundwater management decisions either through better regulatory control or an initiation of collective action. Secured access to groundwater and affordable cost sharing mechanisms are two basic expectations of the farmers. Besides provisioning of groundwater, extra measures to add value such as efficient methods of water application, better agronomic practices, or marketing services could be equally vital for productivity improvement, higher returns, and resilient livelihood.

Making groundwater irrigation viable in Lao PDR is therefore about equipping farmers with information and securing year-round access to groundwater in sufficient quantity and quality. A stronger linkage with local bodies (such as village leaders, agriculture traders, agriculture extension staffs, etc.) and their effective coordination could lead to a productive groundwater use and to undertake risk reduction measures against climatic or

non-climatic factors. A more difficult task is to establish a vertical linkage with line agencies, such as electricity, land use, agricultural development, water resources, which have an important role in providing support, clearing regulatory hurdles, and mainstreaming sustainable groundwater management in the national policies. Considering that groundwater irrigation is still in its infancy in the country, the task of establishing and implementing necessary legal/regulatory frameworks and effective coordination among relevant institutions could take more time. It is quite important that Lao PDR should make the best use of the successful and unsuccessful lessons of groundwater irrigation from other regions and put in place necessary enabling conditions to ensure that groundwater is used in a sustainable way and strategically to protect its agricultural sector from the adverse impacts of climate change.

SECTION III: BIOGRAPHIES OF SPEAKERS

(Alphabetical Order)

Aakanchya Budhathoki, Ms.

Ms. Aakanchya Budhathoki is a Research Associate in Water Engineering and Management at the Asian Institute of Technology (AIT), Thailand. She is working as a conference coordinator in Water Security and Climate Change 2016 (WSCC2016) conference. Her research interests are within the field of (hydrology and water resources including, climate change impact assessment and adaptation in the water, integrated water resources management and groundwater assessment and management.) Prior to her master studies at AIT, Aakanchya worked as a researcher at International Water Management Institute (IWMI) – Nepal wherein she was a part of "Water Management Interventions to cope with climate change and uncertainty in the "Indo Gangetic Plains and Vulnerability and robustness of irrigation systems in Nepal" projects. She has also worked with Sanima Hydro and Engineering Ltd. in Nepal as an intern wherein she worked in Hydrological, Geological and Hydraulic aspects of projects. Her research in AIT was on Climate Change Impact on Water Resources and Crop Yield in the West Seti River Basin in Nepal. She also was a recipient of DAAD Scholarship Exchange Student at Technical University – Braunschweig, Germany from October – December 2015. She completed her masters in May 2016.

Binaya Raj Shivakoti, Dr.

Dr. Shivakoti has been working as a Water Resources Specialist at Institute for Global Environmental Strategies (IGES) since 2010. He has accumulated over ten years of experience working on diverse issues of water resources management in Asia. Currently he is involved in research on improving groundwater governance, climate change adaptation, sanitation, wastewater and water quality management and investigating on the effective implementation of Sustainable Development Goals on Water in Asia. He is also involved in networking activities on groundwater through Asia Pacific Water Forum Regional Knowledge Hub for Groundwater Management and Groundwater Solutions Initiative for Policy and Practice (GRIPP) - a newly established global partnership on sustainable groundwater management. Dr. Shivakoti completed his PhD from Kyoto University, Japan in 2007 and M.Sc. from Asian Institute of Technology (AIT), Thailand in 2004.

Kanoksri Sarinnapakorn, Dr.

Sarinnapakorn is a researcher at Hydro and Agro Informatics Institute (HAII) under the Ministry of Science and Technology in Thailand. She received her Ph.D. degree in Electrical and Computer Engineering at University of Miami, USA, got B.S. and M.S. degrees in Statistics from Kasetsart University in Thailand, and got another M.S. in Computer Sciences from Fairleigh Dickinson University, USA. Her expertise is in applying advanced data mining and statistical machine learning methods to real world problems. She is interested in employing the combination of dynamical and statistical modeling to improve the performance of weather and climate model and, in particular, seasonal and extreme events predictions. During her five years with HAII, she is actively involved in the research and development of weather and climate prediction models for the purpose of water resource management. She attended the Weather Research and Forecasting model (WRF) tutorial and WRF Data Assimilation at National Center for Atmospheric Research (NCAR), USA. She participated in CAS-TWAS-WMO forums and several summer school trainings in Advanced Atmospheric Science research at Institute of Atmospheric Physics (IAP), China. She worked on coupled models, WRF-ROMS, based on Coupled-Ocean-Atmosphere-Wave-Sediment Transport modeling system (COAWST) from U.S. Geological Survey (USGS). She joined the Climate Predictability Tool (CPT) training of International Research Institute for Climate and Society (IRI), USA. She is currently working on 7-day rainfall prediction using coupled models (WRF-ROMS) and seasonal prediction models. She also focuses on research to operation (R2O) and operation to research (O2R) concepts to improve accuracy of weather and climate prediction.

Mukand S. Babel, Dr.

Dr. Babel is a Professor and Coordinator of Water Engineering and Management at the Asian Institute of Technology (AIT), Thailand. In addition, he holds Directorship of the Center of Excellence for **S**ustainable **D**evelopment in the Context of **C**limate **C**hange (SDCC) which supports AIT's vision of responding to global climate change challenges and encourages trans-disciplinary efforts leading towards a more sustainable society. Concurrently, he is leading the **C**limate **C**hange **A**sia (CCA) initiative at AIT, a re-launch of SDCC, for **c**atalyzing **c**apacity for **a**ction to address climate change issues in the region. He has been Visiting Professor at several universities/institutes in the region including Kyoto University (Dec 2012-Mar 2013), University Teknologi Mara, Malaysia (Aug 2013-Jul 2015) and Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHIATS), Allahabad, India (Nov 2014-Oct 2019). Prof. Babel's professional experience in teaching, research and consultancy spans over 30 years in Asia. He teaches graduate level courses on Watershed Hydrology, Hydrologic and Water Resources Modeling, Integrated Water Resources Management and Water Supply and Sanitation. In 2014, He

was appointed as a Member of the Advisory Committee of the World Water Quality Assessment, an initiative of UN-Water Group led by UNEP and GEMS/Water. In 2014 he was appointed as a Member of the Executive Committee, Asia Pacific Division (APD) of International Association for Hydro-Environment Engineering and Research (IAHR) for two years (2015-16). In 2015, he was elected as one of Directors of the Executive Board of International Water Resources Association (IWRA) for three years (2016-18). In 2016, he was appointed as a member of recently established Asian Water Council (AWC) representing the Asian Institute of Technology (AIT). Dr. Babel has supervised 21 doctoral and 170 master theses covering diverse areas of hydrology and water resources. Currently there are 08 doctoral and 14 master thesis students working under his supervision. With over 250 publications in international refereed journals, books (including one on Climate Change and Water Resources), and book chapters and conference proceedings, he currently conducts interdisciplinary research relating hydrology and water resources with economic, environmental and socioeconomic aspects of water to address diverse water problems and issues including climate change impact and adaptation in water sector. Dr. Babel carried out many research and sponsored projects in collaboration with international organizations and governments including CGIAR-WLE Program; Dutch Government; CIDA; The World Bank; FAO; UNESCO-IHE; UNU; ADB; DANIDA, ICH, Norway and NEF, Japan; GWP, Sweden; UN-DESA; ASCE; UNESCO; UNEP; IGES, Japan; APN, Japan; UCC-Water, Denmark; Govt. of Thailand; Govt. of Indonesia; Govt. of Nepal; Govt. of Bhutan; and ICAR, Govt. of India, as well as with respected universities, such as Konkuk University, South Korea; Oregon State University, USA; Tohoku University, Japan; and University of Tokyo, Japan. It is worth mentioning the project on Vulnerability Assessment of Freshwater Resources in Tranboundary river basins (Ganges-Brahmaputra-Meghna, Indus, and Helmand in South Asia and Mekong in Southeast Asia) conducted for UNEP.

Puspa Raj Khanal, Dr.

Dr. Khanal is a senior water and irrigation expert at the Food and Agriculture Organization of the United Nation Regional office in Bangkok. He is engaged in field program development and supervision in irrigation and water sector in the Asia and Pacific region. His research interests are within the field of irrigation modernization, IWRM, water, climate change and food security issues. Dr. Khanal has published several scientific and policy papers in water and irrigation management sector focusing on climate change, food security, poverty and governance issues. He has also contributed in the preparation of strategy and policy papers in water and irrigation sector in many Asia countries.

Ranju Chapagain, Ms.

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The current Deputy Director of Hydro and Agro Informatics Institute (HAII), Ministry of Science and Technology, Thailand, Dr. Sutat Weesakul graduated with a doctoral degree in Engineering (Hydraulic/ Coastal) from The Asian Institute of Technology (AIT), Thailand. Before working with HAII, he was a Director of Research Project, Water Engineering and Management Program at AIT. His research interests focus on Water Resources Engineering and Management, Hydraulic and Hydrology and Numerical computation in sea and coastal area including flood propagation. With over 35-year experience in teaching and researches, he is an expert in hydraulic and coastal engineering and has been involved with many international projects in collaboration with private sectors and government agencies to enhance water resources management in Thailand.

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