DEVELOPING CLIMATE INCLUSIVE POTENTIAL LOSS AND DAMAGE ASSESSMENT METHODOLOGY FOR FLOOD HAZARD

The following collaborators worked on this project:

1. Dr. Senaka Basnayake (Project Leader), Director, Climate Resilience Asian Disaster Preparedness Center, Bangkok, Thailand; email: senaka_basnayake@adpc.net
2. Dr. Peeranan Towashiraporn (Collaborator), Director, Asian Disaster Preparedness Center, Thailand; email: peeranan@adpc.net
3. Prof. Mehmet Ulubasoglu (Collaborator), Professor, Deakin University, Melbourne, Australia; email: mehmet.ulubasoglu@deakin.edu.au
4. Dr. Muhammad Habibur Rahman (Collaborator), Senior Lecturer, Curtin University, Australia; email: habib.rahman@curtin.edu.au
5. Mr. Lalith Chandrapala (Collaborator), Director General, Department of Meteorology, Sri Lanka; email: lalithch@hotmail.com
6. Mr. Sarath Premalal (Collaborator), Director General, Department of Meteorology, Sri Lanka; email: spremalal@yahoo.com
7. Dr. Madan Lal Shrestha (Collaborator), Small Earth Nepal; email: madanls@hotmail.com
APN seeks to maximise discoverability and use of its knowledge and information. All publications are made available through its online repository “APN E-Lib” (www.apn-gcr.org/resources/). Unless otherwise indicated, APN publications may be copied, downloaded and printed for private study, research and teaching purposes, or for use in non-commercial products or services. Appropriate acknowledgement of APN as the source and copyright holder must be given, while APN’s endorsement of users’ views, products or services must not be implied in any way. For reuse requests: http://www.apn-gcr.org/?p=10807
# Table of Contents

Table of Contents ................................................................................................................. 1  
Project Overview .................................................................................................................... 1  
Background of the Project .................................................................................................... 3  
A. Develop a climate inclusive flood hazard risk assessment method for the target areas in Nepal, Sri Lanka and Thailand ........................................................................... 5  
   1. Introduction (Output 1) ................................................................................................. 5  
   2. Methodology ............................................................................................................... 7  
   3. Results & Discussion ................................................................................................. 14  
   4. Conclusions ............................................................................................................... 15  
B. Developing an Econometric Model on Loss and Damage in Agriculture Sector .......... 16  
   1. Introduction (Output 2) ................................................................................................. 16  
   2. Methodology ............................................................................................................... 16  
   3. Results and Discussions ............................................................................................. 21  
   4. Conclusions ............................................................................................................... 27  
C. Assessment of Flood Early Warning System in Nepal .................................................. 27  
   1. Introduction (Output 3) ................................................................................................. 27  
   2. Methodology ............................................................................................................... 27  
   3. Results and Discussion ............................................................................................. 29  
   4. Conclusion ............................................................................................................... 31  
D. Climate Smart Disaster Risk Reduction Interventions in Agriculture Sector – Practitioner’s Handbook (Output 4) ..................................................................................... 32  
   5. Future Directions ....................................................................................................... 33  
   6. References .................................................................................................................. 34  
   7. Appendix .................................................................................................................... 36
Project Overview

Project Duration: September 2014 – October 2019

Funding Awarded: US$ 45,000 for Year 1; US$ 42,750 for Year 2; US$ 38,000 for Year 3

Key organisations involved:
1. Dr. Senaka Basnayake (Project Leader), Director, Climate Resilience Asian Disaster Preparedness Center, Bangkok, Thailand
2. Dr. Peeranan Towashiraporn (Collaborator), Director, Asian Disaster Preparedness Center, Thailand
3. Prof. Mehmet Ulubasoglu (Collaborator), Professor, Deakin University, Melbourne, Australia
4. Dr. Muhammad Habibur Rahman (Collaborator), Research Fellow, Deakin University, Melbourne, Australia
5. Mr. Lalith Chandrapala (Collaborator), Director General, Department of Meteorology, Sri Lanka
6. Mr. Sarath Premalal (Collaborator), Director General, Department of Meteorology, Sri Lanka
7. Dr. Madan Lal Shrestha (Collaborator), Small Earth Nepal

Project Summary

ADPC in collaboration with Deakin University (Melbourne, Australia), Department of Meteorology (Sri Lanka) and Small Earth Nepal (Nepal) has been implementing a project on “Developing climate inclusive potential loss and damage assessment methodology for flood hazards” in Nepal, Sri Lanka and Thailand respectively. The study aims to address regional research to develop econometric methodology for estimating damage and loss due to floods in the agricultural sector, strengthening early warning system for floods and improving the methodology for flood risk assessment considering climate change. The project tends to explore science based DRR and CCA interventions to bring behavioural changes to the farming community to adapt themselves to the change in cropping calendar, crop varieties, and other climate smart technological packages. The project will go a long way in undertaking proactive measures to minimise flood disaster risks through climate smart DRR and CCA interventions. The outcomes will also help local government authorities to mainstream climate smart DRR and CCA practices for development and planning at the local government levels.

Keywords: DRR, CCA, Early Warning, Damage and Loss, Risk Assessment

Project outputs and outcomes

List the project outputs and outcomes. Please refer to the logical framework matrix that you developed in the proposal.

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop a climate inclusive flood hazard risk assessment method for the target areas in Nepal, Sri Lanka and Thailand</td>
<td>Improved methodology for risk assessment for flood hazard in consideration of climate change</td>
</tr>
<tr>
<td>Outputs</td>
<td>Outcomes</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Develop an econometric method for estimating economic loss and damage</td>
<td>Improved methodology for estimation of loss and damage in agriculture sector due to flood</td>
</tr>
<tr>
<td>in agricultural sector in target countries</td>
<td></td>
</tr>
<tr>
<td>Assessment Report and Strengthen flood early warning systems in the</td>
<td>Improved science based DRR and CCA interventions for minimising flood damage to agriculture crops</td>
</tr>
<tr>
<td>target countries</td>
<td></td>
</tr>
<tr>
<td>Develop guidebooks for policy makers through several science-based DRR</td>
<td></td>
</tr>
<tr>
<td>and CCA interventions</td>
<td></td>
</tr>
</tbody>
</table>

**Key facts/figures**
- 2 peer review papers are under review
- 1400 household surveyed in 3 countries (Nepal, Thailand and Sri Lanka)
- 1 tool for Loss and Damage Assessment developed
- Developed climate scenarios for 3 countries (Nepal, Thailand and Sri Lanka)
- 1 report on ‘DRR and CCA Interventions for Agriculture Sector to Cope up with Anticipated Future Extreme Flood Events’ published
- 1 guidebook published for local government officials for mainstreaming Climate Smart DRR and CCA practices for agriculture sector
- 20 government officials trained on Econometric Modelling and DRR and CCA Interventions for Floods

**Potential for further work**
The present work has the potential of expanding into other countries as the methodology developed for loss and damage estimation when clubbed with information on potential flood risk zones can be an effective tool for planning risk mitigation measures, risk insurance planning and impact-based forecasting and warnings. The present work can also be used as baseline for planning Community based early warning systems for better preparedness.

**Publications**
List all journal publications / books etc. published during under this project. Provide the publication’s citation in APA style and cover image where possible.

Guven, C., Rahaman, M.H., Ulubasoglu, M., Basnayake S. and Jayasinghe, S. Effects of Floods on Life Satisfaction among Sri Lankan Farmers in a Randomized Controlled Trial (under Review).


Awards and honours

No awards or honours were received by the project

Pull quote

No specific quotes available

Acknowledgments

The PI would like to express his gratitude to the Asia Pacific Network for Global Change Research for funding the project. He would also like to thank Deakin University, Small Earth Nepal and Department of Meteorology, Government of Sri Lanka for their support in carrying out the research successfully. Sincere thank is due to the Executive Director, Asian Disaster Preparedness Center (ADPC) and other senior management and colleagues of ADPC for encouragement and suggestions on implementation of the activities. Special thanks due to Mr. Susantha Jayasinghe, Technical Specialist and Dr. Niladri Gupta, Senior Climate Risk Management Specialist of ADPC for their valuable contributions to the project. Specials thanks also due to Dr. B.V.R. Punyawardena, Director/ Principal Scientist (Agro-climatology), NRMC, Department of Agriculture, Government of Sri Lanka for his generous support to introduce the project findings to Department of Agriculture in Sri Lanka.

Background of the Project

Flood hazards are one of the consequences of climate change induced extreme event. Considering the effects of climate change-induced floods, South Asia is one of the most flood-vulnerable regions in the world (Mirza, 2011). Floods happen frequently in those places which were hit by higher levels of monsoon precipitation and they can cause large damages to animal and human lives, property, crops and infrastructure. The frequency, magnitude and extent flooding of extreme floods has been increasing in South Asian countries. Therefore, flooding in the monsoon season can primarily cause major damage to rice yields, which may have secondary implications on several socio-economic indicators including the food security of vulnerable groups and public health in the flood plains.

As argued by Aggarwal and Sivakumar (2011), Himalayan glaciers, a major source of water for the rivers in the Indo-Gangetic plains, are projected to significantly reduce in future that could affect food and livelihood security of millions of people in Pakistan, Nepal, Bhutan, India, and Bangladesh. Climate change is further projected to cause a 10–40% loss in crop production in the region by the end of the century. The increased climatic variability in future would further increase production variability. Producing enough food for the increasing population in a background of reducing resources in a changing climate scenario, while minimizing environmental degradation is a challenging task. The authors recommend a “Regional Adaptation and Mitigation Framework” for South Asia to assist the region in increasing its adaptive capacity to climate change. This includes assisting farmers in coping with current climatic risks, intensifying food production systems, improving land, water and forests management, enabling policies and regional cooperation, and strengthening research in critical areas.

Francisco (2008) examines the adaptation strategies and options of developing countries, in particular, Southeast Asia to changes in weather variability. Adaptation is defined as the actions taken by persons,
groups, or governments in response to changes in climate, to decrease the negative effects of such changes. The author argues that adaptation strategies have hardly been considered by many Southeast Asian countries in as recently as two or three years ago. In the paper, the author first presents potential options to deal with climate change. Then, the paper focuses on the calculation of cost of each of these options/strategies. It appears that the cost of these strategies is not small and the countries couldn’t find domestic and foreign funding sources. The paper provides a summary of these funding sources. The author suggests that in order to minimize the cost of employing a strategy to combat climate change, the countries work together to share and transfer the risk.

Sharma (2012) provides an overview of flood disaster trends in the Asia region during past 50 years (1960-2009) and recommends integrated flood management wheel concept and ‘no-regret’ adaptation strategies to reduce impact of such extreme events on society and ecosystem. The number of flood events across various parts of Asia increased by three folds and six folds between 2000-2009, when compared to period 1980s and 1970s, respectively. India is more vulnerable to flood events with about 68% of the total socio-economic damages caused compared to other countries in the region, followed by Bangladesh. Ibrahim (2010) provides a summary of Practical Action Sri Lanka, in partnership with DESMIO, a local NGO, sought to facilitate a housing project with people with disabilities and those most vulnerable in Mannunipattu Division of Batticaloa – a conflict affected and hazard prone division after the 2004 South Asian Tsunami.

With the financial assistance of the Asia-Pacific Network (APN), all of the above evidences directed Asian Disaster Preparedness Centre (ADPC) along with Deakin University (DU), Department of Meteorology (Sri Lanka) and Small Earth Nepal (Nepal) in implementing the project on “Developing climate inclusive potential loss and damage assessment methodology for flood hazards” in Nepal, Sri Lanka and Thailand respectively. In particular, the study aims to address regional research to develop econometric methodology for estimating damage and loss due to floods in the agricultural sector, strengthening early warning system for floods and improving the methodology for flood risk assessment considering climate change. The project tends to explore science based DRR and CCA interventions to bring behavioural changes to the farming community to adapt themselves to the change in cropping calendar, crop varieties, and other climate smart technological packages. The project will go a long way in undertaking proactive measures to minimized flood disaster risks through climate smart DRR and CCA interventions. The outcomes will also help local government authorities to mainstream climate smart DRR and CCA practices for development and planning at the local government levels.

The main outputs for this project were:

1. Develop a climate inclusive flood hazard risk assessment method for the target areas in Nepal, Sri Lanka and Thailand
2. Strengthen flood early warning systems in the target countries
3. Develop an econometric method for estimating economic loss and damage in agricultural sector in target countries
4. Develop guidebooks for policy makers through several science-based DRR and CCA interventions

The four outputs were accomplished year wise and are described output wise.
A. Develop a climate inclusive flood hazard risk assessment method for the target areas in Nepal, Sri Lanka and Thailand

1. Introduction (Output 1)

The delivery of the first output initiated with a focus on collection of historical data, pilot site selection, generation of present and future climate scenarios as well as carrying out hazard and risk assessment for floods affecting the agricultural crops. To accomplish the task, data collection was carried out from relevant departments of Nepal, Sri Lanka and Thailand as well as from secondary data sources in each country to develop hazard maps. The data collected included the following:

1. Country wise administrative boundary were accessed from Royal Irrigation Department (RID), Thailand, Department of Meteorology (DoM), Sri Lanka and International Centre for Integrated Mountain Development (ICIMOD), Nepal.
2. ASTER DEM at 30 m resolution was used to generate Digital Elevation Model for the selected pilot sites. The DEM was used to understand the elevation, slope and aspect of the pilot sites.
3. Country specific Historical flood hazard data were collected from RID-Thailand, Irrigation Department (ID), Sri Lanka and Department of Hydrology and Meteorology (DHM), Nepal at the district level which mostly included information on flood affected area, timeline of flood events, number of casualties, damage and loses to agricultural crops and damage and losses to households.
4. Discharge and water level as well as rainfall data were collected from RID, Thailand, DoM and ID, Sri Lanka and DHM, Nepal.
5. Location of the water level and rainfall station were collected from RID, Thailand and ID and DoM, Sri Lanka.
6. River Network and Catchments were digitized from Google Earth data while available data from RID, Thailand, ID; Sri Lanka and ICIMOD, Nepal were also used (Figure 1).
7. Rainfall Data from RID, Thailand, DoM, Sri Lanka and DHM, Nepal were collected for the period 1970-2014.
8. Landuse/Landcover maps from RID, Thailand; ICIMOD, Nepal and DoM, Sri Lanka were collected to gain understanding of the cropped and non-cropped areas (Figure 2);
9. Paddy cultivation data including crop yield, crop extents, crop patterns/calendars and market prices were collected from RID, Thailand and Department of Statistics, Sri Lanka

2. Methodology

The data collection was followed by historical climate data analyses. Statistical analysis of historical climate data is essential for understanding the present-day climate, climate change, natural climate variability, extreme events, etc.
It also helped us to understand the degree of local climate forcing over the pilot sites in target countries. This information was helpful for impact and vulnerability studies in the agriculture sector. The analysis of historical data was done based on the maximum availability of climatic parameters for each pilot sites in each country. Annual trend and coefficient of variation are presented below for minimum and maximum temperature and precipitation, respectively for one treatment and one control site of each country.

**Nepal**

The control site chosen for Nepal was Chitwan and the treatment site was Dhadling. Analyses results show that rainfall at Chitwan has slightly decreased during the period 1971 – 2010 whereas it has slightly increased at Dhadling over the same period. Minimum temperature trend at Dhadling site is higher than the maximum temperature trend whereas minimum temperature trend at Chitwan is almost the same as maximum temperature trend. This is probably due to the higher elevation of Dhadling than Chitwan. Nevertheless, both maximum and minimum temperatures have been increasing in both the pilot sites. However, these trends, both precipitation and temperatures are statistically significant as indicated by the P (<0.05) values. (Figure 3)

**Sri Lanka**

Analysis of precipitation data of Monaragala (one of the control sites) and Galle (one of the treatment sites) shows that precipitation has slightly increased during the period 1980 – 2008 with less variability (Figure 4). Statistically, the trends of precipitation in both the districts is insignificant. Both minimum and maximum temperatures at Galle has positive trends with 0.02 °C per year. Both temperature trends in Galle are statistically significant as indicated by the P (<0.05) values. Since temperature observation at Monaragala is not available, analyses were not carried out.
Analyses of data from treatment and control site shows that precipitation increase at Muang Chainat (one of the control sites) is slightly higher than that of Bang Ban (one of the treatment sites) as seen in Figure 5. The precipitation variability in both the sites is slightly higher (CV 0.28% & 0.23%) compared to other sites in Nepal and Sri Lanka. Statistically, these trends are insignificant as indicated by the P (>0.05) values. Since temperature observations at Muang Chainat and Bang Ban are not readily available, analyses were not performed.

Future climate change scenarios can play a vital role in the prevention and mitigation of meteorological disasters (Islam et al., 2008). The data generated by climate models can be used as inputs for a number of physical, hydrological and agricultural models that can help predict future impacts of climate change. By using these models, policy-makers are better able to develop evidence-based and rigorous strategies, and reduce the impact of these disasters on communities (Stainforth et al., 2007).

For this study, a thorough review was conducted to acquire / access future climate change data with acceptable horizontal resolution to analyse future precipitation projection in the three countries. NASA Earth Exchange (NEX) models, which has future climate change scenarios from 21 Global Circulation Models (GMCs) under two emission scenarios (RCP 4.5 and 8.5) with 25x25km² resolution was identified.
Model Setup

The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset is comprised of downscaled climate scenarios for the globe that are derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Inter-comparison Project Phase 5 (CMIP5) (Taylor et al., 2012) and across two of the four greenhouse gas emissions scenarios known as Representative Concentration Pathways (RCPs) (Meinshausen et al., 2011). The NEX-GDDP dataset is bias corrected using Spatial downscaling (BCSD) method, a statistical downscaling algorithm specifically developed to address these current limitations of global GCM outputs (Wood et al. 2002; Wood et al. 2004; Maurer and Hidalgo 2008; Thrasher et al. 2012). The purpose of these datasets is to provide a set of global, high resolution, bias-corrected climate change projections that can be used to evaluate climate change impacts on processes that are sensitive to finer-scale climate gradients and the effects of local topography on climate conditions. The data assist the science community for understanding impacts of climate change at regional, national and local scale and to enhance public understanding of possible consequences. A summary of the data field description of NEX-GDDP is given below.

<table>
<thead>
<tr>
<th>CMIP5 models included</th>
<th>21 GCMs</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>RCP scenarios</th>
<th>RCP 4.5 and RCP 8.5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Temporal resolution</th>
<th>Daily from 1950-01-01 to 2100-12-31</th>
</tr>
</thead>
<tbody>
<tr>
<td>from 1950 through 2005 (“Retrospective Run”) and from 2006 to 2100 (“Prospective Run”)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spatial Resolution</th>
<th>0.25 degrees x 0.25 degrees</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Climate Variables</th>
<th>Precipitation, Maximum and Minimum Temperature</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Dataset Projection and Datum</th>
<th>Geographic, WGS84</th>
</tr>
</thead>
</table>

All GCMs of the CMIP5 are not applicable for all regions of the globe. Based on the region of interest, GCMs are required to be selected from the available GCMs under CMIP5. Out of the NASA Earth Exchange (NEX) 21 models (CMIP5 models) with RCP4.5 and RCP8.5 emission scenarios, 12 GCMs were found to be suitable for understanding future change of annual mean temperature ($\Delta T$) and percentage ($\%$) change of annual precipitation ($\Delta P\%$) over South Asia (Nepal and Sri Lanka) while 10 GCMs were found to be suitable for Southeast Asia (Thailand). The details of the GCMs are given in Table below.

<table>
<thead>
<tr>
<th>Target Area</th>
<th>Selected GCMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>South East Asia (SEA)</td>
<td>bcc-csm1-1, BNU-ESM, CanESM2, CESM1-BGC, GFDL-CM3, GFDL-ESM2G</td>
</tr>
<tr>
<td></td>
<td>GFDL-ESM2M, IPSL-CM5A-MR, MPI-ESM-LR, MPI-ESM-MR</td>
</tr>
<tr>
<td>Target Area</td>
<td>Selected GCMs</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td>South Asia (SA)</td>
<td>CanESM2, CCSM4, CESM1-BGC, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, MIROC5, MPI-ESM-LR, IPSL-CM5A-MR, NorESM1-M</td>
</tr>
</tbody>
</table>

As the present study dealt with flood, identifying extreme wettest events in the future was important, thus it was logical to identify which models amongst the 10 models suitable for southeast Asia and 12 models suitable for south Asia were able to depict the extreme precipitation events in the future in the target areas. Future scenarios were generated for 2030 (taking average for the period 2016-2045), 2050 (taking average for the period 2036-2065) and 2080 (taking average for the period 2066-2095) based on current climate (rainfall and mean temperature for the period 1976-2005) over the same study area. The identification of the models was carried out, where change of annual mean temperature (ΔT) and % change of annual precipitation (ΔP%) from each of the models from NASA Earth Exchange (NEX) with RCP4.5 and RCP8.5 emission scenarios were calculated and plotted in a scatter plot for Southeast Asia and South Asia which give possible extreme conditions over the region during 2030s, 2050s and 2080s. The models which are closest to the 5th and 95th percentile of the change of annual mean temperature (ΔT) and % change of annual precipitation (ΔP%) during 2030s, 2050s and 2080s in the two RCPs were considered for the study for the southeast Asia region (Figure 6).

![Figure 6](image-url)  
*Figure 6 Scatter plots identifying suitable GCMs which give possible extreme conditions over SEA region during 2030s, 2050s and 2080s*

Similarly, the models which are closest to the 10th and 90th percentile of the change of annual mean temperature (ΔT) and % change of annual precipitation (ΔP%) during 2030s, 2050s and 2080s in the two RCPs were considered for the study as they represent extreme conditions for south Asia. The most
suitable model identified which shows the precipitation and temperature extreme is CSIRO-Mk3-6-0 (Wettest/Hottest) for south Asia while CESM1-BGC (Wettest/Hottest) for southeast Asia. The model results for RCP 4.5 for the three time periods for the three countries are presented below.

**Analysis Results on the Future Climate Change in Nepal, Sri Lanka and Thailand**

**Precipitation and Temperature changes in Nepal**

Annual precipitation and maximum temperature distribution and change maps for each country were generated to analyse climate change over the 2030, 2050 and 2080 time period under RCP4.5 emission scenarios derived from CSIRO-Mk3-6-0 (Wettest/Hottest). Baseline precipitation and annual maximum temperature distribution maps were then compared with future distribution maps in the same time scale to identify the trends. Figure 7a illustrates the annual precipitation change over the projected three time periods in Nepal, compared to the baseline period (1976 – 2005). The projection suggests that western part of the country will experience a slight increase in precipitation, while all eastern parts of the country will experience a decrease in precipitation over the three time periods. Similarly, Figure 7b shows the change of annual maximum temperature during the projected periods (2030, 2050 and 2080), compared with the baseline period (1976 – 2005). The projection suggests that, over the entire country, the maximum temperature is likely to increase with the area close to the Himalayas showing a significant increase in maximum temperature during 2050s. The change in precipitation would vary between 6% (2030) to 16% (2080) while the change in temperature would vary between 1.27°C to 2.98°C.

**Precipitation and Temperature changes in Sri Lanka**

Figure 8a shows the analyses of annual precipitation changes in Sri Lanka by 2030s, 2050s and 2080s with respect to the baseline (1976-2005) under RCP4.5 emission scenarios derived from CSIRO-Mk3-6-0 (Wettest) show that precipitation will be increasing at the rate of 2% to 43% over the three-time periods till 2080 while for the northeast monsoon season there will be an initial decrease of precipitation for the 2030 time period but will increase by 4% to 42% for the 2050 and 2080 time period. The southwest monsoon season on the other hand shows a projected increase to the range of 24% to 67% in the three-time periods. Similarly, Figure 8b shows the change of annual maximum temperature during
the projected periods (2030, 2050 and 2080), compared with the baseline period (1976 – 2005). The projection suggests that, over the entire country, the maximum temperature is likely to increase uniformly over the three time periods. The change in temperature would vary between 1.5°C to 2.5°C from 2030s to 2080s.

![Graph showing the projected change in precipitation and maximum temperature of Sri Lanka for the period 2030, 2050 and 2080 derived from NEX-GDDP models of south Asia.](image)

**Figure 8 Projected Change in (a) precipitation and (b) maximum temperature of Sri Lanka for the period 2030, 2050 and 2080 derived from NEX-GDDP models of south Asia.**

**Precipitation and Temperature changes in Thailand**

Annual precipitation and maximum temperature change maps for Thailand were generated to analyse climate change over the 2030, 2050 and 2080 time period under RCP4.5 emission scenarios derived from CESM1-BGC (Wettest/Hottest) model. Baseline precipitation and annual maximum temperature distribution maps were then compared with future distribution maps in the same time scale to identify the trends. Figure 9a illustrates the annual precipitation change over the projected three time periods in Thailand, compared to the baseline period (1976 – 2005). The projection suggests that southern part of the country will experience a decrease in precipitation over the three time periods but in 2030s the rest of the country will also experience decrease in precipitation and the central part in 2050s and 2080s though the decrease will be less than the southern region. Similarly, Figure 9b shows the change of annual maximum temperature during the projected periods (2030, 2050 and 2080), compared with the baseline period (1976 – 2005). The projection suggests that, over the entire country, the maximum temperature is likely to increase uniformly over the three time periods. The change in precipitation would vary between 9% (2030) to 14% (2080) while the change in temperature would vary between 1.11°C to 1.88°C.
3. Results & Discussion

To develop a comprehensive flood model, it is necessary to have an accurate topographic data with all land use, accurate elevations to several centimetres, stream cross sections, dimensions and levels of stream network which has been collected and compiled as required for flood modelling. Further, considering the study objectives, the following approach was adopted for assessing the flood risk.

The flood hazard is being assessed by building a flood model merging SHER and a scientific flood model, IFLOW Work, that can run with a fairly accessible data, together with flood model built in combination of ‘flood hearing’ based on anecdotal evidences of long-term residents and satellite observations. Satellite images during floods are available for past floods, where flood duration is long and have deep with larger spread areas. Scientific model results are used as patronage for flood hearing. The advantage of using this flood model is that floods due to the combined effects of heavy rainfall, and other reasons such as flow control effects are reflected in the flood profile. Considering the flood hazard as the worst-case scenario, the risk is determined using deterministic approaches. In the case of Thailand, modelled scenarios for water discharges at Chao Phraya Dam for 2,500, 3,000, 3,500 and 4,000 cum/s have also been considered as the appropriate scenario for downstream flood management (Figure 10).

Using overlaying tools available in the spatial analytical models such as ArcGIS, the hazard scenario maps have been overlaid with the land use maps. The areas under different flood intensities have been determined for the vulnerability and risk assessments. For this study, only the agriculture (paddy) sector has been considered for risk assessment. To determine the vulnerabilities of paddy for the flood hazard, vulnerability curves available for the region has being calibrated using the historical damage data available. The vulnerability has been considered as a function of stage of crop, flood depth as well as inundation period. However, considering the characteristics of the study area and in consultation with experts who dealt with water management in the area, it is assumed that the flood depth and period of inundations are proportionately inter related, and hence the vulnerability curves gave the relationships of flood duration with that of yield reduction. The flood hazard map was prepared for Thailand only and given in Figure 11.
The flood hazard mapping could be carried out only for Thailand based on all required data available from various sources. Due to lack of all required data from Sri Lanka and Nepal the risk assessment could not be carried out for the two countries.

4. Conclusions

The study indicated that historical climate data analyses, projected precipitation and temperature changes can be carried out due to availability of open source data. But lack of data from government sources risk assessment specifically for the agriculture sector is challenging.
B. Developing an Econometric Model on Loss and Damage in Agriculture Sector

1. Introduction (Output 2)

Natural disasters are reported to be happening more frequently across the globe (CRED 2019). Billions of people are affected, and economic losses are huge. Major catastrophes in the 1990s, for example, caused an estimated economic loss of USD 66 billion per year worldwide (Benson and Clay, 2004). The average annual economic loss owing to natural disasters and hazards estimated for developing countries is 49.4 billion in the period 2003-2013 (FAO, 2015). Although the agricultural sector is the most sensitive and vulnerable to natural disasters, the amount of the loss is surprisingly yet to be known (FAO, 2015).

Weather fluctuations and extreme weather events may influence various aspects of social-economic life. Given the natural relationship between agricultural production and weather conditions, the influence of weather fluctuations on agriculture is the focus of numerous studies. The first generation of studies uses production function to simulate the effect of climatic change on crop yields (Adams 1989; Kaiser et al. 1993; Adams et al. 1995) or they use cross sectional data to quantify the effect (Mendelsohn, Nordhaus, and Shaw 1994). While the first approach is criticized for not modelling the effect based on farmers’ behavior in real settings, the second approach is subject to bias due to omitted variables, such as irrigation (Schlenker, Hanemann, and Fisher 2006). A new strand of literature overcomes this problem by employing panel data to extract the within spatial unit variation to identify the causative relationship.

The key objective of developing in the methodology was to investigate the effect of floods on agriculture production as well as the way farmers cope with the losses caused by floods. In addition, as “nowhere that risk is clearer than in agriculture” (Lopes 1987), farmers’ risk attitudes is expected to play an important role in driving their decision. We incorporate risk preference by using willingness-to-take-risk level to understand how farmers’ risk attitude affects their production decision and response in the aftermath of floods.

2. Methodology

A standard selection criterion was followed for selecting the pilot sites that includes flood affected areas as treatment sites and non-flood affected areas as control sites. The criteria followed for site selection is a standard randomized sampling technique developed by the Deakin University, Melbourne (Australia). The project team used an experimental design to conduct the two surveys: one baseline survey and another end line survey in areas affected by climate induced floods (treatment sites) and non-affected areas (control sites).

In Nepal, Sri Lanka and Thailand, the project team identified climate-induced flood hazard regions that would be termed as ‘treatment areas’ and the rest part of the country as ‘comparison areas’ (Figure 12). The unit of areas were defined at the polygon level and spatially clustered based on its potential for crop (paddy) arability along with its level of climate-induced flood hazard risks. The general delineation of polygons into treated and control cohorts were also identified in a similar way for carrying out the risk assessment of the project. In particular, the following steps were followed in identifying the study area:

i. Collecting district level historical flood data (Affected area and timeline of flood events, No. of casualties, and Damage and losses);
ii. Selecting 4 districts in each country and dividing all of the 4 districts into two groups: one experiencing floods (i.e., treated districts) and the rest never exposed to floods (Control Districts);

iii. Collecting the landuse/landcover data in GIS format (Shapefiles) that includes information such as arable/farm land, type of crops cultivated in each unit of land, etc.

iv. This is followed by overlaying district administrative boundary on the landuse map;

v. Within the list of treated districts (referring to selection criteria ii) in each country, 2 districts were picked randomly;

vi. For each of the 2 districts selected as per criterion v above, it was ensured that:
   a. The number of rice plots are equal;
   b. The total area of those rice plots should sum up to similar figure even though there could be variations.

   Rice plots were selected randomly so that the total sizes of the selected plots in each of these districts are similar. For example:

   District A (plot 1: 1000, plot 2: 500, plot 3: 300)
   District B (plot 1: 800, plot 2: 650, plot 3: 350)
   District C (plot 1: 400, plot 2: 600, plot 3: 350, plot 4: 450)

   Total area within each district adds up to 1800

vii. Information were also collected on the characteristics for each of the randomly selected rice plots in Criterion vi about their size of cultivated land, proximity to water body, forest land, elevation/ruggedness, rainfall and temperature statistics, socio-economic status of the households, and on the whole, paddy related data.

Another 2 districts were also randomly selected as control districts to meet the criteria as mentioned below:

i. 2 districts were selected as non-flooded districts (control);

ii. The selection of the rice plots should be such that they resemble approximately the size of the treatment plots;

iii. The number of selected rice plots for treatment and control are kept equal as well as considering the geographic, topographic, demographic, economic and socio-economic attributes same for all the districts.

125 rice plots were considered from each district randomly covering both control and treatment groups. This was followed by carrying out a questionnaire survey developed by Deakin University, Australia in the form of interviews in the selected districts.
Though pilot sites were selected from three countries, the survey data collected from three countries after necessary filtering was found to be suitable for the analysis only in case of Sri Lanka. Thus, the methodology has been developed and tested only for Sri Lanka.

The study utilizes a unique dataset on flood indicators/severity and agricultural outcomes at plot level of 500 surveyed households/plots compiled from our natural field experiment. In our research design, 25 districts in Sri Lanka are categorized into two groups with different extent of proneness to floods in the past 25 years. The first group includes 11 districts that are flooded in at least four years over the last 25 years (affected group) while the other group encompasses 14 districts with less than four flood occurrences over the same period (unaffected group). Two districts were randomly picked as potential treatment districts in the first group, and select two from the other to form the control districts. All
districts in the affected group belong to the wet zone of Sri Lanka where crops are largely rain-fed. Along with two districts in wet zone, the non-affected group includes four districts in the intermediate zone - which share similar irrigation system with the wet zone, and eight districts in the dry zone where the irrigation system has a long history of establishment and has been improving over time. Thus, to minimize potential bias caused by the difference in irrigation, which is the most important factor of crop production, we restrict our selection of control districts from the group of six districts, two in the wet and four in the intermediate zone. Following this procedure, the two picked districts in the affected group are Galle and Gampaha while the two districts in the non-affected group are Kegalle and Monaragala. We randomly pick 125 plots from each of these four districts and conduct a baseline survey of the households that owned the plots (500 households) in January 2016. This survey was followed by a severe flood in May 2016 in the treatment group. While Galle and Gampaha were hit by the floods, Kegalle and Monaragala were free from these floods. Then we carried out the end-line survey to collect the data from these 500 households/plots in May/June 2017. Crucially, we also calculate flood-water height, the key measure of flood severity, using the FEMA (2014) water surface elevation calculation method. This method calculates the flood-water height at a resolution of 0.0002 arc degrees (i.e., around 22 meters) using earth surface elevation data sourced from the Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM v2) and the flood inundation extent map provided by Disaster Management Centre, Government of Sri Lanka.

This study has at least two important contributions to the literature. First, this is the first study investigating the effect of floods on agricultural production in Sri Lanka. Second, we make an innovative contribution in research methodology to the literature on this topic. The panel studies can overcome the challenge of unobserved omitted variables in identifying a causative relationship between natural disasters and agricultural outcomes. However, data used in these studies are often aggregated at country, state, or county level, thus the relationship can be masked up by other characteristics. On a contrary, our study utilizes natural field experiment data at micro-plot level which is less likely to be disturbed by other factors allowing to identify the true effect.

The difference-in-difference (DD) framework is employed to evaluate the effect of the flood on crop production. Recall from section 2 that our treatment group includes 251 affected plots in either year 2015 or 2017 (these plots belong to Galle and Gampaha, the two affected districts). The control group encompasses 697 plots in Kegalle and Monaragala (two non-affected districts in both years) and those in Galle and Gampaha but are not affected by floods in either year. The DD basically compares the average changes in the outcome variables for the treatment group and the control group before and after flood occurrence. The difference in these changes (differences) is attributed to the effect of the intervention (flood strike in this setting). Standard DD equation is as follows:

\[ Y_{it} = \alpha \text{Treatment}_{it} + \beta \text{After}_t + \gamma \text{Treatment}_{it} \text{After}_t + \epsilon_{it} \quad (1) \]

where subscript \( i \) indicates individual (household/plot) and subscript \( t \) is denoted year equal 2015 and 2016. \( Y_{it} \) is the outcome of interest of individual \( i \) at time \( t \). Our primary outcomes of interest include indicators of crop production: crop yield, crop output, and crop area, all in log form as in standard Cobb-Douglass production function. Treatment\(_i\) is an indicator equal 1 for individuals that belong to treatment group in year \( t \) and 0 otherwise. Note that a majority of treatment plots (86%) are being treated in both years (they are hit by both 2015 and 2016 floods) leaving only a small percentage with changing status. Therefore, this variable though is denoted as plot and time observations, it tends to reflect the permanent difference in outcome between treatment and control group. After\(_t\) is an indicator for timing of the treatment which equal 0 for year 2015 and 1 for year 2016; \( \beta \) is the difference in the outcome between the two periods, before and after floods. The coefficient of interaction between these
two variables (Treatment, and After), \( \gamma \), measures the effect of floods. \( \epsilon_{it} \) is a composite measurement error.

The parallel trend assumption is imperative for DD to generate the unbiased effect of the intervention. If individuals in treatment and control groups are randomly taken one may expect that in the absence of the treatment they are identical and parallel trend assumption should be satisfied. However, in economic studies, often called “natural experiments”, treatment and control groups are not randomly assigned resulting in the failure of the DD to generate the true effect of the treatment (Meyer, 1995). Recall that in our research design we randomly choose two treatment districts from more-likely affected group (the group experiences flood occurrence at least 4 years over last 25 years) and the controls from the less-likely affected group (less than 4 years experiencing floods over last 25 years). Our research design intentionally reduces the differences between the treatment and control districts by restricting control districts to those that share the similarity with treatment districts in terms of agricultural production factors (i.e. select control districts in wet and intermediate zones). Nonetheless, the treatment and control districts are different in the level of their likelihood/severity to expose to floods and this may affect their agriculture production at the same time. For example, due to their geographic location treatment districts are more frequent exposure to floods and other extreme weather events such as drought or storms. These extreme weather events influence soil quality and fertility in these districts. Alternatively, as these districts are more frequently hit by floods, producers may develop farming techniques to help offset the negative effect of floods which also affect agriculture productivity. If these districts are treated equally, the estimate is likely to capture all these differences which may bias the effect of floods. These differences should be viewed as permanent differences between treatment and control districts so if exists, they are likely to affect the estimate of \( \beta \), but also can affect the coefficient of interest \( \gamma \), to a lesser extent. In statistics section we can see that several indicators such as paddy yield or area significantly different between treatment and control plots before floods. In fact, these differences disappear once we control for district fixed effect. Thus, we include district fixed effect in the model as follows:

\[
Y_{it} = a_d + \alpha Treatment_{it} + \beta After_t + \gamma Treatment_{it} After_t + \epsilon_{it} \tag{2}
\]

Using equation (2), we utilize the variation of outcomes from randomly picked plots/households within a district. In a given district, the households/plots have the same probability to be selected in the sample so they should be identical in the absence of the floods attributing the difference in differences in an average outcome as the effect of the treatment. Once floods happen farmers are likely to react to the bad events by adjusting the production inputs to offset the negative effect of floods. The response can also depend on the endowment of households/plots. Thus, we incorporate covariates representing household/plot characteristics and inputs for production function into the equation (2) to generate equation (3).

\[
Y_{it} = a_d + \alpha Treatment_{it} + \beta After_t + \gamma Treatment_{it} After_t + Z_{it} + \epsilon_{it} \tag{3}
\]

where \( Z_{it} \) is a set of household/plot characteristics and inputs that appropriate for each of the outcome. In particular, for yield equation we control for household’s endowment including total land area owned (in log), household size (total household members), crop cultivation period (in months), and fertilizer use (in log). Crop cultivated area is an additional control when outcome is crop output. For outcome being crop area, crop output (in log) is added along with the set of control in yield equation.
We utilized several measures of flood incident and severity to investigate the effect. First, we used flood indicator which is equal 1 for affected plots and zero otherwise. Recall that we have 251 affected plots and 697 non-affected plots. Using flood indicator as treatment variable is common in standard DD equations which utilize the discrete changes in the intervention to draw the difference in outcomes. We augment DD framework by using flood severity measure i.e. flood-water height in plots which utilize continuous variation in flood-water height among affected plots. In addition, we use this variable in log form which also extracts continuous variation of treatment but in relative term. Note that in specifications with continuous measure of floods (flood-water height and log of flood-water height), \(Treatment_{it}\) is a continuous variable and changes with both plot and year dimension. Although coefficient of these two variables is insignificant in almost all our regressions once district fixed effect is control for. Nonetheless we include flood fixed effect in the model whenever coefficient of these two variables are different from zero to remove any bias caused by differences between permanent differences between affected and non-affected plots that is not washed out by district fixed effect. Note that incorporating flood fixed effect can capture the variation that actually induced by floods. Therefore, we use this specification only when the coefficient of flood-water height or log of flood-water height is statistically different from zero which suggests that the two groups are permanently different. The coefficient with flood fixed effect is as follows:

\[
Y_{it} = a_d + b_f + aTreatment_{it} + \beta After_t + \gamma Treatment_{it} * After_t + Z_{it} + \epsilon_{it} (3')
\]

Finally, standard errors are clustered at household/plot level in our estimation.

### 3. Results and Discussions

**Effect of the Flood on Paddy Yield: Whole Sample**

To shed light on our research design and econometric model in quantifying the effect of flood on paddy yield we report regression results for three equations (1), (2), (3) in three successive columns for flood indicator. The first regression in each block (corresponding to equation (1)) controls for only flood shock variables. In second regression of each block (corresponding to equation 2) district fixed effect is added to eliminate the variation from permanent differences between control and treatment districts that may bias the estimate. The third regression in each block (corresponding to equation (3)) includes a set of household characteristics and paddy production inputs.

It is shown that the coefficient of \(Treatment_{it}\) (\(\alpha\)) is negative and strongly significant at 1% level in our baseline DD model (column (1)) in both blocks). This indicates that paddy yield between treatment and control groups are permanently different. Recall that this difference emerges in unconditional statistics in Table 1. Once district fixed effect is controlled for (column (2) in each block) the estimate drops in size more than ten times and mute in significance for all measures of the flood incident. This implies that the permanent difference between treatment and control groups is rooted from difference at district level and thus district fixed effect does a good job in removing this difference. Meanwhile the coefficient of \(Treatment_{it} * After\_(\gamma)\) reflecting the actual effect of the flood incident is small and insignificant in the first column of each blocks. The estimate, however, increases in size (absolute value) and becomes significant in all three blocks. The change in size of \(\gamma\), sometimes large, but in general is not as profound as that in \(\alpha\). This is not surprising as \(\alpha\) represents the permanent differences between the two groups so it has stronger correlation with district fixed effect and is affected to a larger extent when permanent district differences are explicitly allowed in the model. When household/plot characteristics and production inputs are controlled for, the estimate of flood effect (\(\gamma\)) increases in size.
(with the same sign) and reveals a better significant level. Meanwhile the coefficient of $\alpha$ stays small and is not different from zero when time varying covariates at household/plot level are included.

When household/plot characteristics are considered, paddy cultivation duration and household size does not have any influence on paddy yield. Though the former has positive sign while the latter is negative, both are negligible and not statistically different from zero. Fertilizer usage has positive effect on paddy yield as normally found in general that fertilizer boosts crop production. Total land area owned by household has negative impact on paddy yield. This may be because households owning larger land area invest less in one specific plot as they spread their resources to other land area.

It is important to highlight that since district fixed effect is controlled for in all three blocks there is no difference between control and treatment group. The difference between the period before and after the flood is also not different from zero. These results support our argument in econometrics section that once the difference between the affected districts and non-affected districts is removed, our research design is qualified as a randomized experiment where treatment and control plots are randomly taken and thus are identical. Given the credibility of our model we calculate the loss caused by the flood to put the number into practise. On average if all else equal, 1 meter of flood-water height in plots causes 2.2% yield loss (column (3) block II) which is equivalent to loss of 44,220 kg paddy output for 1 km$^2$ of paddy production area (estimate times flood-water height times paddy yield times 1km$^2$ which is $0.022^*4.02^*0.5^*10^6$). Although the figure using three measures of flood incident is not far different, we use the second measure (flood-water height in plot) in our calculation if not stated otherwise.

**Effect of the Flood on Paddy Yield: Risk-lover vs. Risk-averse Groups**

As we noticed from the statistics in Table 1 that after the flood yield reduction in the whole sample is driven by a large decrease in the risk-lover sample while it stays the same for the risk-averse sample. Individuals’ risk preferences and their decision under risk have attracted a huge attention from psychologists and economists. Agriculture, because of its natural stringency on whether conditions, is the area overwhelmed with uncertainty and risk. Thus, farmers with varying level of willingness to take risk may develop and opt different farming strategy and their response in the aftermath of the flood which may lead to the divergence in their production outcomes. In this section we investigate the effect of the flood on paddy yield for risk-lover and risk-averse sample separately as well as allowing the interaction between treatment and several measures of risk-loving level. Table 3 reports regression results using our fullest specification which controls for set of district fixed effect, and household and plot characteristics. Whenever the coefficient of permanent differences in treatment and control exists and is statistically significant we check the robustness of the effect by controlling for flood fixed effect (equation (3)) for specifications using flood-severity measures.

Result in Table 3 Panel A columns (1)-(5) show that the effect of the flood on paddy yield doubles in size for risk-lover group compared with the whole sample. The coefficient of flood dummy is positive and statistically significant at 5% level representing that flood-affected and non-affected groups are permanently different regardless of flood incidents. Although this only exists for specification using flood dummy with no differences for flood severity measures (flood-water height and log (flood-water height)). Nonetheless we check if the permanent difference has any influences on the estimate by adding flood fixed effect as we said earlier. Estimates in columns (3) and (5) show a minimal decrease in size of the flood effect (still strongly significant at 1% level) while the permanent difference disappears when flood fixed effect is accounted for. Completely contrary to this, the estimate is small and not statistically different from zero for risk-averse group in all measures of food hazards (columns (6)-(8)).

Panel B which allows the interaction between treatment status, year, and willingness-to-take-risk (triple interaction) in both level and log form yields consistent results with Panel A. In particular, the estimate
of interaction term negative and 5% significant in all specifications and alternative measures of floods. This result indicates that the higher willingness-to-take-risk farmers bear a larger loss in their paddy yield in the aftermath of the flood. Note that the coefficient of flood-water height in both level and log form is negative and significant (10%). We thus add flood fixed effect to control for permanent differences between affected and non-affected flood (columns (3) and (7)). Although the difference still exists, it minimally affects the coefficient of treatment post-flood while causes no change in estimate of triple interaction. When these figures are put into practise, at a given flood-water height in plots farmers with 1 point higher willingness-to-take-risk incur 2.4% larger paddy yield loss post-flood with all else equal (columns (2) and (3)). If flood-water height post flood is taken at mean value of 4.39 meter, it results in 10.5% yield loss for each point increase in risk-loving level. This figure is largely the same as estimated from the first flood measure (9.5% in the first column). The estimate from columns (5)-(8) with risk-loving measured in log form also gives consistent estimate with different measures of flood incidents. In addition, the coefficient of treatment post-flood becomes positive and statistically significant at 5% level in all specifications. This means that negative effect of the flood occurs when willingness-to-take-risk exceeds a threshold. In fact, our division of the whole sample into risk-lover and risk-averse sample is based on calculation of the threshold from these regressions. For example, from equation (3) we can calculate the threshold by dividing 0.13 by 0.024 which is then rounded up to the value of 6. Using other regressions also yield similar value.

As pointed out by Lopes (1987) that all models of crop choice under risk in subsistence agriculture boiled down to the “safety first” principle. Food crops yield stable but low expected return while cash crops can offer a high return accompanying by a high variance and thus are riskier. Farmers whose livelihood is based mainly on agriculture with threat from all sides such as natural hazards, pest and disease tend to opt food crops first for subsistence needs i.e. for feeding, and for seeding next season. Up to their subsistence level they prioritize their food crops in safest plots while leaving the riskiest plots for cash crops. The subsistence or aspiration level depends on individuals’ risk preference with risk-averse people setting a moderate level while risk-lovers dispose to set a higher target (Lopes 1987). Our empirical results show that risk-lovers bear a large loss for their paddy yield while risk-averse farmers do not. Paddy yield for risk-averse group is consistently lower than that of risk-lover group in any circumstances (both before and after the flood). It is also stable for both flood-affected and non-affected groups prior and post flood (Table 1, Panel C). This may suggest the prediction of “safety first” principle of risk-averse farmers who set a low target of paddy yield (or revenue) and allocate their safest plots for paddy production to get that level while leaving the rest for riskier crops. If so, we should expect a large loss in their non-paddy crop production. Motivated by this we proceed to investigate the effect of the flood on non-paddy production for risk-lover and risk-averse group as well as for the whole sample.

**Effect of Flood on Non-paddy Yield**

Table 4 reports the effect of the flood on non-paddy yield (in log form) for risk-lover, risk-averse groups, and whole sample using our fullest specification (with district fixed effect, and household/plot controls). Result in column from (4)-(7) support what we predict earlier for risk-averse group in that they allocate riskiest plots for non-paddy crops. This evidences in a huge loss of non-paddy yield for this group, 84% if using our preferred measure of floods (flood-water height in plots). The estimate of yield loss is significant at 5% level for all three flood measures. Effect of the flood on non-paddy crops is around half of this for risk-lover group though the estimate is not significant with t value highest at 1.62 for the first measure of the flood (flood dummy) while it is 1.2 and 1.3 for the other two measures of the flood respectively. The estimate for whole sample lies in between the estimate for two groups and statistically significant at least 5% level for all three flood measures. The coefficient of permanent difference
between treatment and control group is insignificant for all measures of the flood as in paddy yield equation. This again suggests that after controlling for district fixed effect and household/plot characteristic treatment and control groups are identical in the absence of the treatment. Taken together, it suggests from our results that risk-averse farmers give priority to paddy while cultivating non-paddy crops on riskier plots. Hence, they can avoid yield loss for paddy which comes at the expense of a large loss for non-paddy crops. Risk-lovers, on the other hand, tend to be more open in taking “risky crops” compared with their risk-averse counterparts. In the next section we explore the response of farmers to their loss in the aftermath of the flood for risk-lover versus risk-averse groups, and overall sample as a whole.

**Effect of Flood on Paddy and Non-paddy Output**

We then proceed to evaluate the impact of the flood on crop production which can give more insights of flood effect on yield. Table 6 provides estimation results using our fullest specification with district fixed effect, household characteristics and production inputs. In this case crop production area is controlled for as in standard production function which means that the effect of flood on crop output is evaluated with assumption that crop production area is kept the same as without flood incidents. This allows us to disentangle effect of the flood on crop volume without affecting the crop area. Results in Table 6 show that effect of the flood on output is very similar to the effect estimated from yield functions. Flood has negative and significant effect on both paddy output and non-paddy output in the whole sample. It has a large and significant negative effect on paddy output among risk-lover group while the effect on non-paddy output is large though insignificant in all specifications. On the contrary, no effect on paddy output is observed for risk-averse group while it is huge for non-paddy output. Note that the estimated effect of the flood is generally lower in output function compared with yield function. This is because the return to output of crop cultivated area is less than 1 (0.64-0.68 for paddy and 0.51-0.57 for non-paddy crops). When we adjust crop production area by a power of these elasticities in calculating crop yield we get all estimates in output function exactly the same as in yield function in all regressions. The strong consistency of the estimate using yield and output equation attests our research design and econometric model in quantifying the flood effect. The results logically show that if production area is kept the same, the loss of yield is owing to the damage of the flood on volume.

**Farmers’ Response to the Loss Post Flood**

A common behaviour is that individual would seek to compensate for the loss following the flood. In this section we explore farmers’ possible response in the aftermath of the flood. First, farmers may increase the production inputs such as fertilizer to increase crop yields after the loss (intensive farming). This practice, however, is not likely in Sri Lanka where a majority is small households cultivating fragmented plots with limited investment in production inputs. Intensive farming with high investment in inputs even becomes more unlikely and unaffordable in the aftermath of the flood as farmers tend to face tighter budget constraint due to the flood’s damage. The second response might be shift in cropping pattern. It is common finding from bio-science literature that pest and disease outbreak is more likely to be prevalent in the aftermath of extreme weather events. Meanwhile crop diversification may facilitate the recovery of the bio-system and mitigate the risk of crop failure due to pest and disease prevalence on one or some specific crops. This remedy, however, is not free of charge as farmers have to learn techniques to grow new crops from sowing to harvesting, as well as understand the market demand for the crops before deciding to cultivate new crops if they don’t have experience of cultivating them before. Therefore, this seems not to be an immediate practical solution after the flood but rather is more suitable as a long-term adaptation to cope with climate change if farmers perceive it. The third way to make up for output loss is to expand crop production area. This seems to be one of the most applicable and economical approach in regions with largely rain-fed based agriculture as in the wet
zone of Sri Lanka. Following floods, plots are soaked and ready for cropping that would not be the case without floods. Note however, there is a risk of crop failure or reduced crop yield due to potential pest and disease outbreaks following floods. Thus, this is not an obvious way that all farmers would adopt as a response to the loss but rather it is the matter of empirical finding.

We test the first possibility by exploring the effect of the flood on log of fertilizer use. Meanwhile we use two outcomes: indicator of multi-cropper (whether farmers cultivate only paddy or both paddy and non-paddy crops), and number of cultivated crops for the second possibility. Results for these regressions presented in Appendix Table A1 show no effect on fertilizer use post-flood (for all crops, for paddy and non-paddy crops in columns 1-9). Similarly, no tendency to shift to multi-cropping or to increase number of cultivated crops is observed (columns (10)-(15)). Also, no effect on these outcomes is found when using sample of risk-lover and risk-averse group separately.

Table 6 provides estimate of the flood effect on paddy and non-paddy cultivated area. In these regressions along with full set of district fixed effect, household characteristics and production inputs we control for crop output. The idea is what changes in crop production area are needed so as to keep output unchanged. So, in this case it is the other way round compared with output function. The results show that risk-lover group expands 18-22% paddy cultivated area in the aftermath of the flood (columns (1)-(3) in Panel B). The estimate is strongly significant at 1% for all three flood measures. They also cultivate 26-30% their non-paddy production area though the estimate is not significant in any specifications with t standing around 1.3-1.47. On a contrary, risk-averse group expand their cultivated area for non-paddy crop only. The expansion is large at 52-55% and significant at 5% level in all flood measures (column (4)-(6) in Panel C). For paddy, an opposite direction of change is observed. As the coefficient of Treatment$_t$ (Flood Dummy, Flood-water Height, and Log (Flood-water Height) is significant for this group, we use specification with flood fixed effect incorporated as preferred specification. The result in column (3) indicates that risk-averse farmers cultivate 14% less paddy area in the aftermath of the flood. This is in line with our earlier argument that risk-averse farmers tend to prioritize paddy as a subsistence crop and restrict their paddy production only on safest plots which result in a reduction in production area for this crop. Result in Panel A for the whole sample reflects no area expansion for paddy as expanding effect of risk-lover group is offset by shrinking effect from risk-averse group. There is a clear effect on expansion of non-paddy cultivated area for overall sample with significance at 5% for all three flood measures and the size of the estimate lies in between that for risk-lover and risk-averse groups.

Effect of the Flood on Output after Accounting for Crop Area Expansion

Given our assessment of flood effect on output and farmers’ response in the aftermath of the flood, we now can answer the most important question of our interest: what is the ultimate effect (final effect after accounting for farmers’ response) of the flood on crop production. Although we can calculate these figures based on our estimate in output and area functions, we also have an alternative approach to compare and check the robustness of the results. In particular, we estimate production function with output being outcome variable as in Table 5 with only difference is leaving crop production area outside the model. By not fixing crop production area, we allow adjusted production area in the aftermath of the flood to transfer into the final effect of crop output. Results of these regressions are presented in Appendix Table A2. In the calculation below, we use estimate of output loss (with fixed production area) from Table 5 while area adjustment estimate is taken from Table 6. We then compared the calculation with estimate from Appendix Table A2 which directly gives the ultimate effect of the flood on crop output with possible expansion (contraction) accounted for.

For paddy, 10-13% output is lost due to the flood and there is no expansion in area so this is the final loss owing to the flood for this crop. We can see that these results are largely the same in estimate of
paddy output without controlling for log of paddy production area (columns (1)-(3) Appendix Table A2). Risk-lover farmers incur a large loss in paddy output, 16-18% though they expand their production area at a rate of 18-22% which can make up 12-14% of output loss if return of output to area is accounted for (0.18*0.64 or 0.22*0.64). This means that the ultimate loss of paddy output for this group is small, around 6-8% which is consistent with the direct estimate of ultimate loss of 5.2-5.4% in Appendix Table A2. These estimates are insignificant in all specifications indicating that risk-lover farmers compensate almost all their loss by expanding sufficiently large area of paddy production. On a contrary, the final loss of output for risk-averse group is 9% which is due to their contraction of around 14% in their paddy production area. The direct estimates of paddy output loss for this group is slightly larger at 11% in columns (1)-(3) in Panel C Appendix Table A2 though they are insignificant with t standing around 1.1-1.54.

When non-paddy crop production is considered, the overall loss is large at 22% after accounting for the compensation from expanded production area of 32%. The loss for risk-lover group though exists is not statistically significant in any specifications for yield, area and output functions. Contrary to this, the loss for risk-averse group is obvious. This group loses 64% of their non-paddy output out of which they makeup around 27% of this loss by increasing non-paddy production area (52%). It means that this group still incur around 37% loss of non-paddy production output.

Overall our results show that the flood causes output loss for both paddy and non-paddy crops. Risk-lover group incurs the loss of paddy production while risk-averse bears for the loss of both paddy and non-paddy crop production. They all response to the loss by expanding production area with the former pursuing paddy production while the latter favouring non-paddy crop production. On the one hand, after the flood plots are soaked with water which is a good pre-condition for cultivating crops. On the other hand, in the aftermath of floods, the risk of pest, diseases, and crop failure is more likely to occur due to changes in soil biotic conditions provoked by the flood (cite). Prospect theory predicts that individuals tend to become risk seekers when they face a loss. In the next section we investigate if farmers’ response to the loss of the flood by expanding their crop production area is associated with a higher risk-loving level.

**Effect of Flood on Risk-loving Level**

Table 7 reports regression results for the effect of the flood on several measures of farmers’ willingness-to-take-risk. The first measure is level of willingness-to-take-risk (or risk-loving level), which is a categorical self-reported variable with value from zero (lowest willingness-to-take-risk) to 10 (highest willingness-to-take-risk). Along with this indicator we use the second outcome, log of willingness-to-take-risk level. This is to account for the relative changes of risk-loving level. For example, an individual with risk-loving level of 2/10 can change their risk attitude more substantially compared with those at 8/10 given the same marginal increase in risk-loving level of one point. The last outcome is risk-lover indicator which is equal 1 if risk-loving level is greater or equal 6 and zero otherwise. Results in Panel A show an increase in willingness to take risk in overall sample for all three outcomes with three measures of the flood incident. Columns (1)-(3) indicate an increase of 0.24 point in risk-loving level while this figure is 4% in columns (4)-(6). Columns (7)-(9) show an increase of 10-13% in likelihood to become risk-lover after the flood. The size of the estimate is almost the same for risk-lover as well as for risk-averse group for the first outcome (risk-loving level). The former has the same significance as in overall sample (10%) while the latter become insignificant with t at 1.6 in our preferred specification (with flood-water height as flood measure). In addition, the estimate reduces one third in size for risk-lover group when measuring risk in log form while it doubles in magnitude for risk-averse group. This is because these two groups experience the same increment in risk-loving level which results in a larger percentage change for group with lower risk-loving level.
4. Conclusions

Agriculture production largely depends on the weather condition and is extremely prone to natural disasters and hazards. A more frequent and more severe occurrence of natural disasters such as storms and floods in recent decades put food security at an increasing risk and undermine farmers’ life satisfaction. Farmers in less developed countries are most vulnerable to natural disasters and hazards due to lack of support from government and due to their limited resource to overcome the losses. Sri Lanka, a developing country with 77.4% population residing in rural area with agriculture being the major livelihood has been stricken by floods every year with an increasingly affected area in recent decade. This study investigates the effect of floods on agriculture production and farmers’ response to flood incident using data at plot level. Our research design, after removing the potential bias caused by the difference between treatment and control group at district level generate a sample equivalent to that from a randomized control trial. This allows us to quantify the causal effect of floods using DD framework. The estimate shows a significant loss in paddy yield of 44,000 kg/km2 owning to floods. Farmers offset this loss by expanding crop cultivated area utilizing soaked field after the flood. Our result is robust to different measure of flood incident/intensity and to different model specification.

C. Assessment of Flood Early Warning System in Nepal

1. Introduction (Output 3)

Flood is regarded as one of the most frequent, highly damaging and wide spread natural hazards in Nepal. Each year flood causes considerable damage to human lives and property. Most of the floods in Nepal are rainfall induced, mainly during the monsoon season as about 80 percent of the annual precipitation occurs during the monsoon period, July being the highest precipitation month. Generally huge floods are observed in July and August when southwest monsoon is at its peak. Beside rainfall induced flood, other kind of floods such as glacial lake outburst flood (GLOF), flood from breach of embankments, flood due to inundation, snowmelt floods, landslide river dammed outburst flood are also recorded. According to UNDP Nepal is the second highest country at risk in south Asia from floods. Likewise, it is ranked in the eleventh position in the world in terms of people affected by flood. The records between 1997 and 2011 shows that flood caused 3,329 deaths, affect 3.9 million people and caused economic losses of about USD 5.8 billion (FAO, 2018). Hence, early warning system in flood is very crucial in Nepal context, which could minimize substantially both human and capital losses. Nepal government, national and international non-governmental organizations, civil society groups etc. are also working on the early warning system in Nepal under various activities.

2. Methodology

Existing Services in Nepal

Department of Hydrology and Meteorology (DHM) is the authorized governmental organization for flood forecasting and disseminating the information related to flood. It has daily hydrological data of around 186 Hydrometric stations for more than 30 years. It has been providing early warning service in case of hazardous phenomenon like Flood, Glaciers Lake Outburst Floods (GLOFs), Lake and Dam Outburst Floods (LDOFs) etc. It has the provision of providing the hydrological forecasts in short range term (3 days), information on suspended sediment data for 21 river stations, flood report for insurance, providing snow and glacier hydrology services, and providing technical and scientific guidance and assistance of the hydrological services to the general people (DHM). DHM has also developed flood hazard/risk mapping of major rivers of Nepal.
Dissemination Mechanism

DHM has nation-wide network of hydrological and meteorological stations. Among them, 51 of the hydrological station are in operation. For disseminating the flood related alert, DHM has developed the emergency plan of action and at the same time formulated the standard operating procedure for flood early warning system (SOP-FEWS) in Nepal with the intention of providing consistent and standard procedures at the critical time of flooding events so that communities can act effectively during the period of flood events. The general mechanism of the data and information or warning dissemination mechanism is shown in the Figure 13.

![Figure 13 Data and information flow Mechanism practiced by DHM. Source DHM 2019](image_url)

For the dissemination of the flood information, DHM has been using the toll-free number 1155; Twitter account as well as Facebook account in the name of Nepal Flood Alert. All the information is also being shared in its webpage - http://www.hydrology.gov.np/. It has been giving hydrological and meteorological services as per the requests from general people, media, ministry of home affairs and other stakeholders. It provides the 24 hours information service through the toll-free no.1155 in the emergency or during the flood events and continuously updates the status through the social medias during the emergency situations. DHM has closely coordinated with the different communications companies to send mass SMSs to every registered mobile user in the affected area. DHM is also publishing the weather bulletin on every 6:00 AM and 6:00 PM during the monsoon season. The practices of sharing the information through the mobile during the emergencies are found to be very effective in Nepal. The dissemination mechanism in the emergency situation is shown in Figure 14.
In addition, DHM also sends the flood alerts to the National Emergency Operation System (NEOS) at Ministry of Home Affairs and to the general public. As per the alert from the DHM, NEOS take the action to disseminate these warnings to other relevant organizations/offices. There are different community-based organizations (CBOs), formal and informal community groups working in the local level for disseminating the flood alert as per the information from the DHM and NEOS. It includes relaying the information through the local club or groups, by blowing siren and making public announcement through local FM radio etc. Such activities are managed and run under the community based early warning system. The methodology/process of flood diagnostic and forecasting of warning service is presented in Figure 15.

3. Results and Discussion

In the beginning, early warning system of DHM was mainly focused to minimize the loss of human life and other property, but now it has made effort to extend the service to the agriculture sector. Likewise, there was no formal system in the agriculture ministry to provide the early warnings, weather and climate services to the farmers in order to protect the agricultural product or for the early response of the farmers in their daily functions. However, recently government is setting the system to provide the weather information for the farmers through the SMSs which is in the pilot phase. It has also developed the mobile applications named, *Hamro Krishi* (Nepali words meaning our agriculture) - PPCR/AMIS
(Pilot Program for Climate Resilience/Agriculture Management Information System) which provide the agro-climate and weather information under early warning system and also provides the agriculture decision support tools for the farmers and other stakeholders. Currently, DHM and Nepal Agricultural Research Council (NARC) are working together to provide critical and timely agro-climate and weather information to farmers in order to increase productivity and reduce losses from meteorological and hydrological hazards.

**Future Perspective of Early Warning System**

Human induced changes like various water resources management projects, increased urbanization, land use changes, increased water use demands including climate induced changes like frequency of floods, storms, landslides, extreme weather conditions are the major challenges faced by flood forecasting in Nepal. Such key issues should or needed to be addressed by improving the hydrological practices and product service delivery reinforced by thorough researches.

To make the early warning system effective, DHM is upgrading its hydrological stations in major river system that provide the real time data and also posted in its web page. DHM has been maintaining a network of 28 hydrological stations and 88 meteorological stations equipped with telemetry system and further upgrading 59 hydrometric stations with telemetry system and an additional 7 stations are under consideration in the scheme. Hence, in total 182 hydro-meteorological stations will be in operational network and use real time data acquisition system.

DHM is currently running different projects towards upgrading and strengthening its station networks with latest sophisticated technology. It has also run community-based flood and glacial lake outburst flood (GLOF) risk reduction project with objectivities of developing and implementing community based GLOF early warnings system, GLOF risk management skills and knowledge institutionalized at local and national levels, Furthermore, it provides flood preparedness training for districts and VDC representatives, NGOs, CBOs, and local communities in selected flood prone districts.

DHM is also implementing pilot program for climate resilience (PPCR) with four components – i), institutional strengthening, capacity building and implementation support of DHM, ii) modernization of the observation networks and forecasting, iii) enhancement of the service delivery system of DHM and iv) agriculture management information system. In addition, international agencies like Practical Action Nepal, International Center for Integrated Mountain Development (ICIMOD) etc. are also working on the development of the early warning systems in various parts of the country in close coordination with DHM. ICIMOD has also has worked on the establishment of a regional flood information system where six partner countries Bangladesh, Bhutan, China, India, Nepal and Pakistan were involved. The purpose of this project is to create timely exchange of flood data and information within and among participating countries through an established and agreed platform which is accessible and user friendly. In order to achieve this, the project is upgrading 28 stations in the participating countries by installing modern instruments that are capable of measuring and transmitting vital information in real time.

The continued effort of the government in collaboration with the public, INGOs, NGOs has shown the progress in the early warning mechanism of Nepal. Hence, it is expected to get timely and more reliable information regarding the flood event in the Nepal.
Status of EWS in Project Area

The project has selected the four districts for the research purpose. Two districts Chitwan and Surkhet are located in the flood prone area where as remaining two districts Dhading and Kavre are control district with less or no exposure to the flood. A flood early warning system has been installed in Narayani river of the Chitwan district.

The major gaps in the FEWS in Nepal are as follows:

1. The major gaps in FEWS are the lack of information of the past events.
2. Being in a complex mountain topography existing infrastructure are always inadequate.
3. A major challenge in Nepal’s hydrological services is the need for the modernization of the existing infrastructure, which has been one of the targets of the present PPCR project at DHM. It is essential for the development of an operational flood forecasting system.
4. Recent structural changes in the political division provides various roles in disaster mitigation to the local government offices (municipalities and rural municipalities), however they are not institutionalized and are in dormant phase. A revival in this area is essential.
5. The information provided for the general people are very generic, which needs to be improved with relevant and user-friendly information.
6. The real time data transmission is not always reliable because of the time and location of the stations, which depends upon the network and coverage of the service provider (Nepal Telecom Corporation and Ncell).

4. Conclusion
Roadmaps for Strengthening FEWS

The study showed that There are many areas in Nepal’s FEWS to be improved. Some of the major things that needs to be done to strength FEWS are as follows:

- The Government of Nepal needs to introduce a system of flood assessment that follows the standard international practices.
- There is a good effort from the government in expanding and upgrading of the hydrological and meteorological networks, but at the same time it is of utmost importance to give attention in continued maintenance and operation of these stations.
- Adequate and skilled human resources should be made available.
- The information provided should be specific with sufficient information in a user-friendly mode.
- Need to increase awareness level of the general people through training and education, which is very important to understand the flood alert and other important weather information.

This output was carried out only for Nepal and thus gives further scope of future engagements in the other countries.
D. Climate Smart Disaster Risk Reduction Interventions in Agriculture Sector – Practitioner’s Handbook (Output 4)

Climate Change is inevitable and the agriculture and water sectors are the most vulnerable. Recent studies have shown that due to climate change, the world is moving towards scenarios of either too much, or too little, water. Agriculture is an open system and provides livelihoods for 60% of the world’s population. More than 2.2 billion people depend on agriculture for their livelihoods in Asia. Thus, climate induced natural hazards, especially floods, are likely to affect the sector as well as the livelihoods of the dependent population considerably.

Due to the distinct climatic variability across the Asian continent and its geophysical setting, the majority of countries on the Asian continent are subject to natural disasters. The frequency of these extreme events, especially the hydrometeorological events, has shown an increasing trend. The present study explores the consequences of these extreme events in three countries of the Asian region, namely: Thailand, Nepal and Sri Lanka which have distinct geographical settings. These three countries are subject to frequent natural disasters, especially floods and droughts, due to their respective geographical exposure and climatic regime, which in turn, result in disastrous consequences of varying degrees, affecting the agricultural sector of the respective countries.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has revealed that warming of the climate is unequivocal, and that rapid climate change over the past 50 years is anthropogenic-driven. Climate change has already affected both South and Southeast Asia with rising temperatures, decreasing rainfall, rising sea levels and increasing frequency and intensity of extreme events.

One of the major shortfalls of conventional disaster management strategies is a lack of adequate blends of climatic information on the nature of future climate risks and post-disaster reconstruction processes or modalities which eventually lead to an increased risk of disaster rather than a decrease. The present initiative, funded by the Asia Pacific Network for Global Change Research, Japan, looks into an entire gamut of flood mitigation interventions in the agricultural sector in the three countries of intervention starting from floodplain management, land treatment, flood modification measures and agronomic practices to Integrated Water Resource Management. One of the unique recommendations is a climate inclusive, flood early warning system in these countries which is generally lacking.

We are aware that low-income countries and small islands and their rural communities (whose main livelihood is agriculture in the flood-plain and low-lying areas) are the most endangered communities by flood hazards. Environmental degradation and socio-economic factors like poverty and urban population growth, contribute additionality to the vulnerability by flood hazards of the communities in these three countries where a Flood Early Warning System could make a paradigm shift in community resilience regarding flood hazard.

A Practitioners Guide Book was developed for the use of local Government Employees engaged in mainstreaming Climate Smart Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) practices for development planning at local government level in the Asian Region. This Practitioners Guide Book focuses on three Asian countries, Thailand, Sri Lanka and Nepal. The Guidebook on Climate Smart Disaster Risk Reduction Interventions in the Agriculture Sector, with special reference to flood hazards, will contribute to the various DRR initiatives in these three countries and in Asia as a whole. The Report and the Guide book are enclosed with this report as a reference. The handbook was
officially handed over to the respective agriculture departments and the partner agencies in the three countries (Figure 16 and Figure 17).

![Figure 16 Practitioner's Handbook being handed over to Deputy Director of Agriculture Department, Kurunegala, Sri Lanka by Dr. B.V.R. Punyawardane, Director/ Principal Scientist (Agro-climatology), NRMC, Department of Agriculture, Government of Sri Lanka](image)

![Figure 17 Practitioner's handbook being handed over to different departments of the Royal Government of Thailand during the final dissemination workshop held on 8 – 9 September 2019 at Chonburi, Thailand.](image)

5. Future Directions

The implementation of the present project was a unique experience as four different aspects related to flood hazard was explored. Though it was initially envisaged that all the four aspects would be explored in the three project countries of Thailand, Sri Lanka and Nepal but due to constraints of data availability, quality of survey data collected the interventions could be tested only is selected countries except the Practitioner's Guidebook which was developed for all the three countries. Thus, as way forward the project interventions which were successfully tested in one country can be explored in the other 2 countries as well as countries which have similar geography and vulnerability to flood hazard. The FEWS and the Risk assessment requires more in-depth study and thus has prospects in the future. The climate modelling results can be further enhanced using the new IPCC AR6 models which are due in year 2021.
6. References


7. Appendix
Conferences/Symposia/Workshops

Regional Workshop on Risk Assessment Methodology
Organized under APN project on “Development of Climate Induced Loss and Damage Estimation Method for Agricultural Sector due to Impending Flood Events project”
07-09 September, 2015, Kathmandu, Nepal

| AGENDA |
| --- | --- | --- |
| **Day & Time** | **Activities** | **Remarks** |
| **Day 1: Time** | 07 – September - 2015 |
| 08:30 - 09:00 | Registration of Participants |
| 09:00 - 10:00 | Inaugural Session |
| • Welcome Speech |
| • Opening Remarks and Objectives of the workshop; |
| • Address by the Chief Guest; |
| • Project briefing by ADPC (15 min) |
| • Vote of Thanks |
| Facilitated by SEN/NAST |
| 10:00 - 10:15 | Tea Break |
| 10:15 - 11:00 | Future climate scenarios for selected pilot sites in Nepal, Sri Lanka and Thailand (30 min ppt. + 15 min discussions). |
| Moderated by SEN/NAST |
| 11:00 - 12:30 | Session # 1 Country Specific Presentations |
| • Status of data collection, hazard, vulnerability & risk assessments in Thailand (30 min); |
| • Status of data collection, hazard, vulnerability & risk assessments in Sri Lanka (30 min); |
| Status of data collection, hazard, vulnerability & risk assessments in Nepal (30 min). |
| Moderated by SEN/NAST |
| 12:30 - 13:30 | Lunch Break |
| 13:30 - 15:15 | Session # 2 Risk Assessment Methodology |
| • Measuring Disaster Risk: Concepts, Methodologies and applications (60 min) |
| • Group discussion on understanding of flood risk in Nepal, Sri Lanka and Thailand (45 min) |
| Moderated by ADPC |
| 15:15 - 15:30 | Tea Break |
| 15:30 - 16:30 | Session # 2 Risk Assessment Methodology (Contd...) |
| Moderated by ADPC |
### Day 2: Time - 08 – September – 2015

<table>
<thead>
<tr>
<th>Time</th>
<th>Session #</th>
<th>Description</th>
<th>Moderator</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00 - 10:30</td>
<td>Session # 2</td>
<td>Risk Assessment Methodology (Contd...) • Flood risk assessment in Thailand and Sri Lanka (under APN project): Steps and progress (60 min).</td>
<td>Moderated by ADPC, Thailand</td>
</tr>
<tr>
<td>10:30 - 10:45</td>
<td>Tea Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:45 – 11:45</td>
<td>Session # 3</td>
<td>Econometric Modelling • Pilot site selection criteria and house hold survey for econometric modeling (30 min); • Method of quantify potential loss and damage of climate induced flood hazards and expected outcomes (30 min).</td>
<td>Moderated by SEN/NAST</td>
</tr>
<tr>
<td>11:45 – 12:15</td>
<td>Discussion</td>
<td>on the way forward</td>
<td></td>
</tr>
</tbody>
</table>

### Day 3: Time - 09 – September – 2015

<table>
<thead>
<tr>
<th>Time</th>
<th>Description</th>
<th>Facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00 – 16:00</td>
<td>Field trip to flood vulnerable pilot site selected under APN project (Chitwan District)</td>
<td>SEN/NAST</td>
</tr>
</tbody>
</table>

**List of Participants**

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alok Sharma</td>
<td>Nepal Agriculture Research Council, Nepal</td>
<td><a href="mailto:aloys5@gmail.com">aloys5@gmail.com</a></td>
</tr>
<tr>
<td>Amriat Gyawali</td>
<td>Tribhuvan University, Nepal</td>
<td><a href="mailto:gyawaliamrita24@gmail.com">gyawaliamrita24@gmail.com</a></td>
</tr>
<tr>
<td>Arun Bhattarai</td>
<td>The Small Earth Nepal</td>
<td><a href="mailto:arun@smallearth.org.np">arun@smallearth.org.np</a></td>
</tr>
<tr>
<td>Bandula Wickramaarachchi</td>
<td>ADPC, Thailand</td>
<td></td>
</tr>
<tr>
<td>Binod Parajuli</td>
<td>Department of Hydrology and Meteorology, Nepal</td>
<td><a href="mailto:bp_gorkhali@hotmail.com">bp_gorkhali@hotmail.com</a></td>
</tr>
<tr>
<td>D.A. Jayasinghearachchi</td>
<td>Department of Meteorology, Sri Lanka</td>
<td></td>
</tr>
<tr>
<td>Dilli Bhattarai</td>
<td>The Small Earth Nepal</td>
<td><a href="mailto:dilli@smallearth.org.np">dilli@smallearth.org.np</a></td>
</tr>
<tr>
<td>Dipak Bhattarai</td>
<td>Department of Agriculture Training, DoA, Nepal</td>
<td><a href="mailto:dat.govnp@gmail.com">dat.govnp@gmail.com</a></td>
</tr>
<tr>
<td>Name</td>
<td>Organization</td>
<td>Email</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Dr. Madan Lall Shrestha</td>
<td>The Small Earth Nepal</td>
<td></td>
</tr>
<tr>
<td>Dr. Rijan Bhakta Kayastha</td>
<td>Kathmandu University, Nepal</td>
<td><a href="mailto:rijan@ku.edu.np">rijan@ku.edu.np</a></td>
</tr>
<tr>
<td>Dr. Rishi Ram Sharma</td>
<td>Department of Hydrology and Meteorology, Nepal</td>
<td><a href="mailto:rishisharm@yahoo.com">rishisharm@yahoo.com</a></td>
</tr>
<tr>
<td>Dr. Senaka Basnayake</td>
<td>ADPC, Thailand</td>
<td></td>
</tr>
<tr>
<td>Hemu Kafle</td>
<td>Nepal Academy of Science &amp; Technology, Nepal</td>
<td><a href="mailto:hemukafle@gmail.com">hemukafle@gmail.com</a></td>
</tr>
<tr>
<td>KHMS Premalal</td>
<td>Department of Meteorology, Sri Lanka</td>
<td><a href="mailto:spremalal@yahoo.com">spremalal@yahoo.com</a></td>
</tr>
<tr>
<td>Kabiraj Khatiwada</td>
<td>Central Department of Environmental Science, Tribhuvan University, Nepal</td>
<td><a href="mailto:kabirajkhatiwada@gmail.com">kabirajkhatiwada@gmail.com</a></td>
</tr>
<tr>
<td>Nicky Shrestha</td>
<td>Kathmandu University, Nepal</td>
<td><a href="mailto:sthanicky@gmail.com">sthanicky@gmail.com</a></td>
</tr>
<tr>
<td>Niranjan Bista</td>
<td>The Small Earth Nepal</td>
<td><a href="mailto:bistaniranjan@gmail.com">bistaniranjan@gmail.com</a></td>
</tr>
<tr>
<td>Prof. Lochan Prasad Devkota</td>
<td>Central Department of Hydrology and Meteorology, Tribhuvan University, Nepal</td>
<td><a href="mailto:devkotalp@hotmail.com">devkotalp@hotmail.com</a></td>
</tr>
<tr>
<td>Prof. Mehmet Ulubasoglu</td>
<td>Deakin University, Australia</td>
<td><a href="mailto:mehmet.ulubasoglu@deakin.edu.au">mehmet.ulubasoglu@deakin.edu.au</a></td>
</tr>
<tr>
<td>Prof. Rupak Rajbhandari</td>
<td>Tri-Chandra College, Tribhuvan University, Nepal</td>
<td><a href="mailto:rupak.rajbhandari@gmail.com">rupak.rajbhandari@gmail.com</a></td>
</tr>
<tr>
<td>Rabin Dhital</td>
<td>Department of Agriculture Training, DoA, Nepal</td>
<td></td>
</tr>
<tr>
<td>Siva Nepal</td>
<td>Dept. of Hydrology and Meteorology</td>
<td><a href="mailto:shivaamet@gmail.com">shivaamet@gmail.com</a></td>
</tr>
<tr>
<td>Sudarshan Rajbhandari</td>
<td>The Small Earth Nepal</td>
<td></td>
</tr>
<tr>
<td>Sujit Karmacharya</td>
<td>IDS, Nepal</td>
<td><a href="mailto:karmasujit@gmail.com">karmasujit@gmail.com</a></td>
</tr>
<tr>
<td>Susanthan Jayasinghe</td>
<td>ADPC, Thailand</td>
<td></td>
</tr>
<tr>
<td>Tulasi Ram Nepal</td>
<td>Tribhuvan University, Nepal</td>
<td><a href="mailto:nepalshambhu1988@gmail.com">nepalshambhu1988@gmail.com</a></td>
</tr>
<tr>
<td>Name</td>
<td>Organization</td>
<td>Email</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Yasotha Thevaruban</td>
<td>Dept. of Irrigation, Sri Lanka</td>
<td><a href="mailto:yasotha.ponnampalam@gmail.com">yasotha.ponnampalam@gmail.com</a></td>
</tr>
<tr>
<td>Rameshwor Rimal</td>
<td>Soham Nepal</td>
<td><a href="mailto:rameshwharrimal@gmail.com">rameshwharrimal@gmail.com</a></td>
</tr>
</tbody>
</table>

Regional Workshop on Climate Inclusive Flood Impact Assessment (CLIF-IA)

Organized under APN project on “Developing Climate Inclusive Potential Loss and Damage Assessment Methodology for Flood Hazards”

13-15 September, 2016, Colombo, Sri-Lanka

AGENDA

<table>
<thead>
<tr>
<th>Day &amp; Time</th>
<th>Activities</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1: Time</td>
<td>Registration of Participants</td>
<td></td>
</tr>
<tr>
<td>08:30 – 09:00</td>
<td>Inaugural Session</td>
<td>Facilitated by ADPC</td>
</tr>
<tr>
<td>09:00 – 10:00</td>
<td>Welcome Speech; Opening Remarks and Objectives of the workshop; Address by the Chief Guest; Project briefing by ADPC (15 min); Vote of Thanks</td>
<td></td>
</tr>
<tr>
<td>10:00 – 10:15</td>
<td>Tea Break</td>
<td></td>
</tr>
<tr>
<td>10:15 – 11:00</td>
<td>Presentation #1: An overview on the method of estimating loss and damage in agriculture due to climate change induced floods (30 min ppt. + 15 min discussions)</td>
<td>Presented by Dr Habibur Rahman Deakin University</td>
</tr>
<tr>
<td>11:00 – 12:30</td>
<td>Presentation #2: Method of selecting treatment and control areas</td>
<td></td>
</tr>
<tr>
<td>12:30 – 13:30</td>
<td>Lunch Break</td>
<td></td>
</tr>
<tr>
<td>13:30 – 15:15</td>
<td>Presentation #3: Descriptive statistics on our baseline survey data</td>
<td>Presented by Dr Habibur Rahman Deakin University</td>
</tr>
<tr>
<td>15:15 – 15:30</td>
<td>Tea Break</td>
<td></td>
</tr>
<tr>
<td>15:30 – 16:30</td>
<td>Group Task #1: On the appropriateness of the proposed selection criteria: Identifying its associated strength, weaknesses, Opportunities and Threats</td>
<td>Facilitated by Dr Habibur Rahman Deakin University</td>
</tr>
<tr>
<td>18:30 – 21:00</td>
<td>ADPC Official Dinner</td>
<td></td>
</tr>
</tbody>
</table>

Day 2: Time

| 09:00 – 10:30 | Presentation #4: A Hypothetical case study on how the method can estimate loss and damage | Presented by Dr Habibur Rahman Deakin University |
| 10:30 – 10:45 | Tea Break                                                                 |                                              |
| 10:45 – 12:15 | Group Task #2: Recommendation on what we need to do during End-line survey for improving our Method | Facilitated by Dr Habibur Rahman Deakin University |
| 12:15 – 13:15 | Lunch Break                                                               |                                              |
| 13:15 – 14:15 | Session on geospatial information                                          | Moderated by ADPC                            |
| 14:15 – 15:00 | Discussion on the way forward                                              | Moderated by ADPC                            |
| 15:00 – 15:30 | Wrap up and closing remarks                                               | Moderated by ADPC                            |

Day 3: Time

| 08:30 – 10:00 | Group Task #3: Extension of the method to other data-sets                  | Facilitated by Dr Habibur Rahman Deakin University |
| 10:00 – 11:00 | Tea Break                                                                  |                                              |
| 11:00 – 12:30 | Discussion on the downstream regional implications                          |                                              |
| 12:30 – 13:30 | Field Visit to Gampaha and Kegalle (APN Pilot Sites)                        |                                              |

Field Visit to Gampaha and Kegalle (APN Pilot Sites)
List of Participants

Regional Workshop on Climate Inclusive Flood Impact Assessment (CLIF-IA)
Organized under APN project on “Developing Climate Inclusive Potential Loss and Damage Assessment Methodology for Flood Hazards”
13-15 September, 2016, Colombo, Sri-Lanka

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name</th>
<th>Designation</th>
<th>Department</th>
<th>Email</th>
<th>Phone Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K. Ilyarachchi</td>
<td>Senior Lecturer</td>
<td>Building Economics</td>
<td><a href="mailto:isilworld@gmail.com">isilworld@gmail.com</a></td>
<td>071-1845496</td>
</tr>
<tr>
<td>2</td>
<td>M. S. Dharmapriya</td>
<td>AE</td>
<td>Agronomy</td>
<td><a href="mailto:msdharmapriya@gmail.com">msdharmapriya@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>M. A. Seyasunderawardh</td>
<td>AD</td>
<td>Dept. of Meteorology</td>
<td><a href="mailto:masetty@agriculture.lk">masetty@agriculture.lk</a></td>
<td>0773773780</td>
</tr>
<tr>
<td>4</td>
<td>T. W. Premal</td>
<td>Director</td>
<td>Agronomy</td>
<td><a href="mailto:masetty@agriculture.lk">masetty@agriculture.lk</a></td>
<td><a href="mailto:spremal@yahoo.com">spremal@yahoo.com</a> 071-1934289</td>
</tr>
<tr>
<td>5</td>
<td>P. N. Malachith</td>
<td>Agronomist</td>
<td>Dept. of Meteorology</td>
<td><a href="mailto:pranasi@agriculture.lk">pranasi@agriculture.lk</a></td>
<td>0773311200</td>
</tr>
<tr>
<td>6</td>
<td>W. R. E. S. Gunaratne</td>
<td>Director</td>
<td>Agriculture</td>
<td><a href="mailto:w_e_s_gunaratne@agriculture.lk">w_e_s_gunaratne@agriculture.lk</a></td>
<td>0723364825</td>
</tr>
<tr>
<td>7</td>
<td>Anura Senaratne</td>
<td>D. M. C</td>
<td></td>
<td><a href="mailto:anuraSenaratne@gmail.com">anuraSenaratne@gmail.com</a></td>
<td>071-2320625</td>
</tr>
<tr>
<td>8</td>
<td>S. W. Bandara</td>
<td>Assistant Director</td>
<td>Export Agriculture</td>
<td><a href="mailto:ranketh@gmail.com">ranketh@gmail.com</a></td>
<td>071-4989919</td>
</tr>
<tr>
<td>9</td>
<td>S. R. D. Perera</td>
<td>SAP</td>
<td></td>
<td><a href="mailto:sriperera@gmail.com">sriperera@gmail.com</a></td>
<td>0773793016</td>
</tr>
<tr>
<td>10</td>
<td>R. S. W. Perera</td>
<td>Deputy Secretary</td>
<td>Ph.D. Officer</td>
<td><a href="mailto:rswperera@agriculture.lk">rswperera@agriculture.lk</a></td>
<td>0773773785</td>
</tr>
<tr>
<td>11</td>
<td>L. E. Ramadasna</td>
<td>B. E.</td>
<td>Dept. of Meteorology</td>
<td><a href="mailto:lalith@agriculture.lk">lalith@agriculture.lk</a></td>
<td>0537311358</td>
</tr>
<tr>
<td>12</td>
<td>Ann Perera</td>
<td>Program Coordinator</td>
<td></td>
<td><a href="mailto:annperera@gmail.com">annperera@gmail.com</a></td>
<td>0411553911</td>
</tr>
</tbody>
</table>
Regional Workshop on Climate Inclusive Flood Impact Assessment (CLIF-IA)
Organized under APN project on “Developing Climate Inclusive Potential Loss and Damage Assessment Methodology for Flood Hazards”
13-15 September, 2016, Colombo, Sri Lanka

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name</th>
<th>Designation</th>
<th>Department</th>
<th>Email</th>
<th>Phone Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dr. Priya Devi Seneviratne</td>
<td>Senior Lecturer</td>
<td>Physical Planning</td>
<td><a href="mailto:priyad@spc.gov.lk">priyad@spc.gov.lk</a></td>
<td>071 79 15 212</td>
</tr>
<tr>
<td>2.</td>
<td>Dilh Ram Bhatikai</td>
<td>Program Coordinator</td>
<td>The Small Earth Nepal</td>
<td><a href="mailto:dill@smallearth.org.np">dill@smallearth.org.np</a></td>
<td>077 98 11 63 29</td>
</tr>
<tr>
<td>3.</td>
<td>Buddhika Hariparakhami</td>
<td>1st AD, PNM</td>
<td>Ministry of PNM</td>
<td><a href="mailto:chris@nmbrg.com">chris@nmbrg.com</a></td>
<td>077 49 85 226</td>
</tr>
<tr>
<td>4.</td>
<td>S. Anula Arunadhara</td>
<td>Director of Agriculture</td>
<td>District Secretariat</td>
<td><a href="mailto:anula@agriculture.gov.lk">anula@agriculture.gov.lk</a></td>
<td>071 46 06 86</td>
</tr>
<tr>
<td>5.</td>
<td>J. D. Asmanath</td>
<td>C.E.</td>
<td>Irrigation</td>
<td><a href="mailto:jay@asmanath.org">jay@asmanath.org</a></td>
<td>071 86 27 076</td>
</tr>
<tr>
<td>6.</td>
<td>Sumithra Jayasinghe</td>
<td>Climate Data Analyst</td>
<td>ADPC</td>
<td><a href="mailto:sumithra@adpc.net">sumithra@adpc.net</a></td>
<td>071 84 58 05</td>
</tr>
<tr>
<td>7.</td>
<td>R. Dharmage Thanha</td>
<td>Technical Specialist</td>
<td>ADPC</td>
<td><a href="mailto:dharmage@adpc.net">dharmage@adpc.net</a></td>
<td>071 84 58 05</td>
</tr>
<tr>
<td>8.</td>
<td>Senaka Basnayake</td>
<td>Head, CCCR</td>
<td>ADPC</td>
<td><a href="mailto:senaka@basnayake.org">senaka@basnayake.org</a></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>R. N. Pradeep Khandre</td>
<td>Research Fellow</td>
<td>Gokarna University</td>
<td>pradeep.khandre@iit-gokarn</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Anamika Panda</td>
<td>Tech. Advisor</td>
<td>ADPC</td>
<td><a href="mailto:anamika@adpc.net">anamika@adpc.net</a></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Designation</td>
<td>Department</td>
<td>Email</td>
<td>Phone Numbers</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------</td>
<td>----------------------</td>
<td>-----------------------</td>
<td>------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>13</td>
<td>S. Abul Ameenarigya</td>
<td>Director Agriculture</td>
<td>District Secretary</td>
<td><a href="mailto:reg.agri@gmail.com">reg.agri@gmail.com</a></td>
<td>077 4460686</td>
</tr>
<tr>
<td>14</td>
<td>K. D. N. Wamsingh</td>
<td>Ad. Engineer</td>
<td>Univ. of Kubam</td>
<td>ramsingh.kubam@</td>
<td>079 2787817</td>
</tr>
<tr>
<td>15</td>
<td>Azim Ali Bhattadari</td>
<td>Program Coordinator</td>
<td>SVN</td>
<td><a href="mailto:azim@smallworld.com">azim@smallworld.com</a></td>
<td>085 5155320</td>
</tr>
<tr>
<td>16</td>
<td>is e. Kumarshetti</td>
<td>Scientist</td>
<td>NRRO</td>
<td><a href="mailto:ebhakshetti@gmail.com">ebhakshetti@gmail.com</a></td>
<td>071 9388111</td>
</tr>
<tr>
<td>17</td>
<td>R. K. Ranade Kumbhar</td>
<td>Asst. Director</td>
<td>Dept. of Export</td>
<td><a href="mailto:ranade@gmail.com">ranade@gmail.com</a></td>
<td>021 7459999</td>
</tr>
<tr>
<td>18</td>
<td>Dilli Ram Bhattarai</td>
<td>Program Coordinator</td>
<td>Small Scale Industry</td>
<td><a href="mailto:dilli@smallscale.com">dilli@smallscale.com</a></td>
<td>097 7841632509</td>
</tr>
<tr>
<td>19</td>
<td>G. Yasotha</td>
<td>Irrigation Engineer</td>
<td>Dept. of Irrigation</td>
<td><a href="mailto:yasotha.pahar@gmail.com">yasotha.pahar@gmail.com</a></td>
<td>071 2911204</td>
</tr>
<tr>
<td>20</td>
<td>Harshadasewa</td>
<td>Senior Lecturer</td>
<td>Economics</td>
<td><a href="mailto:mahesh.g@gmail.com">mahesh.g@gmail.com</a></td>
<td>071 1820320</td>
</tr>
<tr>
<td>21</td>
<td>Vidya Maya Herath</td>
<td>Senior Lecturer</td>
<td>University of</td>
<td><a href="mailto:herathv@gmail.com">herathv@gmail.com</a></td>
<td>071 1845496</td>
</tr>
<tr>
<td>22</td>
<td>Manoj L. Harrekar</td>
<td>Academic/Advisor</td>
<td>SBV</td>
<td>mhd@g miał@gmail.com</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>M. Kalpana Pratik</td>
<td>Project Manager</td>
<td>NPO</td>
<td><a href="mailto:kpratik@nic.in">kpratik@nic.in</a></td>
<td>071 18202740</td>
</tr>
<tr>
<td>24</td>
<td>Arundhati Banerjee</td>
<td>Tech. Director</td>
<td>ABPC</td>
<td><a href="mailto:arundhati@ege.com">arundhati@ege.com</a></td>
<td>086 8408014</td>
</tr>
<tr>
<td>25</td>
<td>Ramkishan Shrivastava</td>
<td>Director</td>
<td>Dom</td>
<td><a href="mailto:rshrivastava@gmail.com">rshrivastava@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>R. Rathiya Shyama</td>
<td>Technical Specialist</td>
<td>ADPC</td>
<td><a href="mailto:rshyama@rshyama.com">rshyama@rshyama.com</a></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Sarojkha Rajsingh</td>
<td>Project Officer</td>
<td>ADPC</td>
<td>sarojkha@<a href="mailto:raj@gmail.com">raj@gmail.com</a></td>
<td>071 4452032</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>Designation</td>
<td>Department</td>
<td>Email</td>
<td>Phone Numbers</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------</td>
<td>-------------</td>
<td>------------</td>
<td>---------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>13</td>
<td>W.A. Munawar</td>
<td>Scientist</td>
<td>NCR</td>
<td><a href="mailto:wamunawar@gmail.com">wamunawar@gmail.com</a></td>
<td>0777622165</td>
</tr>
<tr>
<td>14</td>
<td>D.A. Jogasingh</td>
<td>DA</td>
<td>DOM</td>
<td><a href="mailto:da_jogasingh72@hotmail.com">da_jogasingh72@hotmail.com</a></td>
<td>0773712150</td>
</tr>
<tr>
<td>15</td>
<td>K.J. Neevathy</td>
<td>Prof.</td>
<td>Univ. Ruhr</td>
<td><a href="mailto:kjk_neevathy@uni-ruhr.de">kjk_neevathy@uni-ruhr.de</a></td>
<td>0777176547</td>
</tr>
</tbody>
</table>

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dissemination Workshop on Developing Climate Inclusive Potential Loss and Damage Assessment Methodology for Flood Hazards

**Agenda**

<table>
<thead>
<tr>
<th>Day &amp; Time</th>
<th>Activities</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 Feb</td>
<td>1200 hrs</td>
<td>Departure to workshop venue (Khao Yai) from Bangkok</td>
</tr>
<tr>
<td>Day 1: Time</td>
<td>13 February 2019</td>
<td></td>
</tr>
<tr>
<td>08:30 - 09:30</td>
<td>Registration of Participants</td>
<td></td>
</tr>
<tr>
<td>09:30 - 09:50</td>
<td>Inaugural Session</td>
<td>Facilitated by ADPC</td>
</tr>
<tr>
<td>09:50 – 10:10</td>
<td>Setting the Scene</td>
<td>Facilitated by ADPC</td>
</tr>
<tr>
<td>10:10 – 10:15</td>
<td>Group Photo</td>
<td>Facilitated by ADPC</td>
</tr>
<tr>
<td>10:15 - 10:30</td>
<td><strong>Tea Break</strong></td>
<td></td>
</tr>
<tr>
<td>10:30 - 10:40</td>
<td>Introduction to the Project</td>
<td>by ADPC</td>
</tr>
<tr>
<td>10:40 - 11:10</td>
<td>Session # 1 Country Presentations on Project Activities (Nepal, Sri Lanka &amp; Thailand)</td>
<td>Moderated by ADPC</td>
</tr>
<tr>
<td>10:40 – 12:00</td>
<td>Session # 2 Climate inclusive Flood Risk Assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Risk Assessment Methodology</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Climate Scenarios for Countries</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Hands-on Exercise on Local Scenario</td>
<td></td>
</tr>
<tr>
<td>12:00 - 13:30</td>
<td><strong>Lunch Break</strong></td>
<td></td>
</tr>
<tr>
<td>13:30 - 15:15</td>
<td>Session # 2 Climate inclusive Flood Risk Assessments (Hands-on exercise on understanding flood risks &amp; Group Presentations)</td>
<td>Moderated by ADPC</td>
</tr>
<tr>
<td>15:15 - 15:30</td>
<td><strong>Tea Break</strong></td>
<td></td>
</tr>
<tr>
<td>15:30 - 16:30</td>
<td>Session # 3 Econometric Modelling (Loss &amp; Damage)</td>
<td>Moderated by Deakin University</td>
</tr>
<tr>
<td>Day 2: Time</td>
<td>14 February 2019</td>
<td></td>
</tr>
<tr>
<td>09:00 - 10:00</td>
<td>Session # 3 Econometric Modelling (Loss &amp; Damage) (Continued)</td>
<td>Moderated by Deakin University</td>
</tr>
<tr>
<td>10:00 - 10:30</td>
<td>Session # 4 Early Warning System Assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Introduction to EWS</td>
<td>Moderated by ADPC</td>
</tr>
<tr>
<td>10:30 - 10:45</td>
<td><strong>Tea Break</strong></td>
<td></td>
</tr>
<tr>
<td>10:45 – 12:30</td>
<td>Session # 4 Early Warning System Assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Country presentations (Nepal, Sri Lanka &amp; Thailand)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Panel Discussion on EWSs</td>
<td></td>
</tr>
<tr>
<td>12:30 - 13:30</td>
<td><strong>Lunch Break</strong></td>
<td></td>
</tr>
<tr>
<td>13:30 - 16:00</td>
<td>Session # 5 DRR and CCA Interventions for Floods</td>
<td>Moderated by ADPC</td>
</tr>
<tr>
<td></td>
<td>- Presentation on DRR &amp; CCA interventions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Case Study</td>
<td></td>
</tr>
<tr>
<td>16:00 - 16:15</td>
<td><strong>Tea Break</strong></td>
<td></td>
</tr>
<tr>
<td>15:30 - 16:30</td>
<td>Discussion and the Way Forward</td>
<td>Moderated by ADPC</td>
</tr>
<tr>
<td>Name</td>
<td>Organization</td>
<td>Email</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Ms. Karnjana Saengprapai</td>
<td>Hydro and Agro Informatics Institute</td>
<td><a href="mailto:karnjana@haii.or.th">karnjana@haii.or.th</a></td>
</tr>
<tr>
<td>Ms. Sasiprapa Tanyong</td>
<td>Hydro and Agro Informatics Institute</td>
<td><a href="mailto:sasipra@haii.or.th">sasipra@haii.or.th</a></td>
</tr>
<tr>
<td>Ph. D. Noppadon Kowsuvon</td>
<td>Royal Irrigation Department (RID)</td>
<td><a href="mailto:princethai@gmail.com">princethai@gmail.com</a></td>
</tr>
<tr>
<td>Mr. Adisorn Champaithong</td>
<td>Royal Irrigation Department (RID)</td>
<td><a href="mailto:adisorn_eng@hotmail.com">adisorn_eng@hotmail.com</a></td>
</tr>
<tr>
<td>Dr. Sarawee Aroon</td>
<td>Royal Irrigation Office 12 (RID12)</td>
<td><a href="mailto:sarawee_777@hotmail.com">sarawee_777@hotmail.com</a></td>
</tr>
<tr>
<td>Ms. Manatchanok Pannak</td>
<td>Royal Irrigation Office 12 (RID12)</td>
<td><a href="mailto:m.pannak.s@gmail.com">m.pannak.s@gmail.com</a></td>
</tr>
<tr>
<td>Ms. Kamonwan Ekachoth</td>
<td>Department of Disaster Prevention and Mitigation (DDPM)</td>
<td><a href="mailto:kamonwan_e@hotmail.com">kamonwan_e@hotmail.com</a></td>
</tr>
<tr>
<td>Ms. Benyapat Jarupakchanon</td>
<td>Department of Disaster Prevention and Mitigation (DDPM)</td>
<td><a href="mailto:benyapat425@gmail.com">benyapat425@gmail.com</a></td>
</tr>
<tr>
<td>Ms. Ruthikarn Buaphean</td>
<td>Thai Meteorological Department</td>
<td><a href="mailto:ruthaigarn@hotmail.com">ruthaigarn@hotmail.com</a></td>
</tr>
<tr>
<td>Mr. Pattara Sukthawee</td>
<td>Thai Meteorological Department</td>
<td><a href="mailto:pattaradini@gmail.com">pattaradini@gmail.com</a></td>
</tr>
<tr>
<td>Mr. Phakawat Phuengtua</td>
<td>Banphung subdistrict administrative organization</td>
<td><a href="mailto:phakawatpsy@gmail.com">phakawatpsy@gmail.com</a></td>
</tr>
<tr>
<td>Mr. Nawassaphon Hachit</td>
<td>Office of Natural Resources and Environmental Policy and Planning (ONEP)</td>
<td><a href="mailto:nawassaphon.hac@gmail.com">nawassaphon.hac@gmail.com</a></td>
</tr>
<tr>
<td>Ms. Pimrat Mattayanumat</td>
<td>Office of Natural Resources and Environmental Policy and Planning (ONEP)</td>
<td><a href="mailto:Pear_19@hotmail.com">Pear_19@hotmail.com</a></td>
</tr>
<tr>
<td>Dr. Margaret C. Yoovatana</td>
<td>Department of Agriculture</td>
<td><a href="mailto:luckymegy@yahoo.com">luckymegy@yahoo.com</a></td>
</tr>
<tr>
<td>Mrs. Suangsan Tawieng</td>
<td>Department of Agriculture</td>
<td><a href="mailto:planningdoa@doa.in.th">planningdoa@doa.in.th</a></td>
</tr>
</tbody>
</table>

List of Participants
<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Mihindukulasuriya Christy Lal Fernando</td>
<td>Ministry of Public Administration and Disaster Management</td>
<td><a href="mailto:McIfenando@gamil.com">McIfenando@gamil.com</a></td>
</tr>
<tr>
<td>Dr. B. V. R. Punyawardane</td>
<td>Department of Agriculture</td>
<td><a href="mailto:batugedara_vrp@yahoo.com">batugedara_vrp@yahoo.com</a></td>
</tr>
<tr>
<td>Mr. K. H. M. S. Premalal</td>
<td></td>
<td><a href="mailto:spremalal@yahoo.com">spremalal@yahoo.com</a></td>
</tr>
<tr>
<td>Mr. D.A. Jayasingheachchi</td>
<td></td>
<td><a href="mailto:dananda52@hotmail.com">dananda52@hotmail.com</a></td>
</tr>
<tr>
<td>Madan L. Shrestha, Ph.D.</td>
<td>Nepal Academy of Science and Technology / Small Earth Nepal (SEN)</td>
<td><a href="mailto:madanls@hotmail.com">madanls@hotmail.com</a></td>
</tr>
<tr>
<td>Mr. Nammy Hang Kirat</td>
<td>Small Earth Nepal (SEN)</td>
<td>-</td>
</tr>
<tr>
<td>Mr. Arun Prasad Bhattachai</td>
<td>Small Earth Nepal (SEN)</td>
<td><a href="mailto:arun@smallearth.org.np">arun@smallearth.org.np</a></td>
</tr>
<tr>
<td>Rahman Md Habibur, Dr</td>
<td>Monash University Malaysia</td>
<td><a href="mailto:habibur.rahman@monash.edu">habibur.rahman@monash.edu</a></td>
</tr>
<tr>
<td>Prof. Mehmet A. Ulubasoglu</td>
<td>Deakin Business School, Deakin University</td>
<td></td>
</tr>
<tr>
<td>Dr. Senaka Basnayake</td>
<td>Climate Resilience, ADPC</td>
<td><a href="mailto:Senaka_basnayake@adpc.net">Senaka_basnayake@adpc.net</a></td>
</tr>
<tr>
<td>Mr. Susantha Jayasinghe</td>
<td>Climate Resilience, ADPC</td>
<td><a href="mailto:susantha@adpc.net">susantha@adpc.net</a></td>
</tr>
<tr>
<td>Ms. Chinaporn Meechaiya</td>
<td>Climate Resilience, ADPC</td>
<td><a href="mailto:chinaporn.m@adpc.net">chinaporn.m@adpc.net</a></td>
</tr>
</tbody>
</table>
AGENDA
Outreach Workshop on Developing Climate Inclusive Potential Loss and Damage Assessment Methodology for Flood Hazards
8th September 2019
Venue: Ravindra Beach Resort, Chonburi, Thailand

<table>
<thead>
<tr>
<th>Time</th>
<th>Agenda Item</th>
<th>Name / Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:30 – 10:00</td>
<td>Introduction to the APNCF Project and the Outreach Workshop Plan in 3 countries (Thailand, Sri Lanka and Nepal)</td>
<td>Dr. Senaka Basnayake, Director CLR &amp; PI – APN Project</td>
</tr>
<tr>
<td>10:00 – 10:30</td>
<td>Tea / Coffee Break</td>
<td></td>
</tr>
<tr>
<td>10.30 – 13:00</td>
<td>Group Work: Effective usage of the Practitioner’s Guidebook by the Stakeholders</td>
<td>CLR Team</td>
</tr>
<tr>
<td>13:00 – 14:00</td>
<td>Lunch</td>
<td>Mr. Susantha Jayasinghe, Technical Specialist (Weather and Climate) &amp; Dr. Niladri Gupta, Sr. Project Manager (CRM)</td>
</tr>
<tr>
<td>14:00 – 15:30</td>
<td>Presentation of Group Work and Team Discussion</td>
<td></td>
</tr>
<tr>
<td>15:30 – 16:00</td>
<td>Tea / Coffee Break</td>
<td></td>
</tr>
<tr>
<td>16:00 - 1700</td>
<td>Review of the Outreach workshop Plan (9 September, 2019) and discussion on topics for future APN Calls.</td>
<td>Dr. Senaka Basnayake, Director CLR &amp; PI – APN Project</td>
</tr>
</tbody>
</table>

CLOSING

List of Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Satja Prasongsap</td>
<td>Department of Agriculture</td>
<td><a href="mailto:herbdoa@gmail.com">herbdoa@gmail.com</a></td>
</tr>
<tr>
<td>Mr. Napat Sirisuntornlak</td>
<td>Department of Agriculture</td>
<td><a href="mailto:nabhadra2526tourkrab@gmail.com">nabhadra2526tourkrab@gmail.com</a></td>
</tr>
<tr>
<td>Ms. Jansima Saengsuriya</td>
<td>Department of Disaster Prevention and Mitigation (DDPM)</td>
<td><a href="mailto:jeabjeabjansima@gmail.com">jeabjeabjansima@gmail.com</a></td>
</tr>
<tr>
<td>Name</td>
<td>Organization</td>
<td>Email</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Ms. Praschana Roungra</td>
<td>Department of Disaster Prevention and Mitigation (DDPM)</td>
<td><a href="mailto:P.rounga@gmail.com">P.rounga@gmail.com</a></td>
</tr>
<tr>
<td>Ms. Ticha Lolupiman</td>
<td>Hydro Informatics Institute</td>
<td><a href="mailto:ticha@hii.or.th">ticha@hii.or.th</a></td>
</tr>
<tr>
<td>Ms. Kashapon Chettanawanit</td>
<td>Hydro Informatics Institute</td>
<td><a href="mailto:kachapond@hii.or.th">kachapond@hii.or.th</a></td>
</tr>
<tr>
<td>Mr. Pronmongkol Chidchob</td>
<td>Royal Irrigation Department</td>
<td><a href="mailto:waterman44@gmail.com">waterman44@gmail.com</a></td>
</tr>
<tr>
<td>Ms. Phattaporn Mekpruksawong</td>
<td>Royal Irrigation Department</td>
<td><a href="mailto:phatta05@yahoo.com">phatta05@yahoo.com</a></td>
</tr>
<tr>
<td>Mr. Stanan Phanapaipong</td>
<td>Department of Agricultural Extension</td>
<td><a href="mailto:star.stanan@agmail.com">star.stanan@agmail.com</a></td>
</tr>
<tr>
<td>Mr. Sithipong Suriyakarn</td>
<td>Department of Agricultural Extension</td>
<td><a href="mailto:tuk_newman@hotmail.com">tuk_newman@hotmail.com</a></td>
</tr>
</tbody>
</table>
### Funding sources outside the APN

**Support Leveraged from sources other than APN:**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Organization</th>
<th>Total In-Kind Contribution (US$)</th>
<th>In-kind Contribution for Year 1 (USD)</th>
<th>In-kind Contribution for Year 2 (USD)</th>
<th>In-kind Contribution for Year 3 (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss &amp; Damage Assessment Tool development</td>
<td>Deakin University - Australia</td>
<td>8,600</td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel support</td>
<td></td>
<td></td>
<td></td>
<td>7,600</td>
<td></td>
</tr>
<tr>
<td>Administration Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EWS assessment in Sri Lanka</td>
<td>ADPC - Thailand</td>
<td>3,905</td>
<td>3,905</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNESCO - TTF funds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AUSAID Mainstreaming PIP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administration Support</td>
<td>ADPC - Thailand</td>
<td>24,348</td>
<td>4,170</td>
<td>1,692</td>
<td>1,000</td>
</tr>
<tr>
<td>Personnel support</td>
<td></td>
<td>7,830</td>
<td>3,656</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>Coordination and implementation support</td>
<td>Department of Meteorology – Sri Lanka</td>
<td>2,100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel support</td>
<td></td>
<td></td>
<td></td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Coordination and implementation support</td>
<td>Nepal Academy of Science and Technology - Nepal</td>
<td>4,200</td>
<td>1,600</td>
<td>1,750</td>
<td></td>
</tr>
<tr>
<td>Personnel support</td>
<td></td>
<td></td>
<td></td>
<td>400</td>
<td>450</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>43,153</strong></td>
<td><strong>26,505</strong></td>
<td><strong>9,648</strong></td>
<td><strong>7,000</strong></td>
</tr>
</tbody>
</table>

### List of Young Scientists

1. **Mr. Susantha Jayasinghe**, Climate Data Analyst, Asian Disaster Preparedness Center (ADPC), Thailand  
   Email: susantha@adpc.net  
   *Involvement in this project: Climate scenarios development, GIS analysis*

2. **Ms. Soobin You**, ADPC Intern, Seoul National University, South Korea  
   Email: suvin8992@snu.ac.kr  
   *Involvement in this project: Econometric Modeling, Statistical Analysis*

3. **Mr. Yasin Kursat Onder**, Research Assistant, Deakin University  
   Email:  
   *Involvement in the project: Econometric Modeling, Survey Data Analysis*

4. **Mr. Nourin Shabnam**, Technical Assistant, Deakin University  
   Email:  
   *Involvement in the project: Statistical Analysis, Survey Data Analysis*
Glossary of Terms

Include list of acronyms and abbreviations

ADPC – Asian Disaster Preparedness Center
AMIS – Agriculture Management Information System
ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer
CBDRMC – Community Based Disaster Reduction Management Center
CBO – Community Based Organization
CCA – Climate Change Adaptation
DD – Difference-in-Difference
DEOC – District Emergency Operation Center
DHM – Department of Hydrology and Meteorology
DoM – Department of Meteorology
DRR – Disaster Risk Reduction
FAO – Food and Agriculture Organization
FEMA – Federal Emergency Management Agency
FEWS – Flood Early Warning System
GCM – General Circulation Model
GDEM – Global Digital Elevation Map
GIS – Geographical Information System
GLOF – Glacial Lake Outburst Flood
ICIMOD – International Center for Integrated Mountain Development
ID – Irrigation Department
INGO – International Non-Governmental Organization
IPCC – Intergovernmental Panel on Climate Change
LDOF – Lake and Dam Outburst Flood
LDRMC – Local Disaster Risk Management Community
MoHA – Ministry of Home Affairs
MoIC – Ministry of Information and Technology
MoPE – Ministry of Population and Environment
NARC – Nepal Agricultural Research Council
NASA – National Space and Aeronautical Agency
NEOC – National Emergency Operation Center
NEX – NASA Earth Exchange
NGO – Non-Governmental Organization
PPCR - Pilot Project on Climate Resilience
RCM – Regional Climate Model
RID – Royal Irrigation Department
SD – Standard Deviation
SOP – Standard Operating Procedure
SRES – Special Report on Emissions Scenarios
UNDP – United Nations Development Programme
USD – United States Dollar
Photographs

Figure 18 Regional Workshop on Developing Climate inclusive Potential Loss and Damage Assessment Methodology for Flood Hazard
Figure 21 Meeting with provincial officials in Thailand