# Analysis and Proposal of Foreign Policies Regarding the Impact of Climate Change on Fragility in the Asia-Pacific Region
## - With focus on natural disasters in the Region -

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Ministry of Foreign Affairs of Japan

## Introduction

Climate change is regarded as one of the most critical issues which pose a threat to the security and economic prosperity at a global level. Spearheaded by the United Kingdom, which was the President of the G7 Summit, G7 countries held an expert meeting in 2013, and thereafter, discussions have continued in subsequent G7 foreign ministers' meetings and working groups. According to A New Climate for Peace, an independent report commissioned by the G7 foreign ministers to a group of think tanks in 2015, seven climate fragility risks with the potential of posing a substantial threat to national and social security were specified, and the respective G7 countries have decided to consider the effects of these factors on diplomatic policies.

1. Local resource competition
2. Livelihood insecurity and migration
3. Extreme weather events and disasters
4. Volatile food prices and provision
5. Transboundary water management
6. Seal level rise and coastal degradation
7. Unintended effects of climate policies

The necessity for a fast response against climate-related fragility risks was recognized at the G7 Foreign Minister Meeting held in Hiroshima in April 2016, along with the importance of taking action towards a common goal of mitigating fragility risks, in order to strengthen the global recovering capacity against climate change.

Against such backdrop, the Ministry of Foreign Affairs of Japan hosted an international conference with the participation of G7 experts to accelerate the work in Japan and among G7 countries, around 50 experts from various fields such as refugees, infectious diseases, maritime security, disaster prevention, food, ocean/water resources, finance and business were brought together at the "Impact of Climate Change and Fragility on International Security" roundtable seminar in Tokyo in January 2017, and actively engaged in discussions on the cross-sectional impacts of climate change. Many participants concurred on the importance of cooperation between stakeholders and to conduct further analysis in detail. Hence, the Ministry of Foreign Affairs organized three follow-up meetings with researchers, think tanks and involved NGOs in February and March 2017 apropos of climate change implications on energy and resources, finance, disaster prevention, migration (infectious diseases and immigration) and security in furtherance to reflect these issues in diplomatic policies.

This report is based on specific proposals from the roundtable seminar in January 2017 and the follow-up meetings in February and March. Japan institutes this report in light that it may facilitate efforts by the Working Group on G7 Climate Change and Fragility to consolidate the relation between climate change issues and policy measures. Following the reviews and feedback by the Working Group on G7 Climate Change in 2017 as well as various stakeholders involved in this discussion on climate and fragility, Japan endeavors to improve and expand its contents furthermore.

## Executive Summary

The Working Group on G7 Climate Change and Fragility focused on the correlation between climate change and security, particularly drawing attention to specific regions in order to focus on regional fragility issues and presenting the significance of the possibility of implementing a case study or a pilot program. With consideration to such discussions, focus was placed on the Asia and Pacific Region which is inhabited by a great number the world's population, where the population will continue to increase and which is susceptible to natural disaster. The purpose of this initiative undertaken by Japan is to analyze the correlation between the effects of climate change on natural disasters and the socioeconomic fragility of the region and presenting the results thereof to the Working Group.

In this report, within the Asia-Pacific Region, various challenges faced by areas most vulnerable to disasters attributed to climate change are specified, and a qualitative analysis is made on the instability of public security, politics and social climate observed in the region. The purpose of these two exercises are to gain insight into the situation through the overlapping of natural science and social science perspectives.

First, a global analysis on human security risks deriving from climate change were made on a) changes in the frequency and intensity of tropical cyclones, b) changes in storm surges, c) changes in wave height, and d) transitional changes in agricultural production. The following results could be obtained, such as an increase in tropical cyclones in the Central North Pacific region, a decrease in wave height to that extent that an increase in temperature is expected by 2100 in the Central North Pacific region and near 40 degrees latitude south, and according to future projection, by 2080, a yield loss in maize will be seen in many regions. On the other hand, there will be a yield increase with respect to rice in developing countries.

As a result of analyzing the effects of climate change in the Asia-Pacific Region, despite differences in the various assumptions and models, the main results were obtained as described below.

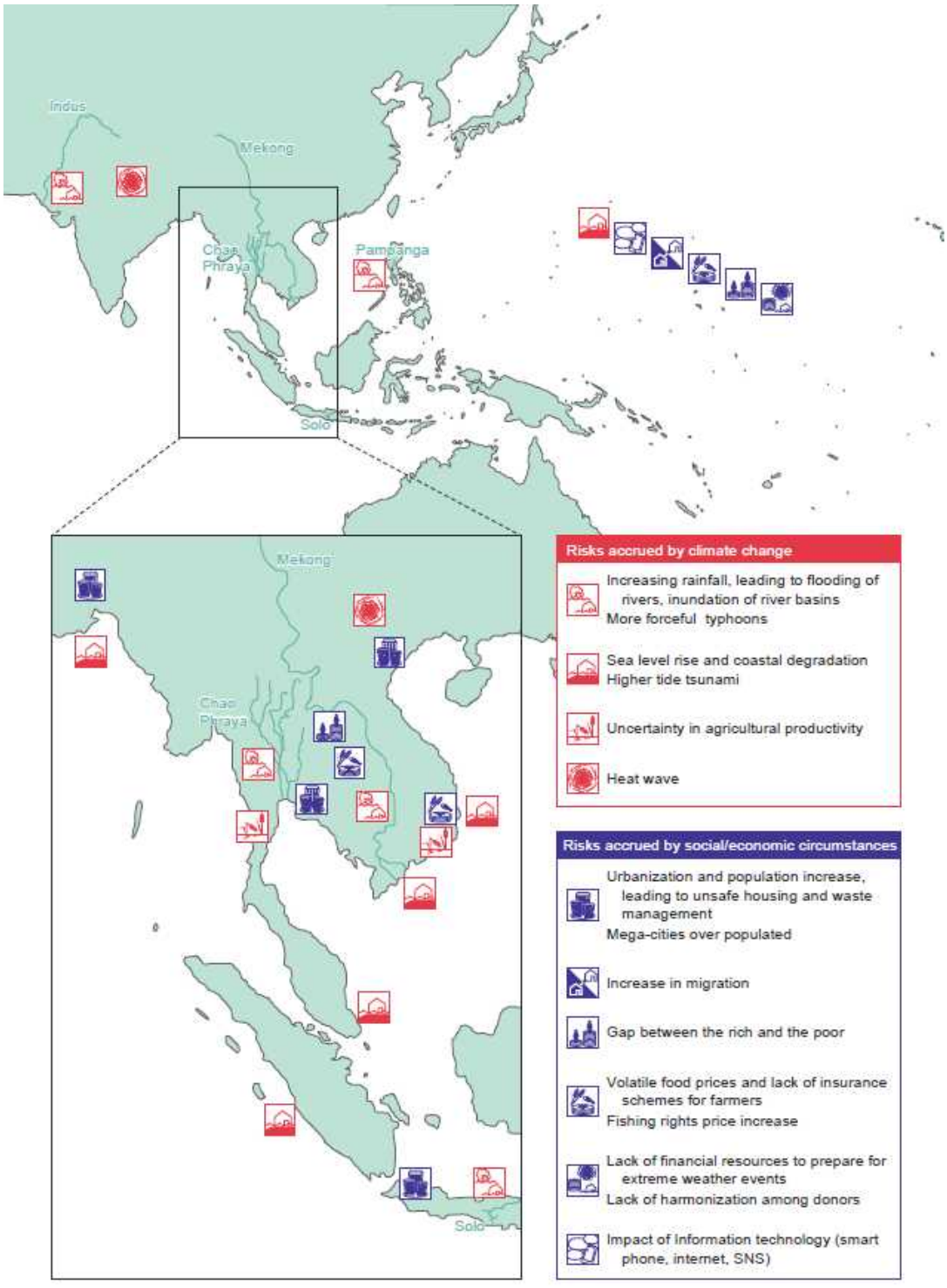
1. The average temperature may rise greater than 2$^{o}$C with high probability in most areas.
2. In the five river basins of Indus River, Chao Phraya River, Mekong River, Pampanga River and Solo River, annual precipitation will be on the increase in the future.
3. The inundated area in the Pampanga River basin and lower Mekong River basin will expand. The extent of financial damage due to inundation in the Mekong River basin will also increase. In the Solo River basin, large-scale flooding is expected due to the same probability of occurrence with regard to precipitation, and the frequency of inundation in the Chao Phraya River basin will increase.
4. The intensity of extreme flooding in eastern and southeastern Indochina Peninsula and southern Thailand will increase.
5. The flood water level and inundated area on the Mekong delta will increase substantially. In Bangladesh, compared to the present, many areas will face the risk of flooding, and the period of inundation will be more extensive compared to the present.

Second, regarding the socioeconomic analysis in the Asia-Pacific Region, the following perspectives were presented based on the observation of the experts of the respective regions.

1. Increased social insecurity due to the social infrastructure unable to sufficiently keep up with urbanization. In urban areas, the widening of gap between the young generation and the high-income group will become an increasingly serious problem.
2. While further development promotes economic growth, foreign capital-dependent development accompanies the risk of stagnating investment through the sluggish economic growth, as well as the risk of the decline in such industries as agriculture in rural areas.
3. In addition to the future risk of an aging population along with declining birth rate due to economic growth in various countries, an increased fragility to climate change risks results unless the social security and social infrastructure are not adequately developed to cope with such changes.
4. Although migration of the population transcending national borders and settling down at the destination can be observed in Southeast Asian countries, how this trend will affect the situation from the viewpoint of stagnant economic growth and urbanization is an unknown factor. In addition, due to climate change risks, there is a potential for increased flow from population migration transcending borders, accompanied by security risks.
5. Due to the effects of climate change such as sea level rise, the financial burden on the infrastructure development is likely to increase.
6. As to low flatted atoll island countries in particular in the Pacific are most vulnerable to sea level rise. However, many of the present problems occurred in islands with capital cities of these countries are mainly resulted from population increase in the capitals under socioeconomic globalization. To sustain national land against various climate and socioeconomic challenges, ecosystem-based management and measures should be considered alongside with engineering ones.

Risks identified in social sciences and natural sciences elicit the need to assess them in accordance with their dependency. Moreover, while the importance of technical innovation in addressing climate change risks was reaffirmed, there was a critical awareness for the need to sufficiently consider social changes accompanying such innovation. Furthermore, in reducing the long-term effects of climate changes in the respective regions, it was discerned that, any government policies including adaptation measures should take into account aspects of not only climate change perspectives but also urbanization and socioeconomic issues, as well as the maintenance and recovery of the ecosystem.

The analysis of the nexus between climate change and fragility in the Asia-Pacific Region in this report is still in its initial stage, requiring further investigation and more detailed examination. For example, this study was carried out based on existing study results and analyseis of the current regional situation. Therefore, in order to reflect the impact of climate change on foreign policies more effectively, focus on the correlation of the studies both in the natural science field and the socioeconomic field is required, and clarification of the study target and perspective is needed through discussions with policy makers.




**Correlation between Climate Change and Socioeconomic Fragility in the Asia-Pacific Region**

Figure above displays a mapping on risks accrued by climate change and social/economic circumstances deprived from the studies and interviews introduced in this report. Further studies are required to see correlations among the risks in order to better understand the nexus between climate change and socioeconomic fragility.

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## Glossary

AHA Center (ASEAN Coordinating Center for Humanitarian Assistance on Disaster)

Located in Jakarta (Indonesia), this is a center for regional disaster prevention, conducting disaster risk assessment, monitoring, information sharing and coordination in the event of emergencies.

ASEAN Standard Operating Procedure for Regional Standby Arrangements and Coordination of Joint Disaster Relief and Emergency Response Operations (SASOP)

Documented procedure containing forms, registered contacts, coping capacity, information flow, etc. for the smooth running of coordination efforts among the nations of the region and various institutions (including AHA Center) when requesting and implementing emergency support in the event of a disaster .

Mitigation

Mitigating the effects of climate change by suppressing and reducing greenhouse gas emission, etc.

Climate risk

Potential for being affected by the climate. It can be thought of as “potential for being affected by climate anomaly” multiplied by “the scale of that effect.” (Japan Meteorological Agency)

Green technology

Engineering work using and creating ecological and natural geological functions (coastal protection by means of coral reefs, mangroves, and wetlands).

Global value chain

A system in which the production process is distributed to multiple countries for optimization

Fragility

Lack of laws and functions of public institutions to provide basic services and to protect the citizens, or lack of governmental function, in whole or in part, with the nation being unable to fulfill its responsibilities (A New Climate for Peace)

Adaptation

Adapting to the effects of climate change when the effects of climate change are unavoidable.

Human security

With focus on individuals, the concept of protecting people from widespread and serious threats to their existence, living and dignity, and promoting sustainable individual independence and establishment of a society through protection and development of abilities to achieve the full potential of each individual. (Ministry of Foreign Affairs)

C3 Vegetation

Vegetation which initially produces compounds with three carbon atoms when taking in carbon dioxide in the photosynthesis process. (e.g. rice)

C4 Vegetation

Vegetation which initially produces compounds with four carbon atoms when taking in carbon dioxide in the photosynthesis process. (e.g. maize)

CMIP3, CMIP5 (Phase 3/5 of Coupled Model Intercomparison Project, respectively)

d4PDF (database for Policy Decision making for Future climate change)

Ensemble climate prediction database for global warming countermeasures.
By conducting ensemble experiments with unprecedented numbers (maximum 100 members), sufficient discussions could be presented on the reproduction and changes of extreme climate corresponding to the range of probability density distribution. (Ministry of Education, Culture, Sports, Science and Technology=MEXT)

GIS (Geographic Information System)
With the geographical location as a clue, data containing location-related information (spatial data) is comprehensively managed, processed and visually displayed so as to make possible sophisticated analysis and speedy decision-making. (Geospatial Information Authority of Japan)

IPCC (Intergovernmental Panel on Climate Change)
An organization established in 1988 by the World Meteorological Organization (WMO) and the UN Environmental Program (UNEP) with the objective of making an evaluation from a scientific, technological and socioeconomic perspectives regarding anthropogenic climate change, the impact thereof, and adaptive and mitigating measures thereto. (Japan Meteorological Agency)

MRI-AGCM (Meteorological Research Institute - Atmospheric Global Climate Model)
Ultra-high resolution Meteorological Agency atmospheric global model

RRI model
Rainfall-Runoff-Inundation analysis model

SST (Sea Surface Temperature)

Threat Multiplier
Factors which multiply existing threats.

## I. Considering climate change and fragility risks

This section begins with (a synopsis on) the background of the G7 discussions, followed by descriptions of the purpose, scope and method of the study and a framework on the results.

### 1. Background of G7 discussions

The expert meeting under the presidency of the United Kingdom in 2013 issued a statement on climate change as a factor that increases economic and security risks worldwide. In the G7 foreign ministers' conference held in 2014, with the cooperation of the research institutes and think tank consortium related to climate change and security, the preparation of a report concerning the risk and fragility thereof was decided upon, and in 2015, "A New Climate for Peace" was announced. In addition, a Working Group was established in order to evaluate the contents of the suggestions given in the said report.

In the G7 foreign ministers' conference held in Hiroshima in April, 2016, it was determined that a 2-year activity would be carried out by G7 with regard to fragility risks associated with climate change. As a specific undertaking, verification of climate change risks in specific instances are planned to be taken up at the G7 Working Group.

In the foreign ministers' meeting in Lucca, Italy in May 2017, continuous efforts toward the G7 "Climate Change and Fragility" Working Group and the operation procedures of the Working Group were praised, and eager anticipation for the progress report scheduled to be given in 2018 was expressed. It was encouraged that the Working Group makes a definite proposal toward actions to be implemented in order to strengthen the resilience in fragile countries.

### 2. Objective

G7 places great importance on diplomatic authorities in each country connecting the climate change issue to overall foreign policies, reflecting such in policy-planning and decision-making in order to carry out various initiatives. In particular, in order to focus on the correlation between climate change and security issues, especially regarding fragility in the region, the significance of not merely finding the correlation between climate change and various issues in the international society, but also of searching for possibilities to implement case studies and pilot programs on designated areas was presented.

With the background of such discussions, Japan has, as its initiative, decided to analyze the impact climate change has on the Asia-Pacific Region, the region which Japan is knowledgeable of and which is of highest interest thereto, and the correlation of climate change with socioeconomic fragility of the region, and present the findings to the G7 Working Group, it is expected that the contents of the consideration of the climate change and fragility of the Asia-Pacific Region will be discussed in future Working Group meetings. In the Asia-Pacific Region of which Japan is a part and where a great percentage of the world's population inhabits, increase in future population is anticipated, accompanied by natural disaster risks. In view of this situation, it is foreseen that climate change will greatly affect the social economy of the region. Specifically, in this region, there are 12 out of 20 countries which rank the highest in natural disaster risks, also indicating high fragility risks with regard to climate change. This is of utmost concern, not only within Japan, but in various countries throughout the region and outside the region, making it worthy of full consideration, with focus on the above points.

| Rank | Country | WorldRiskIndex | Exposure | Vulnerability | Susceptibility | Lack of coping capacities | Lack of adaptive capacities |
|---|---|---|---|---|---|---|---|
| 1. | Vanuatu | 36.28 % | 63.66 % | 56.99 % | 34.90 % | 81.16 % | 54.90 % |
| 2. | Tonga | 29.33 % | 55.27 % | 53.08 % | 28.66 % | 81.80 % | 48.76 % |
| 3. | Philippines | 26.70 % | 52.46 % | 50.90 % | 31.83 % | 80.92 % | 39.96 % |
| 4. | Guatemala | 19.88 % | 36.30 % | 54.76 % | 35.82 % | 81.00 % | 47.46 % |
| 5. | Bangladesh | 19.17 % | 31.70 % | 60.48 % | 38.23 % | 86.36 % | 56.84 % |
| 6. | Solomon Islands | 19.14 % | 29.98 % | 63.83 % | 44.01 % | 85.56 % | 61.90 % |
| 7. | Brunei Darussalam | 17.00 % | 41.10 % | 41.36 % | 17.40 % | 63.17 % | 43.53 % |
| 8. | Costa Rica | 17.00 % | 42.61 % | 39.89 % | 21.32 % | 63.78 % | 34.57 % |
| 9. | Cambodia | 16.58 % | 27.65 % | 59.96 % | 37.55 % | 86.84 % | 55.49 % |
| 10. | Papua New Guinea | 16.43 % | 24.94 % | 65.90 % | 54.81 % | 83.94 % | 58.95 % |
| 11. | El Salvador | 16.05 % | 32.60 % | 49.25 % | 27.84 % | 74.78 % | 45.14 % |
| 12. | Timor-Leste | 15.69 % | 25.73 % | 60.98 % | 49.93 % | 81.39 % | 51.61 % |
| 13. | Mauritius | 15.53 % | 37.35 % | 41.58 % | 18.02 % | 61.59 % | 45.14 % |
| 14. | Nicaragua | 14.62 % | 27.23 % | 53.69 % | 33.67 % | 80.70 % | 46.71 % |
| 15. | Guinea-Bissau | 13.56 % | 19.65 % | 68.99 % | 52.64 % | 89.93 % | 64.38 % |
| 16. | Fiji | 13.15 % | 27.71 % | 47.47 % | 24.18 % | 74.69 % | 43.55 % |
| 17. | Japan | 12.99 % | 45.91 % | 28.29 % | 17.82 % | 38.04 % | 29.00 % |
| 18. | Viet Nam | 12.53 % | 25.35 % | 49.43 % | 24.95 % | 76.67 % | 46.67 % |
| 19. | Gambia | 12.07 % | 19.29 % | 62.58 % | 44.77 % | 83.87 % | 59.11 % |
| 20. | Jamaica | 11.83 % | 25.82 % | 45.81 % | 25.43 % | 71.30 % | 40.70 % |

**Table 1 : Ranking of the top 20 countries with the highest natural disaster risk (World Risk Report 2016)**

Studies on climate change and fragility risks in the Asia-Pacific Region have been conducted to a certain extent in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), and likewise, extensively in Japan. For example, concerning the long-term scenario of climate change in the Asia-Pacific Region, there has been a measure of results from the "Program for Risk Information on Climate Change" (SOUSEI Program) spearheaded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) from 2012 to 2016. Using such study results for reports on policy analysis and planning in Japan with regard to climate change and fragility is beneficial from the perspective of making an international contribution through the presenting of the latest study results. By linking the long-term effects of climate change to the regional situation (various political, economic and social factors which have the potential of becoming destabilizing elements), prior consideration of potential risks can be assessed, thereby contributing to policy-making in the regions concerned.

3. Scope and method of this activity

The purpose of this study is to present regions vulnerable to climate change and security. To this extent, a map of vulnerable regions against climate change induced natural disasters (flood, sea level rise) was associated with regular reports on regional affairs where safety, political and societal conditions are unstable. The target scope is the impact on flood damage and agriculture, and in this study, effects on health (heatstroke and infectious diseases) and effects on the ecosystem are excluded.

In this activity, knowledge and data available as of the present was utilized to the fullest, with emphasis on generating a measure of results as speedily as possible. Additional surveys and data analysis were not carried out, and a report was compiled using existing study results. Regarding the scientific aspect, study reports based on the IPCC AR5 and the SOUSEI Program promoted by MEXT between 2012～2016 were used, as well as relevant expert study results in Japan. Regarding the political, economic and social aspects, in presenting the overview of the regional situation and main arguments, information was compiled through interviews with experts of the respective regional studies carried out within Japan. At the same time, concerning the JICA project (peacebuilding assessment) which is already being implemented from the perspectives of conflict prevention and peacemaking, methods of risk evaluation and considerations conducted on a national level and project level were introduced. A certain measure of

consideration was given to how such assessment methods could be utilized in future analysis of politics, economy and social state.

With respect to the details of the analysis of the situation in the Asia-Pacific Region (especially Southeast Asia and the Pacific Region), of the information obtained from interviews which are reconstructed, some parts appear to lack unity and are fragmented. However, editing such parts has been kept to a minimum from the perspective of maintaining consistency within each interviewee. This is done so as to place emphasis on grasping the situation of the region from various perspectives and to prioritize the extraction of indications obtained therefrom in combination with scientific analysis. The purpose of this study is not to obtain a definite or consistent explanation or analysis. Therefore, the contents of the analysis regarding the regional situation may not be in harmony with the views and evaluations of the Ministry of Foreign Affairs or the Japanese government.

## 4. Overview of Results

Both scientific observations and regional affairs should be incorporated for an effective discussion on climate change and fragility. However, at the present stage, while a detailed estimated value down to several kilometer units is attainable from a scientific perspective, the same level of resolution in information organization related to the regional situation is difficult. In addition, predicting potential future political, economic and social fluctuations or instability factors based on scientific knowledge is not considered to be an effective method, in view of the difficulty in explaining in definite terms the factors climate change has on the regional situation and the causal relationship thereof.

Therefore, in this activity, in an overview of the long-term fluctuation scenario is provided in section II., after which the latest study results of fragility risks, such as natural disasters caused by climate change in the respective regions, are introduced. In the consideration of the respective regional situations concerning the political, economic and social conditions, section III. provides a qualitative overview of the various political, economic and social changes occurring in the respective regions. Finally, in section IV., an examination is made on how the long-term impact of climate change affects the respective regions, and whether there is a provision to keep such risks to a minimum. It is thought that the sharing such risk evaluation methods and risk countermeasures will be useful in the evaluation of risks, etc. in areas outside the Asia-Pacific Region.

Furthermore, in section V., issues which could not be investigated and analyzed in detail in this general consideration and other points which require further consideration are extracted, and elements which can be used as a reference in conducting further studies, policy-making and implementation are presented.

## II. Examinations in Detail: Regarding long-term estimations on climate change

This chapter will introduce estimations concerning climate change in the long run. Section II. 1. will examine the ramifications of climate change as a whole. Later, II. 2. Implications of Climate Change in Asia, along with, 3. Implications of Climate Change in the Pacific Region, will examine estimations at a higher resolution, in the lines of regional characteristics, which make allowances for topographical effects inter alia, to investigate the effects of climate change in a region that are indistinguishable at spherical estimations. In order to project climate change, it is imperative to prepare scenarios in which changes in atmospheric levels of greenhouse gas concentration and aerosol, which engender radioactive forcing (triggers global warming), are postulated. Furthermore, special care must be taken as estimations in future changes depend on the aforementioned scenarios. In circumstances where there are no citations, RCP8.5 (4°C increase in 2100) is used (See VI. Appendix 1.).

### 1. Global factors

Asia-Pacific regions encompass a large proportion of ocean: In this region, impacts of tropical cyclones, and the impacts of sea level rise are of particular interest. In this section, premises indicated in the IPCC AR5 such as climate change induced human security risks are introduced, followed by a) changes in typhoon frequency/intensity, b) changes in storm surges, c) changes in wave heights, d) transitivity of farm production. This resulted in findings: the number of tropical cyclones in the Central North Pacific will increase; in 2100, wave height decreases inversely as temperatures rise in central North Pacific and the vicinity of latitude 40 degrees. Yield estimation in 2080 showed reduction in maize yield in multiple regions, but rice yield increase in developing countries.

(1) Climate change risk concerning human security

Working Group II Report (Impacts, Adaptation and Vulnerability) of IPCC AR5 (IPCC, 2014) assesses the global trend on the correlation between human security risks induced by climate change (climate stress) and the level of risk to livelihood, conflict, culture and migration in Figure 1.

- Climate change over the twenty-first century is projected to increase displacement of people (medium evidence, high agreement).
- Climate change can indirectly increase risks of violent conflicts in the form of civil war and inter-group violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks (medium confidence).
- The impacts of climate change on the critical infrastructure and territorial integrity of many states are expected to influence national security policies (medium evidence, medium agreement).

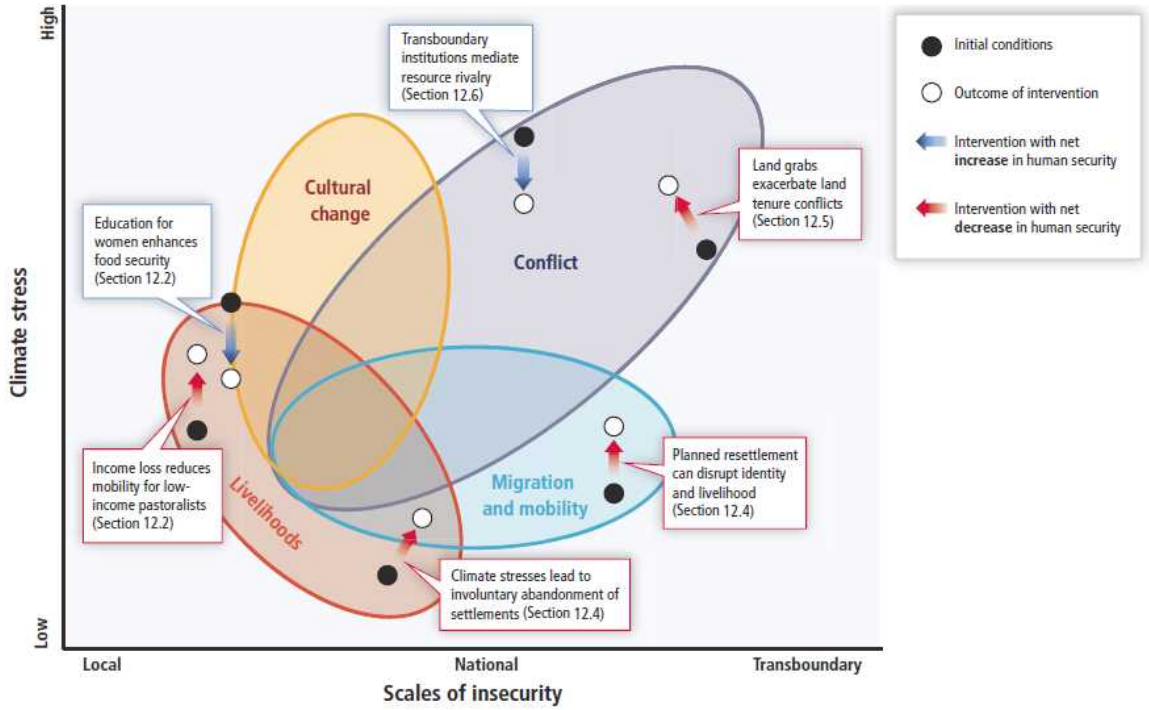



**Figure 1 : Schematic of climate change risks for human security and the interactions between livelihoods, conflict, culture, and migration. Interventions and policies are indicated by the difference between initial conditions (solid black circles) and the outcome of intervention (white circles). Some interventions (blue arrows) show net increase in human security while others (red arrows) lead to net decrease in human security. (WGII TS Figure TS.11, IPCC, 2014)**

In addition, damages caused by effects of climate change in island countries must be considered carefully given that the small sizes of each country may make their damages appear relatively paltry in comparison to other countries. For example, in Table 2 describing typhoon damages in Asia-Pacific Region between 1998 and 2009, island countries do not appear among the top countries in number of victims, yet, the severity of damages can be recognized in the proportion within the country.

| Rank | Absolute exposure | Relative exposure | Absolute GDP loss | Loss of GDP |
|---|---|---|---|---|
| **1** | Japan | Northern Mariana Islands | Japan | Northern Mariana Islands |
| **2** | Philippines | Niue | Republic of Korea | Vanuatu |
| **3** | China | Japan | China | Niue |
| **4** | India | Philippines | Philippines | Fiji |
| **5** | Bangladesh | Fiji | Hong Kong | Japan |
| **6** | Republic of Korea | Samoa | India | Philippines |
| **7** | Myanmar | New Caledonia | Bangladesh | New Caledonia |
| **8** | Vietnam | Vanuatu | Northern Mariana Islands | Samoa |
| **9** | Hong Kong | Tonga | Australia | Tonga |
| **10** | Pakistan | Cook Islands | New Caledonia | Bangladesh |

**Table 2 : Top ten countries in the Asia–Pacific region based on absolute and relative physical exposure to storms and impact on GDP (between 1998 and 2009) (IPCC, 2014)**

(2) Changes in intensity and occurrence frequency of tropical cyclones

Impacts of climate change, especially on tropical cyclones, draw attention in Asia-Pacific Region as it could cause extensive socioeconomical damage.

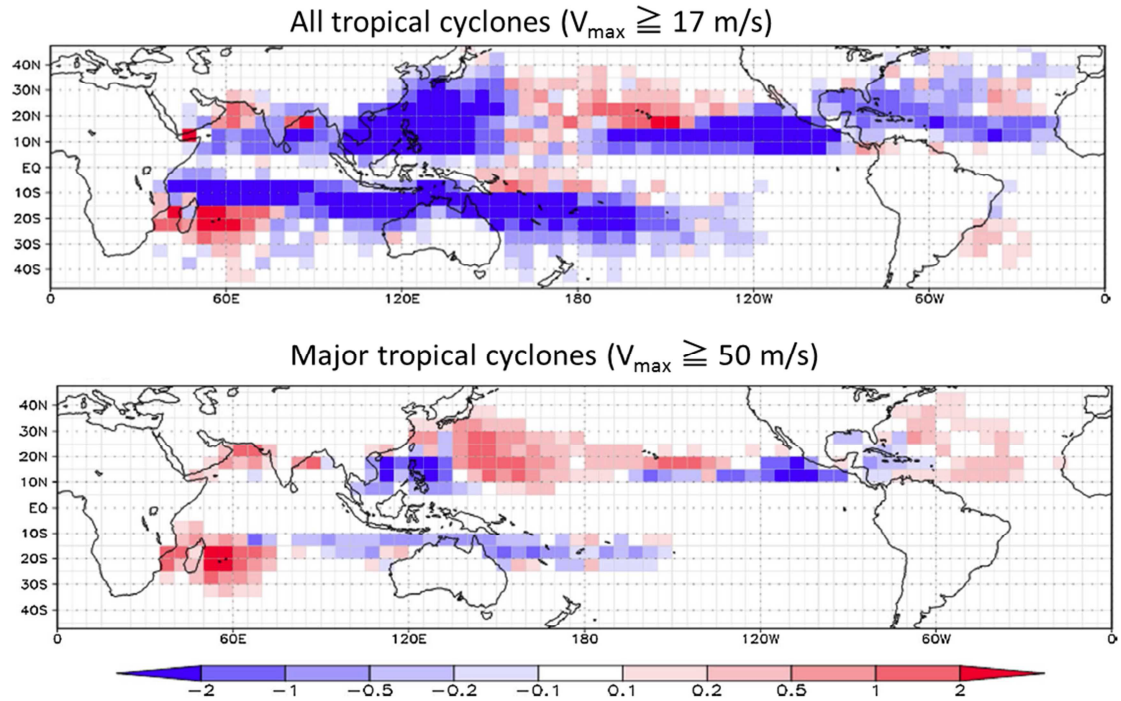



**Figure 2 : Changes in occurrence frequency (tropical cyclone days) of tropical cyclones. All tropical cyclones (upper panel) and major tropical cyclones (lower panel) (Sugi et al., 2016)**

Figure 2 shows the future changes in occurrence frequency of all tropical cyclones (maximum wind speed is greater than or equal to 17 m/s, upper panel) and major tropical cyclones (maximum wind speed is greater than or equal to 50 m/s, lower panel). These changes are calculated by using many high resolution global model simulations of the present-day climate (1979-2003) and the global warming climate (2075-2099). (See VI. Appendix 4.) As the color of the grid box becomes darker red or blue, more or fewer number of tropical cyclones is expected in the warmer climate, respectively. It is projected that the number of all tropical cyclones will generally decrease; however, it will increase in the Central North Pacific Ocean or some other regions. On the other hand, it is projected that the number of major tropical cyclones will increase in most regions; however, it will decrease in southwestern part of the Northwest Pacific, the Northeast Pacific, and in the vicinity of Australia. (Sugi et al., 2016)

(3) Changes in storm surge

There are a number of countries facing the Pacific Ocean in the Asia-Pacific Region, and changes in storm surge are also attracting people's attention (See VI. Appendix 5.). The result is shown in Figure 3 on the long-term assessment of storm surge using sea surface pressure and wind speed data of d4PDF.

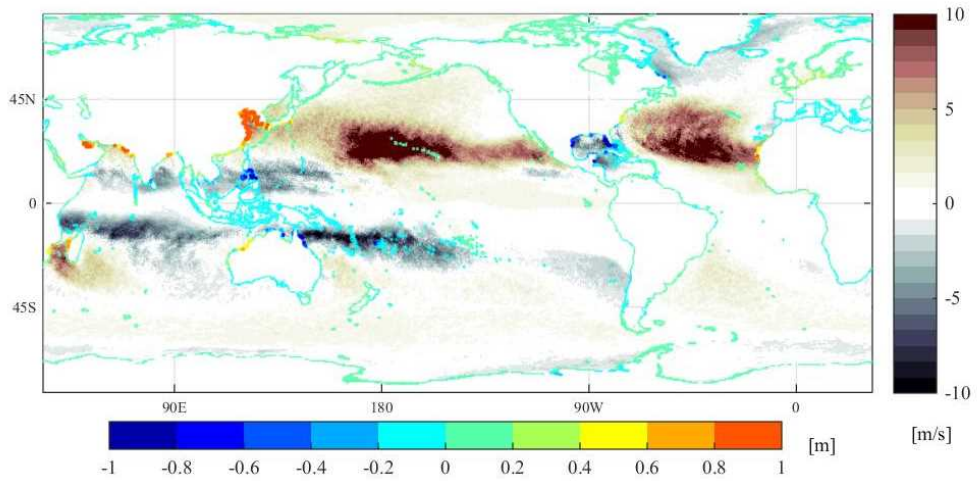


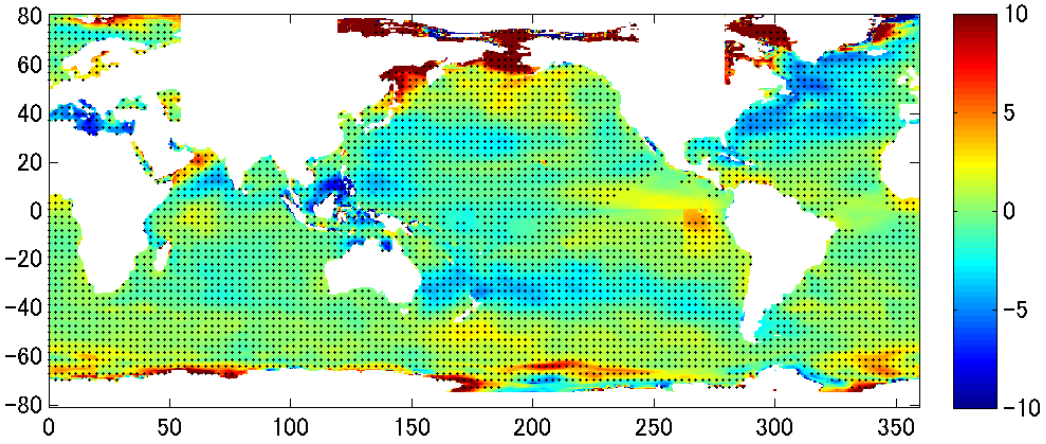

**Figure 3 : Wind speed probability and future variation of storm surge height at a 100-year return period (Mori et al., 2016)**

Future projection on storm surge height was estimated in Figure 3 by showing the change rate of storm surge height from the present-day climate to the 4°C-increase climate (RCP8.5 scenario) at a 100-year return period. Contours on oceans and shores represent condition corresponds to mean global temperature at the end of twenty-first century by wind speed and the change rate of storm surge height, respectively. When it comes to the future change rate of tropical cyclones, it is estimated to be bigger in mid-latitude in the Northern Hemisphere. As to the change rate of storm surge height, it showed discernible correlation with that of wind speed at a 100-year return period; however, in East Asia from China to western Japan, the change rate of storm surge showed more than 20 % while that of wind speed was estimated to be around 10 %. Therefore, the change of storm surge height could be greater than that of wind speed. On the other hand, negative change rate was shown in the Southern Hemisphere. It could lead the conclusion that the peculiarity of the change rate of tropical cyclones predicted by d4PDF showed weak decrease of the central pressure of future tropical cyclones while the number of tropical cyclones decreases outstandingly. (Mori et al., 2016)

(4) Changes in wave height

Recent studies show that climate change could impact changes in wave height in a long-term manner. Figure 4 shows future annual mean wave height estimated by statistical ocean modeling of global mean wave height.

(a) RCP4.5 scenario




(b) RCP8.5 scenario

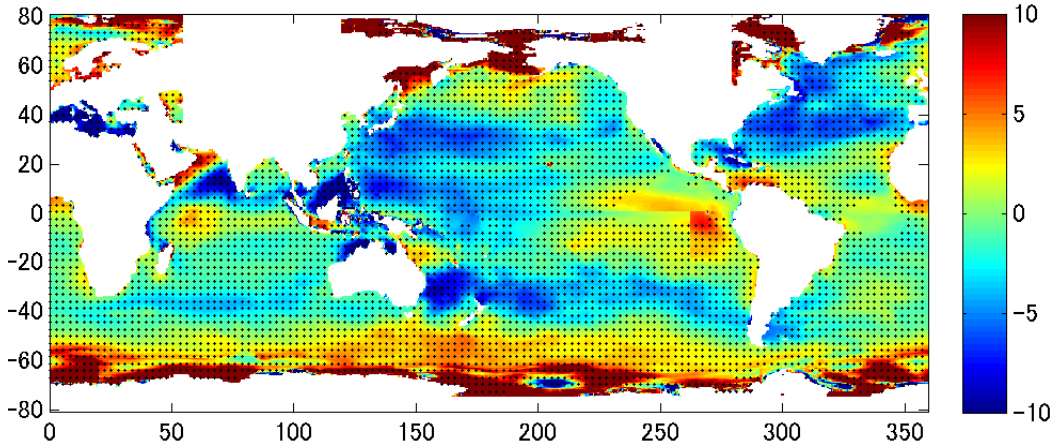



**Figure 4 : Future changes of annual mean wave heights from present condition under (a) RCP4.5 scenario and (b) RCP8.5 scenario (Kishimoto et al., 2017)**

Figure 4 (a) and (b) illustrate projections for RCP4.5 (Stabilization without overshoot pathway) and RCP8.5 (Rising radiative forcing pathway), respectively. In northern part of the North Pacific, the future wave height was estimated to increase in both scenarios. It is believed that the increase in wave height in winter period overwhelms the decrease in wave height in summer period. In the North Atlantic, the C entral North Pacific, and in the vicinity of 40 degrees south latitude, the future wave height showed greater decrease. It was predicted that the decrease in mean wave height could make a significant impact on either advance or retreat of beach shore lines. (Kishimoto et al., 2017)

(5) Transition of agricultural production

The impact of climate change on food production is an important factor in the light of security. Maize and rice were chosen as examples for estimations.

Figure 5 shows the estimated global average yield of maize and rice under RCP2.6 scenario and RCP8.5 scenario, where relatively lower and higher temperature rises are estimated, respectively (See VI. Appendix 6.).

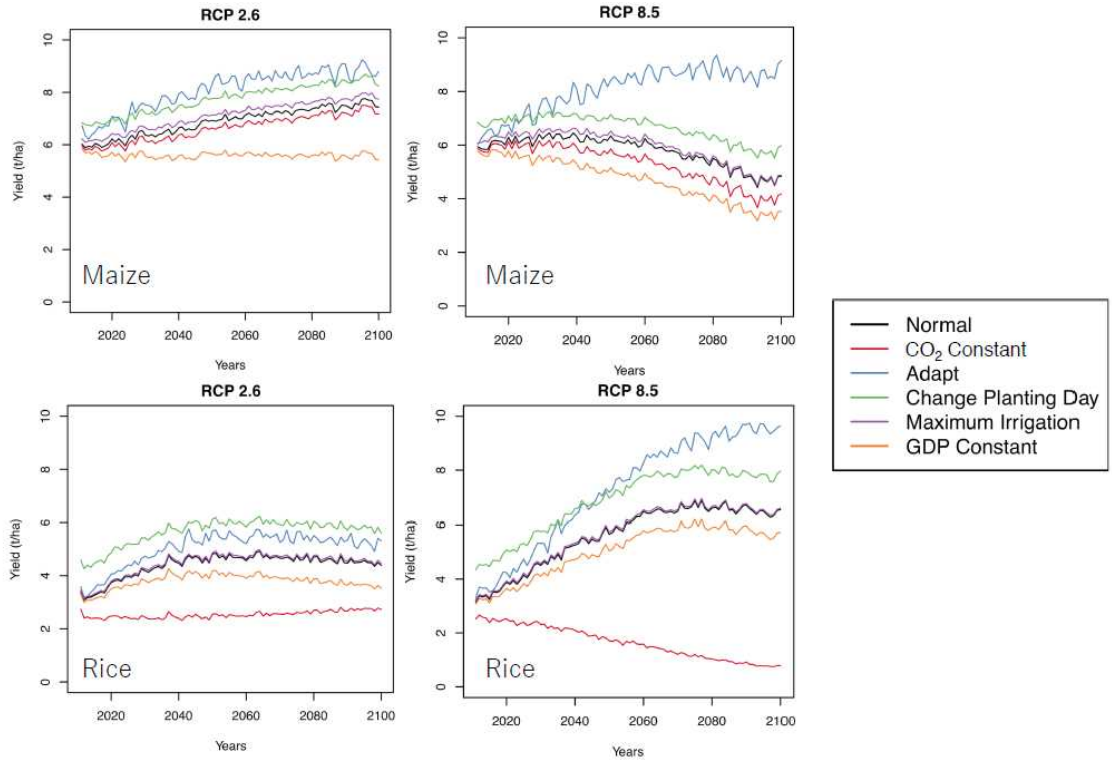



**Figure 5 : Estimated global average of maize and rice yield.（ICA-RUS REPORT, 2017）**

SSP2, a middle of the road scenario was selected as the shared socio-economic pathway (See VI. Appendix 2.) in this study. As to maize, large increases in yield were not expected under both climate change scenarios (RCP2.6 nor RCP8.5), given that maize is a C4 plant (See Glossary) and the $CO_2$ fertilization effect is very low. However, the negative effect of climate change could be minimized by using appropriate crop cultivars. When it comes to rice, significant increase in yield was expected, particularly under the RCP8.5 scenario due to an increase in the notable $CO_2$ fertilization effect. However, planting appropriate crop cultivars is necessary to achieve the twofold rice yield by 2050 which is needed to meet future demand. (ICA-RUS REPORT, 2017)

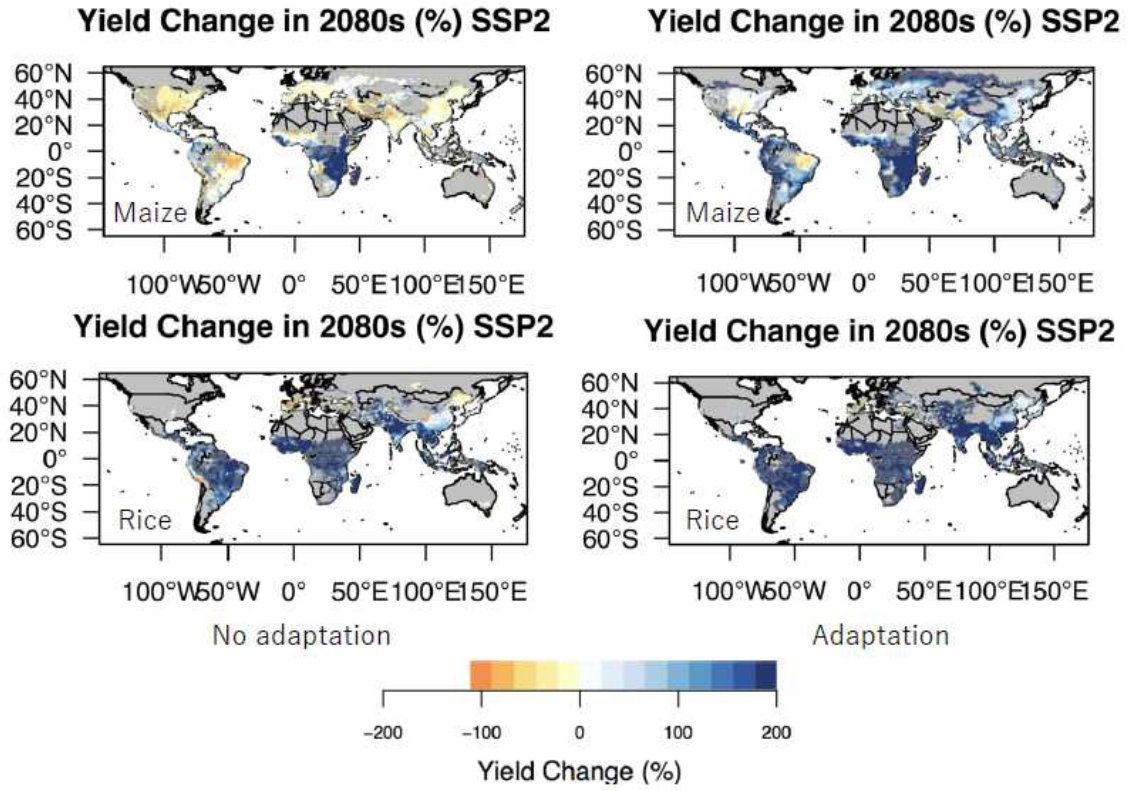



**Figure 6 : Map of the estimated average yield during 2080-2090 (figures above: maize, figures below: rice, figures left: without adaptation, figures right: with adaptation) (ICA-RUS REPORT, 2017)**

Figure 6 shows the maps of estimated maize and rice average yields in 2080s under the RCP8.5 scenario (see VI. Appendix 7). If no adaptation measures were to be implemented, the maize yield may decrease in many parts of the world. On the other hand, the rice yield may increase especially in developing countries. This can be explained by a possible improvement in agricultural technology in developing countries and a significant $CO_2$ fertilization effect for C3 crops (See Glossary). If appropriate adaptation measures were to be implemented, maize yield is also expected to increase in multiple regions of the worlds. These results imply the importance of transferring appropriate expertise to developing countries. (ICA-RUS REPORT, 2017)

## 2. Implications of Climate Change in Asia

According to IPCC AR5, the amount of some rivers' streamflow is predicted to increase with high confidence. Some recent studies on the future change of temperature, precipitation, and flooding showed that monthly averaged temperature in most regions would increase greater than 2°C. Studies on streamflow of five rivers in Southeast Asia projected that annual precipitation would increase. In these five rivers, inundation area, frequency of flood occurrence, and the damage caused by these incidents are expected to increase. Increase in temperature or events of salinity intrusion due to sea level rise are not the only factors that damage agricultural production such as rice and maize crops. Lack of fund for building fundamental infrastructures in most of the expected flood areas is one of the problems as well. Without appropriate countermeasures, the damage would increase and the recovery rate would decrease.

### (1) Examples of climate change impacts in Asia

According to IPCC AR5, impacts of climate change on water-related disasters and

agriculture in Asia have been assessed as in Figure 7.

(a) Snow, ice, rivers, lakes, floods and/or drought
- Increased flow in several rivers due to shrinking glaciers (high confidence, major contribution from climate change)
- Permafrost degradation in Siberia, Central Asia, and Tibetan Plateau (high confidence, major contribution from climate change)

(b) Food production
- Negative impacts on aggregate wheat and maize yields in China, beyond increase due to improved technology (low confidence, minor contribution from climate change)

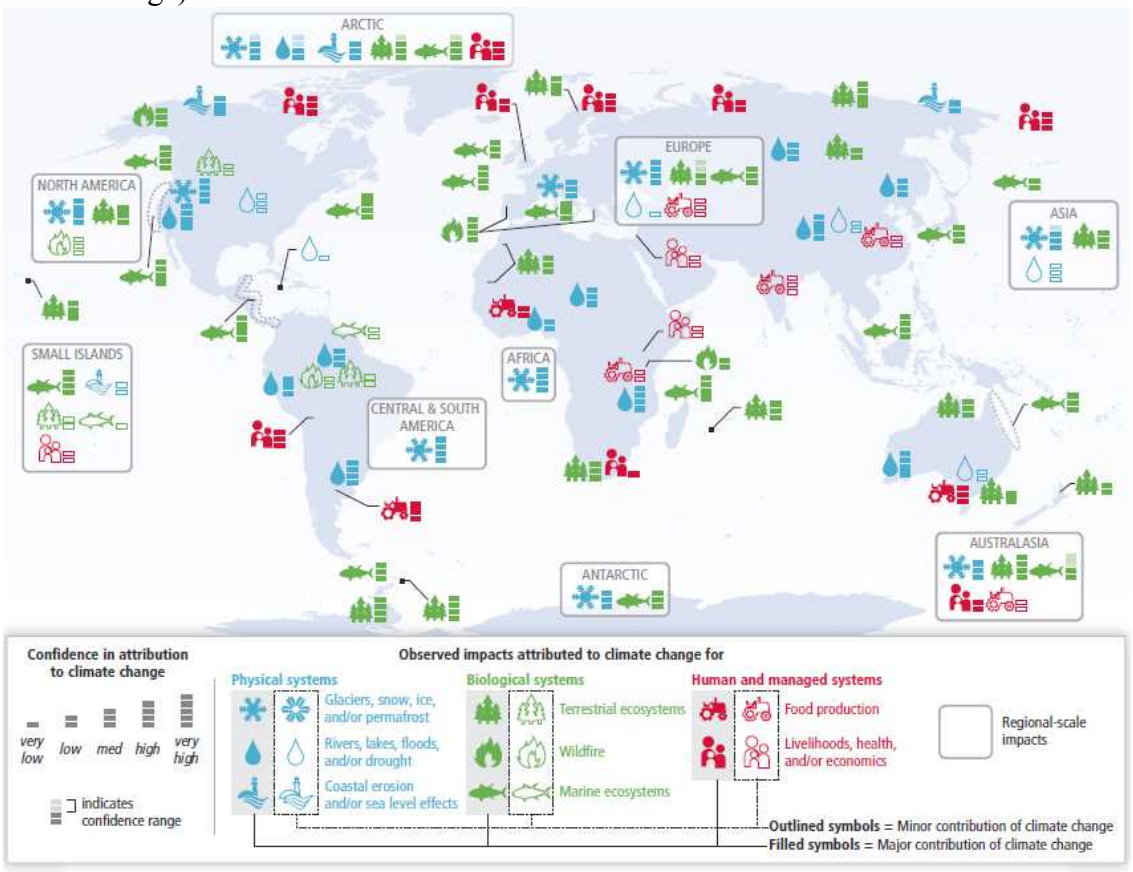



**Figure 7 : Global patterns of impacts in recent decades attributed to climate change, based on studies since IPCC Fourth Assessment Report. Impacts are shown at a range of geographic scales. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution. (IPCC, 2014)**

(2) Temperature projections

It is projected in IPCC AR5 that temperature increases globally in future. The following shows examples of probabilistic future temperature projections in East Asia.

Figure 8 shows the probability map of future temperature projections in East Asia estimated by using the data in the late twentieth century (1969 to 1998) and SRES-A1b scenario (See VI. Appendix 3.).

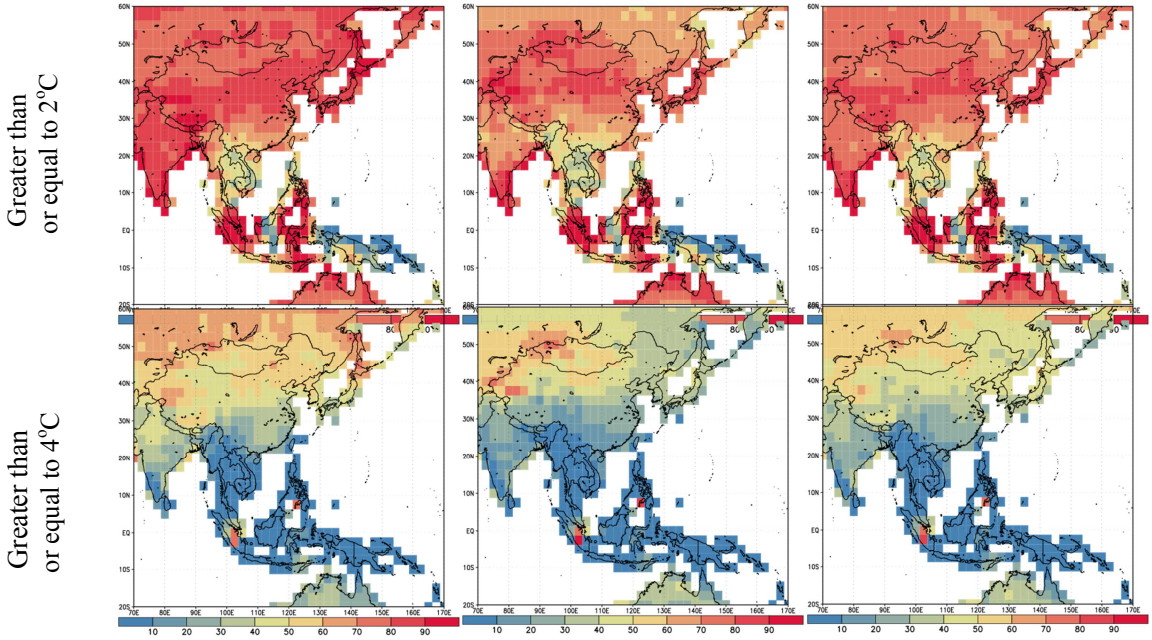



**Figure 8 : Probability map of temperature change in the late twenty-first century in East Asia (NIED, 2017) (Probability (%) of temperature increase: Greater than 2°C (figures above) and 4°C (figures below), respectively. Average for January (left), July (center), and annual average (right)) (see VI. Appendix 8.) (Dairaku, 2016)**

The increase of monthly average temperatures of greater than 2°C was estimated in most regions with probability of more than 70 to 80 % except some regions such as Thailand, Vietnam, and Papua New Guinea, and it was projected that the temperature increase of greater than 2°C is more probable in winter than in summer (figures above). On the other hand, the probability of the increase of monthly average temperatures greater than 4°C was estimated less than 10% in tropical area, and 30 to 60 % in the mid-latitude where the result showed 60 to 70 % in winter (figures below). (NIED, 2017)

(3) Precipitation projection (South China)

A study was conducted on impacts of climate change on precipitation at the end of twenty-first century focusing in South China. Figure 9 shows the distribution of the frequencies of the maximum annual daily precipitation averaged over South China for the past day climate (60 years, blue) and the 4°C-increase climate (4°C-increase at 2100 with RCP8.5 scenario (see VI. Appendix 1.), red).

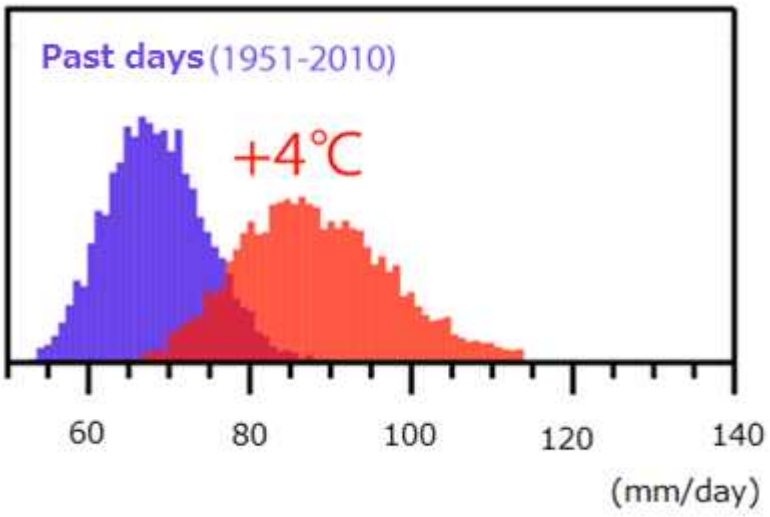



**Figure 9 : Distribution of frequencies on the annual maximum daily precipitation averaged over South China (NIES, SOUSEI Program, 2017)**

It was shown that the precipitation with higher intensity increases in the 4°C-increase climate when compared to the past day climate, and strong precipitation that occurs several times in 60 years x 100 members in the past day climate was estimated to be the average precipitation in the 4°C-increase climate (see VI. Appendix 9.). It was also projected that, in the 4°C-increase climate, precipitation with high intensity that the region has not been experienced would occur frequently. (NIES, 2017)

(4) Precipitation projection (Southeast Asia)

The change in precipitation due to climate change leads the change in flow in rivers. Precipitation projection under RCP8.5 scenario is illustrated in Figure 10 over Southeast Asia where many international rivers flow.

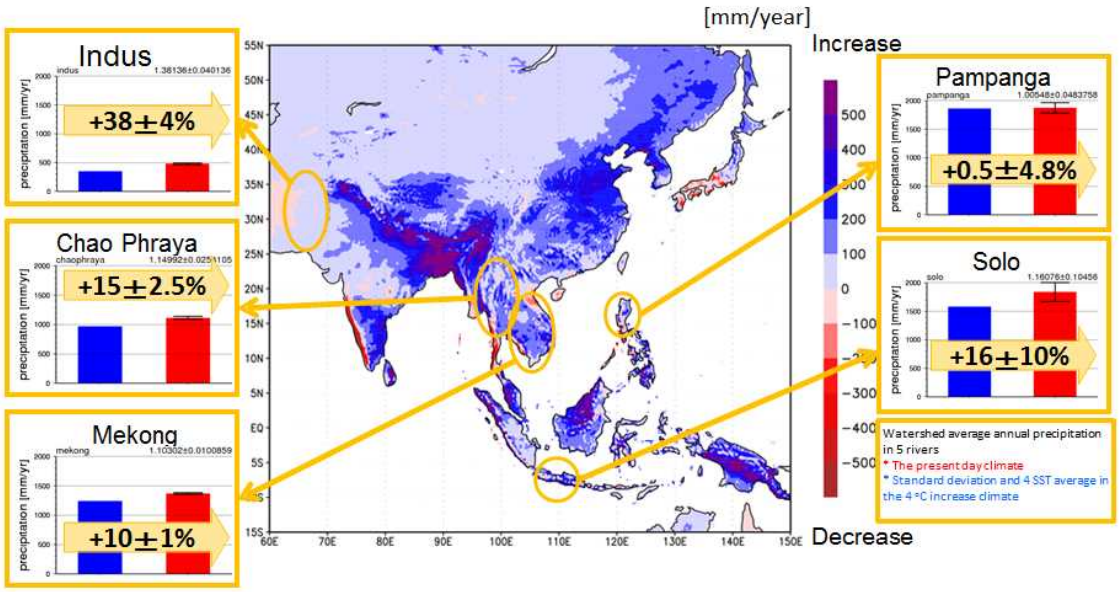



**Figure 10 : Annual average precipitation in the present-day climate and the 4 °C-increase climate over Indus River, Chao Phraya River, Mekong River, Pampanga River, and Solo River (ICHARM, SOUSEI Program, 2017)**

The central figure on Figure 10 shows the difference of annual precipitation between the tests of the future climate under RCP8.5 scenario and the present-day climate

by using ensemble average of sea surface temperatures (SSTs) (see VI. Appendix 10.). The amount of water vapor increases due to the global warming, and it was estimated that it would lead the increase in annual precipitation over the wide range of Asia (dark blue to purple shading).

Bar charts around the central figure show the change rate in annual precipitation averaged over river area for the five rivers (Indus River, Chao Phraya River, Mekong River, Pampanga River, and Solo River) from the present-day climate to the future climate. The result implied that, even though there is uncertainty in climate predictions, the annual precipitation of ensemble average of SST in the future climate would increase with the range of 0.5 % to 38 % in the five rivers. (ICHARM, SOUSEI Program, 2017)

(5) Assessment of water-related disaster: Mekong River, Chao Phraya River, Solo River, and Pampanga River

Figure 11 to 15 show the projections of change in flood intensity over Southeast Asia where the precipitation increase is estimated under RCP8.5 scenario. The results also show the projections of damage on agriculture.

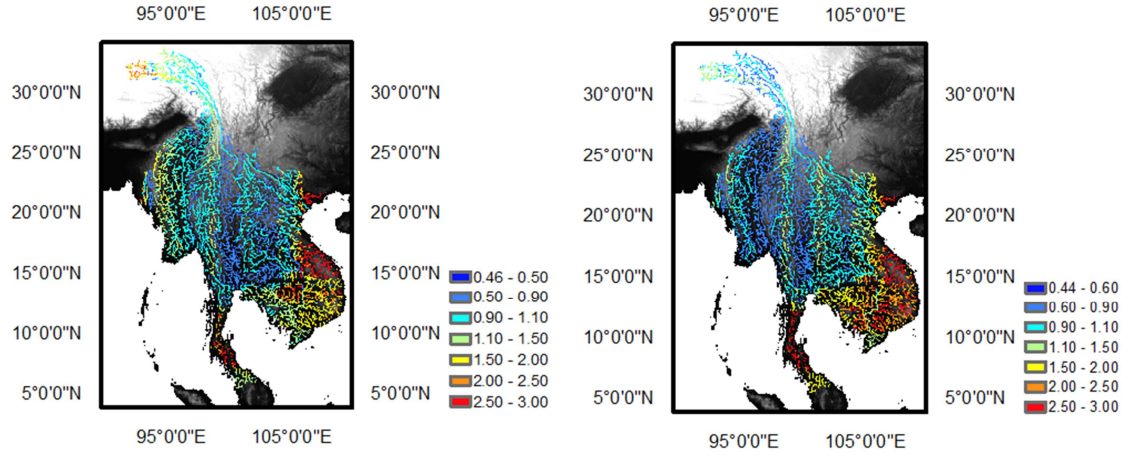



**Figure 11 : Annual maximum flow in rivers over Indochina Peninsula using d4PDF for the past day climate and the 4°C-increase climate experiment based on the RCP8.5 scenario (future projection of SST pattern calculated by MRI-GCM3(MR) was used). Figure left: future change rate for the average of annual maximum river flow, figure right: future change rate for the standard deviation of annual maximum river flow. (Tachikawa et al., 2017)**

Calculation of continuous river flow under RCP8.5 scenario was conducted by inputting the amount of generated runoff in the d4PDF into a river flow routing model which was developed for Indochina Peninsula region (see VI. Appendix 11.). The continuous river flow data was used to analyze the change in annual maximum river flow. Figure 11 displays the spatial distribution of the change rate of the average (left) and standard deviation (right) of the annual maximum daily river flow for the past day climate and the 4°C-increase climate experiment based on the RCP8.5 scenario. Over the east and southeast parts of Indochina Peninsula and the southern Thailand, the rates were estimated to increase, implying that the intensity of extreme floods with the same frequency would be stronger. (Tachikawa et al., 2017)

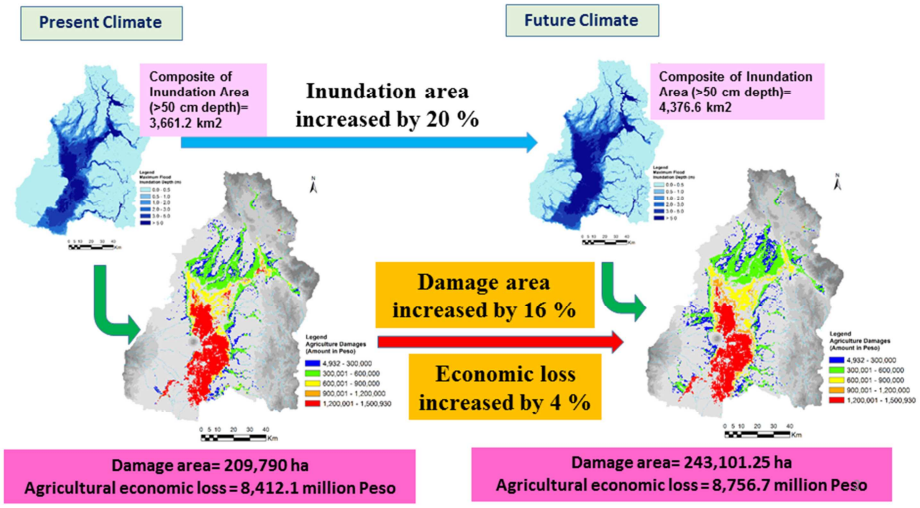



**Figure 12 : Estimation of inundation depth, inundation area, inundation period, agricultural damage quantity, and agricultural damage brought by 100-year precipitation over Pampanga River (ICHARM, 2017)**

Inundation depth, inundation area, and inundation period brought by 100-year precipitation were estimated over Pampanga River by Rainfall Runoff Inundation (RRI) model using the present-day climate and the future climate. The agricultural damage quantity was calculated by applying the damage curve on rice developed by ICHARM, and the agricultural damage was estimated by using the unit of current shipment value on rice in the region. Figure 12 shows that the inundation area would increase by approximately 20% under the future climate; however, the agricultural damage was estimated to remain at a few percent increase. (ICHARM, 2017)

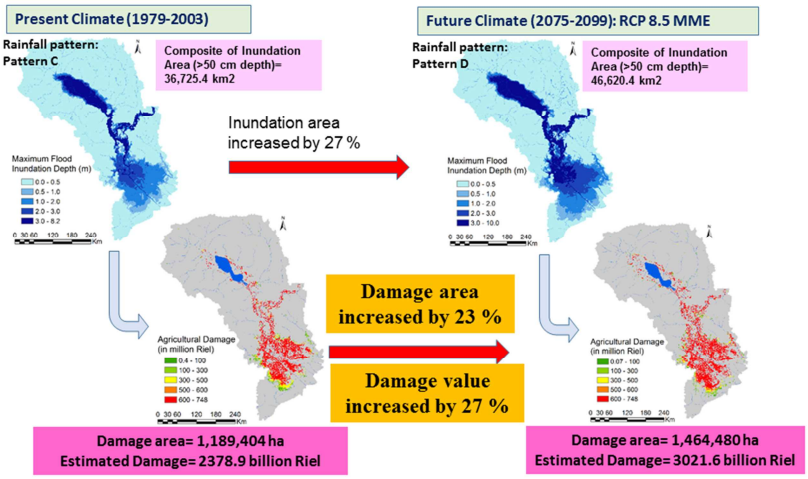



**Figure 13 : Estimation of inundation depth, inundation area, inundation period, agricultural damage quantity, and agricultural damage brought by 100-year precipitation over lower reach of Mekong River (ICHARM, 2017)**

The same method was used in lower reach of Mekong River. Figure 13 represents that both the inundation area and damage were estimated to increase approximately 30%. (ICHARM, 2017)

| Precipitation pattern | Maximum inundation area (km2) |
|---|---|
| 1 | 932 |
| 2 | 808 |
| 3 | 1,019 |
| 4 | 390 |
| 5 | 932 |
| 6 | 683 |
| 7 | 1,055 |
| 8 | 803 |
| 9 | 836 |
| 10 | 357 |


| Precipitation pattern | Maximum inundation area (km2) |
|---|---|
| 1 | 1,049 |
| 2 | 855 |
| 3 | 926 |
| 4 | 1,024 |
| 5 | 1,119 |
| 6 | 733 |
| 7 | 1,009 |
| 8 | 1,053 |
| 9 | 959 |
| 10 | 793 |

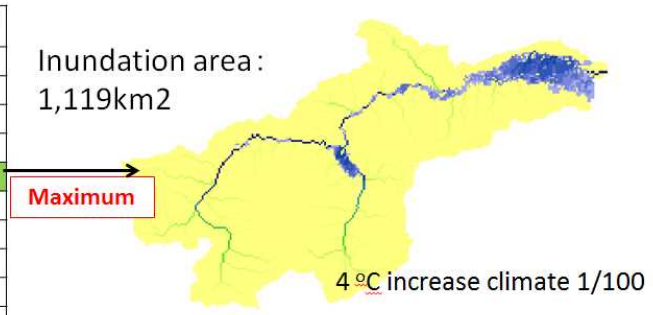



**Figure 14 : Comparison of the worst case scenarios between the present-day climate and the future climate among 10 patterns of precipitation for 100-year precipitation over Solo River (ICHARM, SOUSEI Program, 2017)**

Statistics analysis was used to generate 100-year precipitation data for the precipitation data of the present-day climate and the future climate calculated by MRI-AGCM3.2S (See Glossary) over Solo River. Figure 14 illustrates that, in the future climate, the inundation area was estimated to increase in the worst case scenario, leading a conclusion that inundation of larger scale could occur in the future climate under the precipitation of the same occurrence probability. (ICHARM, SOUSEI Program, 2017)

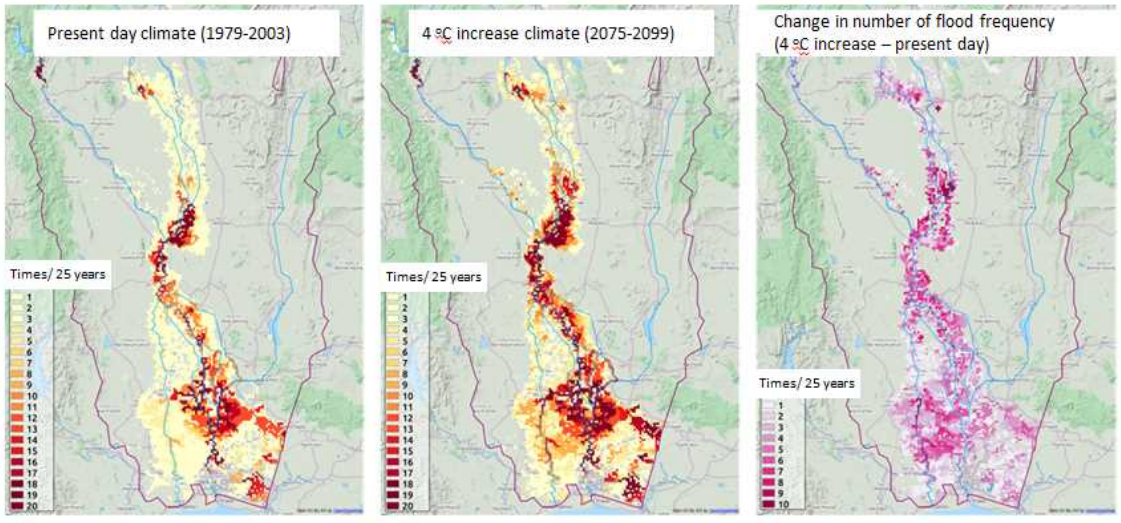



**Figure 15 : Projection of the change of flood frequency in inundation analysis over Chao Phraya River (ICHARM, SOUSEI Program, 2017)**

Flood frequency (inundation depth greater than or equal to 0.5 m) for the present-day climate and the future climate were compared over Chao Phraya River. The left, center, and right figures in Figure 15 depict the spatial distribution of the number of inundation for the present-day climate, the future climate, and the difference between the

two, respectively, calculated by RRI model with the annual maximum inundation depth for 25 years. The result showed little difference in inundation area; however, flood frequency was estimated to increase in the future climate approximately 10% and 20% along the main stream of Chao Phraya River and the northwest part of Bangkok, respectively. (ICHARM, SOUSEI Program, 2017)

(6) Impacts of sea level rise on agriculture: rice production and water environment in Mekong Delta

In estuarine region of Mekong Delta, impacts of sea level rise on agriculture should be considered. A hydraulic model was developed to assess the impacts of salinity intrusion and flood at the same time where both are considered as a result of the change in Mekong River flow. The model made it possible to see the influence on rice production in Mekong Delta in Vietnam resulting from sea level rise caused by climate change. The result of the assessment is shown in Figure 16.

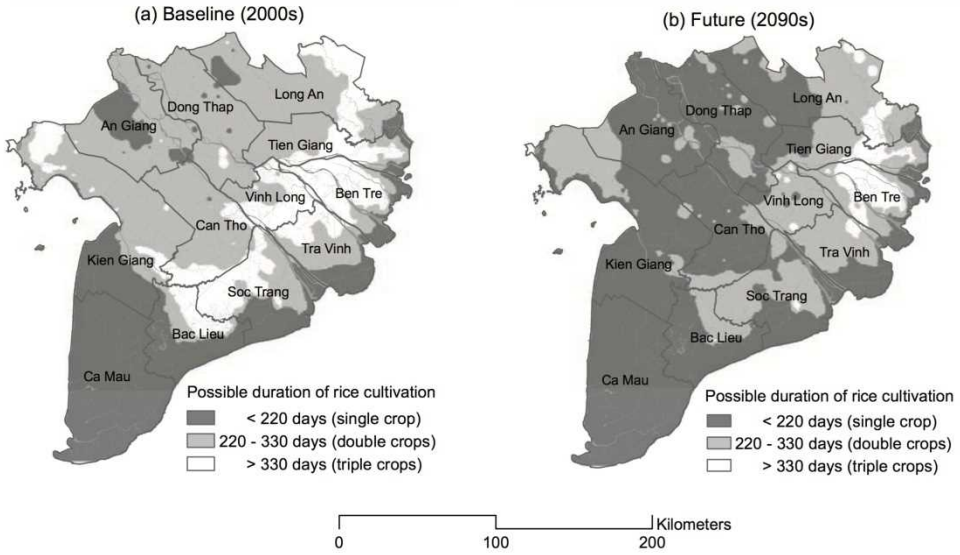



**Figure 16 : Spatial distribution of the possible duration of rice cultivation as a result of salinity intrusion and flooding in the baseline (left) and future scenario (right) (Khang et al., 2010)**

SRES-B2, one climate change scenario in 2090s (See VI. Appendix 3.) was chosen with following parameters: temperature; precipitation; solar radiation; sea level rise inside the Mekong Delta; streamflow change in the upstream of Mekong River in order to estimate the quantity of streamflow and the degree of salinity intrusion between December to June in mid-2090s. The result indicated that both water level and flood area were estimated to become higher and larger in Future (in 2090s) in comparison to Baseline (from 1998 to 2006). While the potentially available area for triple rice crops showed a decrease from 31% to 5%, the area for a single rice crop showed an increase from 21% to 62%. These major changes in rice cultivation period in the future could be mostly due to the longer duration of flood resulting from the increase in streamflow in the upstream (Figure 16). (Khang et al., 2010, Collection of Report from Agro-Environmental Sciences, 2011)

(7) Changes in extreme wave heights

Climate change impacts on wave heights at the coast. The changes in average wave heights are assessed in IPCC AR5 and the section II. 1. (4) in this report. After the release of the report, the future change in extreme wave heights have been studied, and one of the results is shown in Figure 17.

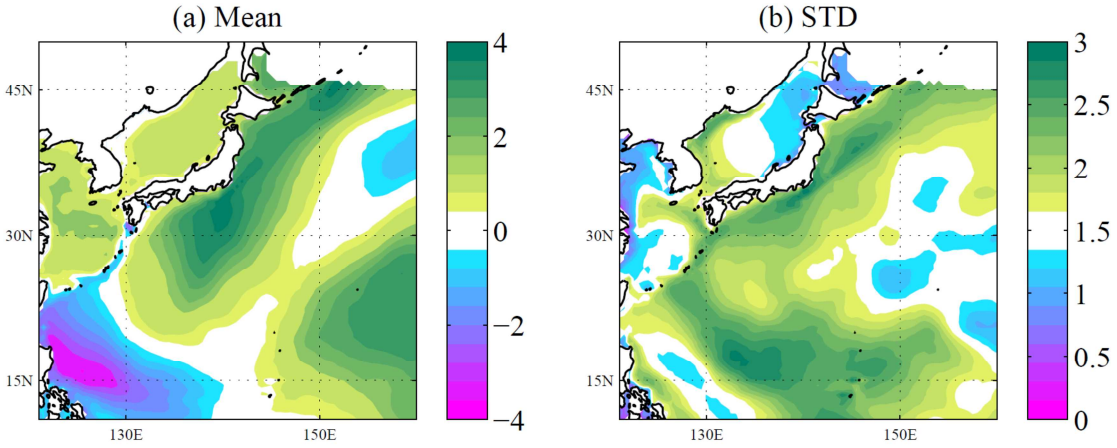



**Figure 17 : The result of the ensemble experiment of the future changes in extreme wave heights of 10 years return period ((a) mean, (b) standard deviation. Unit: m) (Shimura et al., 2015)**

It has been estimated that extreme wave heights would increase to approximately 1m over the middle to high latitudes in the Southern Ocean and Central North Pacific and decrease to around 1m over mid-latitudes and the North Atlantic. Future projections of extreme wave heights were carried out with single-model ensemble experiments of the atmospheric global climate model MRI-AGCM3.2H (Figure 17). The 10-year return wave heights over the Pacific Ocean near Japan showed significant increase, and this increase can be explained by eastward shift of tropical cyclone tracks (when ignoring the uncertainty in climate prediction, genesis locations of tropical cyclones are expected to shift toward east in the Northwest Pacific Ocean). It has come to the realization that future changes in extreme waves along Japan coast depend on the estimated decrease in cyclogenesis number, increase in intensity, and eastward shift of tropical cyclones. (Shimura et al., 2015)

(8) Fragility at the coast

The assessment has conducted in Southeast Asia on what kind of impacts climate change could bring on the fragility at the coast.

(a) Vietnam

Fragility assessment was carried out over Red River Delta and Mekong River Delta in Vietnam considering sea level rise, down-scaled population scenario, and socioeconomic impacts such as poverty, and the result is illustrated in Figure 18.

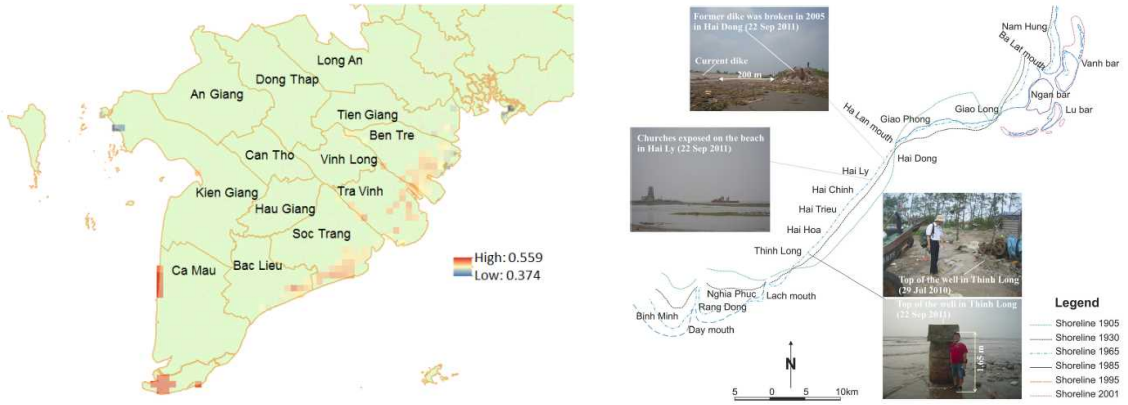
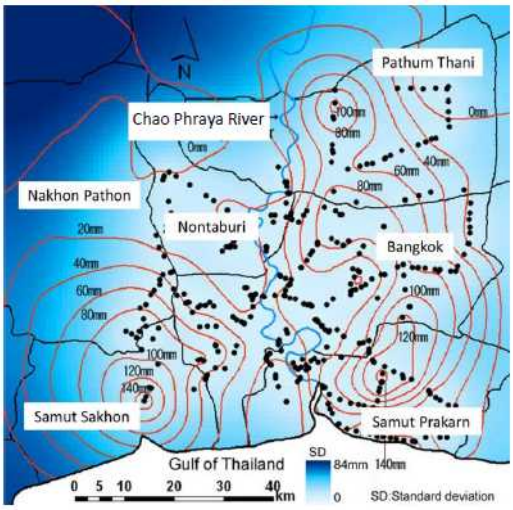



**Figure 18 : Fragility and erosion along the coast in Vietnam (left: Mekong Delta in the south, right: Hai Hau coast in the north) (Tamura et al., 2013, Yasuhara et al., 2016, Duc et al. 2012)**

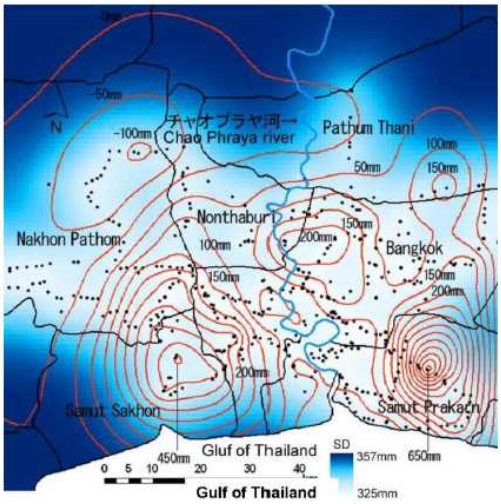
Several dozen meters of erosion per a year has been observed in some areas of Vietnam. It has been pointed out that the cause of erosion is not only sea level rise resulting from climate change, but also other factors such as the decrease of sand supply from the

upstream and the change in land use from mangrove to shrimp farm. (Tamura et al., 2013, Yasuhara et al., 2016, Duc et al. 2012)

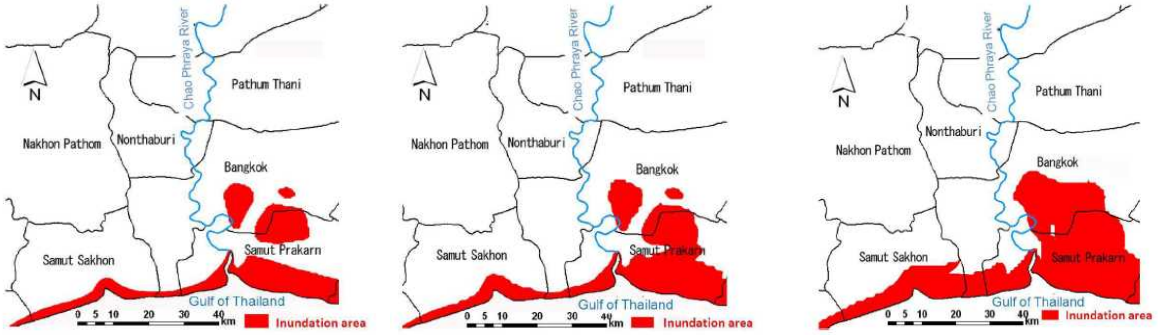
(b) Thailand




**(a) Contour map of land subsidence in Chao Phraya Delta (1996 to 2003)**




**(b) Contour map of the interpolated future land subsidence (2001 to 2100)**




**(c) Inundation area caused by only sea level rise (left), sea level rise and land subsidence (center), and sea level rise and subsidence with estimation error (right)**

**Figure 19 : Sea level rise and subsidence in Chao Phraya, Thailand (Yasuhara et al., 2015)**

Land subsidence in Chao Phraya due to groundwater pumping has been observed in delta area at the downstream of Chao Phraya River. It was implied by using satellite data and sea level rise model that, when adding sea level rise resulting from climate change in the future as a parameter, flood risk could escalate in the region (Figure 19). (Yasuhara et al., 2015)

(c) Bangladesh

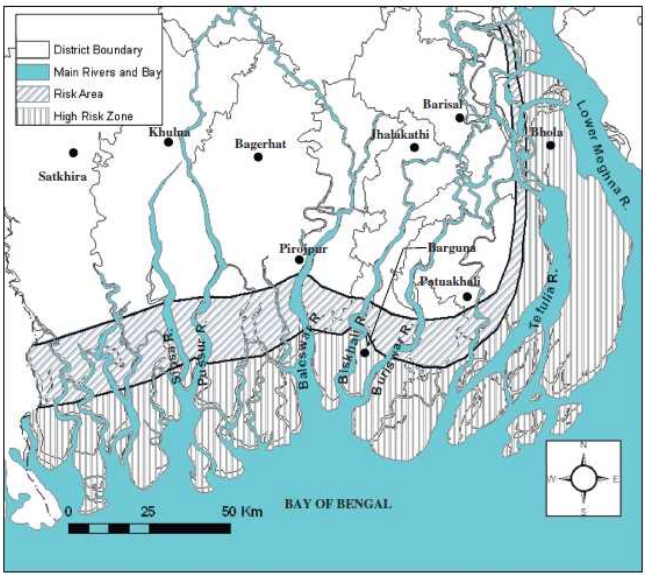



**Figure 20 : Predicted surge intrusion length and flooding area under 2 $^{o}$C of SST rise and 30 cm of sea level rise (above) and Flood risk map corresponds to a typical projected climate (Karim and Mimura, 2008)**

Figure 20 displays the predicted surge intrusion length and flooding area when severe storm such as tropical cyclones occurs under 2$^{o}$C of SST rise and 30 cm of sea level rise using a fluid dynamics model. It was estimated that 15.3 % larger land would be under flood risk compared to the present risk area, and the inundation period would be longer than that in the present. (Karim and Mimura, 2008)

## 3. Implications of Climate Change in the Pacific Region

There are many indicators that island countries (particularly atoll nations) face risk of obliteration as a consequence of rising sea level in future. However, instead of only focusing on sea level rise, it is also important to consider the following issues that are currently arising in the capital such as expansion of residential areas in vulnerable area; degradation of coral reef ecosystems caused by urbanization such as landfill, household effluents, and waste; and socioeconomic aspects of migration. A nation's vulnerability accumulates as a corollary of these issues.

### (1) Effects of Climate Change in Small Island Countries (particularly Atoll Nations) of the Pacific Region

IPCC AR5 estimates 0.3-1m rise in sea level during this century as a result of global warming. There are also studies after this report presenting an estimation of 0.5-1.2m sea level rise, accounting for the contingent melting of the Antarctic ice sheet. Sea level will continue to rise, even after reaching the maximum of $CO_2$ concentration and global warming, owing to glacier-melt and the thermal expansion of sea water. The sea level is estimated to rise 1-6m in a few centuries (See Figure 21).

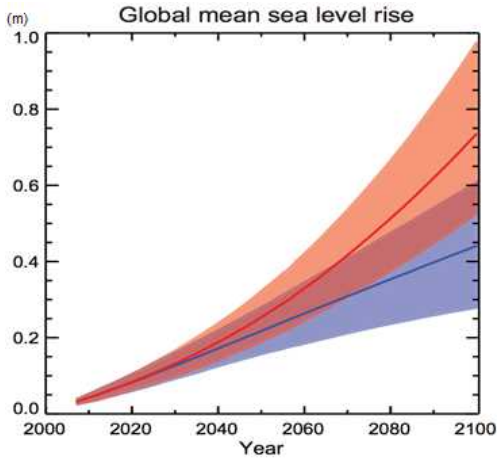



**Figure 21 : Projection of global mean sea level rise (IPCC, 2014)**

Small island countries in the Pacific face risk of submergence from climate change. In atolls, where coral reefs are connected in rings, islands (atoll state islands) consist of low-lying lands are only 1-2m in altitude. In such atoll nations, increased storm surge/tropical cyclone damages and adverse effects of salination in ground water will lead to coastal erosion, resulting in submergence risk.

| Number of Atolls | | | | | |
|---|---|---|---|---|---|
| Pacific Ocean | 392 | | | | |
| Micronesia | 88 | Polynesia | 107 | Melanesia | 29 |
| Southeast Asia | 114 | Australia | 54 | | |
| Indian Ocean | 67 | | | | |
| Central Indian Ocean | 41 | Western Indian Ocean | 25 | Middle East | 1 |
| Atlantic Ocean | 23 | | | | |
| North Caribbean Sea | 4 | West Caribbean Sea | 15 | East Caribbean Sea | 4 |
| Total | 482 | | | | |

| | Number of Atolls | Population |
|---|---|---|
| **Pacific Ocean** | | |
| Federal States of Micronesia | 30 | 13.3 |
| Republic of the Marshall Islands | 28 | 6.8 |
| Tuvalu | 6 | 1.1 |
| Republic of Kiribati | 26 | 9.2 |
| Cook Islands | 8 | 2 |
| French Polynesia | 79 | 24.9 |
| **Indian Ocean** | | |
| Republic of Maldives | 22 | 30.1 |
| Total | 177 | 87.4 |

**Table 3 : Number of atolls (Kayanne, 2008)**

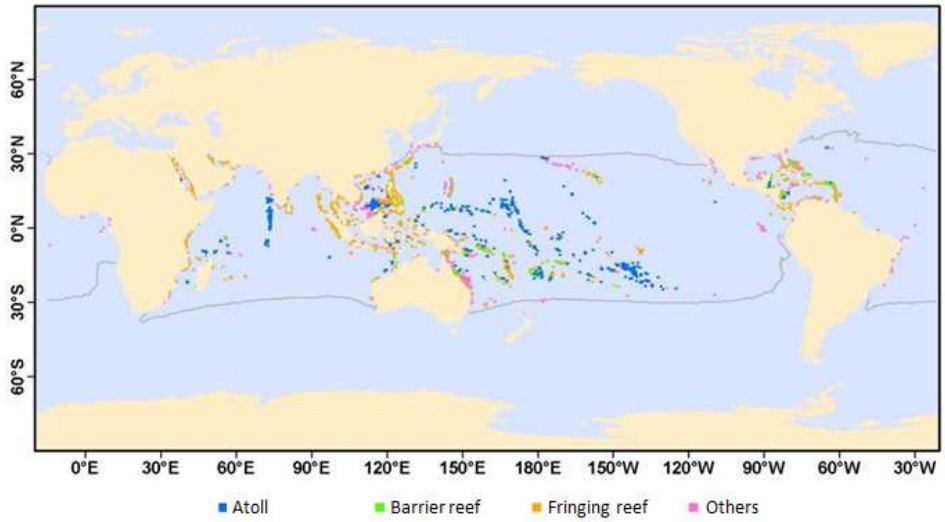



**Figure 22 : Distribution of coral atolls in the world (Kayanne, 2008)**

There are approximately 500 atolls in the world, of which 400 are dispersed in the Pacific Ocean (See Table 3, Figure 22). In addition, countries such as Republic of the Marshall Islands, Republic of Kiribati and Tuvalu located in the Pacific Ocean and Republic of Maldives located in the Indian Ocean are entirely founded upon coral atolls.

Media including scientific journals are reporting that these archipelagos have already begun to submerge as a result of sea level rise (Figure 22). However, this phenomenon is not only caused by sea level rise. Urbanization and issues arising as by-products of economic activity in atoll nations are also large factors that must be thoroughly considered along with the impacts of sea level rise when examining the climate change implications on the economic society of each country.

## III. Examinations in Detail: Elements for consideration regarding the regional socioeconomic situation

1. Asia and Southeast Asia

Socioeconomic disparity issues caused by the economic growth and urbanization are commonly seen in a large part of Southeast Asia. Citizens who do not benefit from economic growth in these regions may be contrived to live in poorer living conditions once climate change implications surface on top of foregoing issues. Furthermore, migration predominantly resulting from economic reasons in Southeast Asia had been noted, but there are regions incapable of responding adequately to these population influxes alongside capable regions. Climate change implications may surge sources of socioeconomic instability in politically unstable regions. In addition, climate change implications bear factors that expedite sources of regional conflict such as changes in fishing ground and exhaustion of resources, which increase the fragility within the area.

(1) Socioeconomic aspect

(a) Changes in economic affairs

- Data on economic disparities in the last two decades were organized from the IMF "World Economic Database". The results show differences in growth of real national income per capita between Europe and Asia in both 1996-2005 and 2006-2015.
- In Europe, real national income increased steadily in the first decade (1996-2005) from 100 to 120-130, living standards rose, and so did people's hope for the future. Instead, the growth in 2006-2015 was sluggish, 100 to 102-103.
- On the other hand, real national income per capita increased more in 2006-2015 than in 1996-2005 in Asian countries. That of China increased over fourfold; even those of Indonesia and Philippines increased from 100 to 120-135. As a result, living conditions in those countries improved significantly in single generation. However, there is no guarantee that there will be a similar economic growth in Asian countries in the next decade. If a steady economic growth is not accomplished, there is a risk of political insecurity.
- Furthermore, there are countries in South Asia that face risk of becoming a society with declining birth rates without escaping the Middle Income Trap. Social welfare and infrastructure are still inadequate in these countries, thus making them vulnerable against future climate risks.

(b) Inter-regional disparity

- Income gap issues do not simply consist of the growing disparities between rural and urban areas. The fact that this wealth, concentrated in cities, is not redistributed within, let alone in provinces, and is conductive to increased disparity. In this condition, only large cities will receive the benefits, and discontentment against certain privileged tiers in these cities will accrue.
- While urbanization prompts growth in service industry, it also induces informal sector to grow under inadequate social policy conditions. Especially, in areas with fragile infrastructure such as slums and squatters, climate change risks combined with

reduced governance may, for instance, incite the outbreak of infectious diseases, international terrorism, and organized crime.
- On top of regional inequality, there is also inequality between generations. Inequality between generations is not limited to Southeast Asia, instead, it is a critical issue arising world-wide.

(c) Rural Areas (farming villages, fishing industries)
- In Asian regions, the farming population still makes the majority today, but Southeast Asia still struggles on how to increase agricultural productivity. During the economic crisis twenty years ago, there were workers returning from cities to farming. However, it remains uncertain whether the workers return to farming like before if another economic crisis happens.
- A safety net, such as income compensation for farmers with lowered productivity, will be important in this region. However, it also needs to be taken into account that the effect of safety net is limited.
- Effects of haze are even more critical than safety nets regarding agricultural productivity. Lack of forest management skills will exacerbate their effects. Inadequate forest administration will make the influence severer.
- The inequality between nations can greatly influence logistics for items such as food. For instance, during food shortage, cheaper rice compared to other regions can be smuggled from overseas.
- Given that a vast majority of countries in Southeast Asia are enclosed by the ocean, fishing is an important livelihood of a large part of the region's population. In order to gain sufficient profits in the long run, the resources of fishing industry and the marine environment must be conserved while placing the whole fishery on the global value chain.

(d) Risk management of disasters and supply chains
- The low-lying Mekong basin is at a major risk of incurring frequent flood damages. Consequently, some companies have taken countermeasures by relocating their factories in areas less liable to flood.
- For example, the vulnerability of the global supply chain was reacknowledged during a flooding in Thailand in 2011, which devastated many Japanese factories. However, isolating the clustered industrial complex is complicated. In many cases, companies responded by reinforcing flood disaster prevention measures. In addition, the relocationg embodies new risks such as running out of supplies like water, which factories depend on. Typhoon Haiyan (known as Yolanda in the Philippines) which struck central Philippines in 2013 presents an analogous situation.
- "Visualization" by means of employing IoT (Internet of Things) is important. Amid recent years' rapid development of IoT, movement of goods are now easily tracked in real time. The most realistic way to respond to disaster risks is to manage the risk by checking the supply chain more accurately throughout the distribution of commodity. Moreover, IoT made it possible not only to make the factory and the supply chain more efficient, but to include information about the risks. In fact, it is becoming possible to replenish supplies while collecting the information on risks.

(e) Development
- Developing countries typically pursue industrialization for their economic development. Consequently, not many countries consider agriculture, the current key industry, as a top-priority, prospective field for development.

- If countries with their comparative advantage in agriculture pursue industrialization prematurely, they may lose human and natural resources to the wrong sort of sectors for their development In fact, many young labor forces are moving from farms to cities, and if this trend continues, environmental destruction might accrue, depending on how the abandoned farmland will be used.
- Several countries are facing the same issue where the long-term user right of broader part of lands is transferred to foreign capital by concession contract through buying up lands or transferring interests. The governments are trying to protect their vulnerable land by better regulating land concession procedures.
- Relying heavily on foreign investment might create a risk of volatility in capital flows. There is a need to foster enabling environment for domestic enterprises to thrive and domestic capital to accumulate.
- Inadequate environmental assessment and governance in development investment by the foreign capital will affect the environment and may cause tension between the tradition and the culture of the local residents.
- Influx of migrant laborers among countries at different levels of economic development can cause political and social conflicts, particularly where neighbor countries share long land borders and migrants are difficult to regulate.
- It is pointed out that the political and economic interest may relate behind disorderly land development or overexploitation of the natural resources. Better governance would require independent media and professional security and law enforcement agencies in particular.
- Issues relating to the management of basin environment and water resources would tend to be focused by the climate change risk. This risk needs to be considered especially in the regional coordination and assessment of the international river management (such as the Mekong River Commission).

(f) Influence of the technological innovation

- The disparity between the young generation and high income earners has been observed in large cities. In addition, the emergence of young generations who are apt in establishing networks via social media, may increase tension between them and the older generation who are relatively less competent with digitalization.
- It has been pointed out that the situation each country is facing about the technological innovation has changed since 2016. Amid the advance of digitalization, the high penetration rate of smartphone in Southeast Asian countries made it possible to share the political climate on video in real time. Digitalization is considered not only as tool to learn about the political climate in real time, but also a tool to change the working style in each country.
- In the developed countries, SNS is commonly used to transmit information on natural disasters. Including the combination of the latest information technology, precise gathering, analysis, and transmission is expected to become a suitable technology to address climate change risk.

(2) Demographics

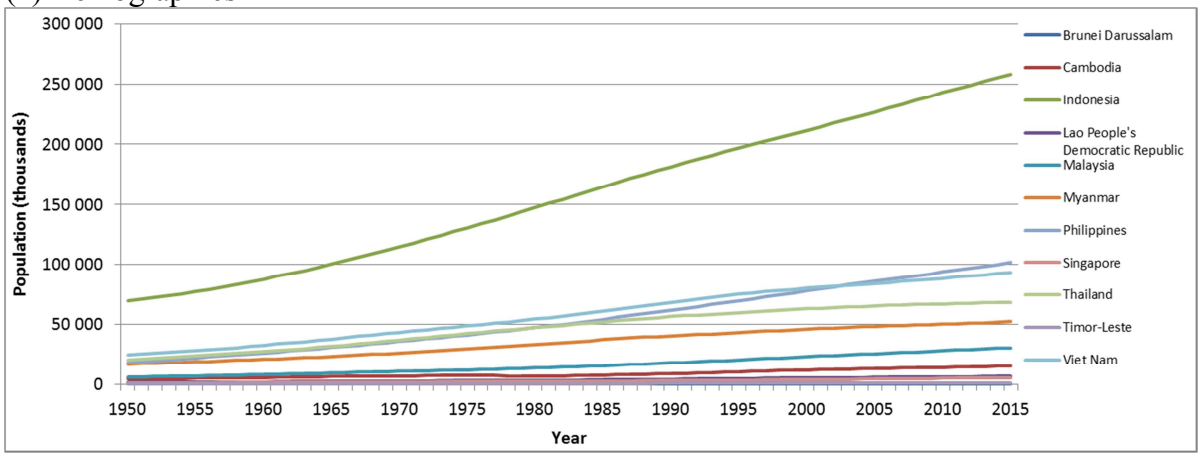



**Figure 23 : Demographic transition in Southeast Asia（United Nations World Population Prospects, 2017）**

- Severe labor shortage is observed in Southeast Asian countries with emerging symptoms of declining birthrates and a growing proportion of elderly people. Finding substitutes for the labor force within the region is a trend in Southeast Asia. An increasingly larger proportion of the region depends on foreign laborers to support their economies. Contrarily, some cases show a national economy supported by the transfer of income by oversea workers.
- Governments of the economies that benefit from the influx of foreign workers tend to be lenient on regulating them. However, this might lead to a conflict as many migrants are said to be staying illegally. It is unclear whether those workers are staying for short-term or permanently.
- Dull economic growth in Asian countries or slowdown in development of the large city may lead to fewer jobs. It depends on the circumstances of each country or national traits whether migrant workers from foreign countries and rural areas return home, assimilate or repel.
- Uncertainty of migrant movements inside the Southeast Asia region and between South Asia may increase, depending on the climate change risk. Furthermore, migration may increase the risk of the national security.

(3) Political aspect

(a) Ethnicity

・ In Asian politics, in general, ethnic inclusiveness had been demanded locally, but later incorporated into national development agenda as part of central governments' shift to decentralization strategy. This led to a successful institutional design at a community level.

(b) Cooperation with ASEAN

- ASEAN proposes disaster support and addresses regional support. In this respect, the support for the AHA center (ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management) is an effective tool. We think that the support for capacity building, regarding the climate change risk assessment, will lead to the increase in the intraregional resilience.
- There is no political opposition against the reinforcement of partnerships between ASEAN countries.
- Also, some countries in ASEAN are building a cooperation measures with countries

outside of the region aimed at marine environment protection such as the “Coral Triangle Initiative”.

- Some points out the risk where the unity of ASEAN will be influenced by the development investment and economic assistance by the countries outside of the region. From the perspective of increasing the regional resilience, we think that increase in unity and centrality by the progress of ASEAN Economic Community, ASEAN Political-Security Community, and ASEAN socio-cultural Community, including efforts in regard to climate change, will be beneficial.
- Contribution to the creation of systems for security such as the contribution to SASOP will strengthen the resilience in ASEAN.

(4) Effect of climate change and geopolitics

- Though the nexus between climate change and the recent tropical cyclones and sudden rainfall is uncertain, regions vulnerable to flood incur serious damages. In general, financially poor people live in areas that are vulnerable to effects of climate change. This in itself becomes a factor that increases fragility. Furthermore, the burden of infrastructure is increased due to sea level rise.
- Illegal operation by the foreign ships in undefined border zone located in inland sea and Small Islands in Southeast Asia is becoming an issue. Climate change may intensify the conflict as it induces resource scarcity and change in fishery. On the other hand, economic distress in fishery village will encourage illegal trafficking and trans-border criminal activities by inducing local residents to illegal side businesses.
- Based on the increase in disaster risks, it is anticipated that the significance of the risk management in the supply chain will increase. Therefore, providing information and its infrastructure which enables comprehensive assessment including disaster and security risks, followed by climate change risk, is expected.

2. Pacific Region

Indeed, conditions vary depending on the economic scale and the urban population size, however, changes in socioeconomic systems in view of urbanization is often a factor that increases vulnerability. Current population concentration in cities are accelerating the vulnerability of island countries, not limited to the occurrence of natural disasters, etc. due to climate change.

Among the island countries of the Pacific Region, the situation varies considerably according to the country, ranging from Papua New Guinea which has a larger land area than Japan, to Tuvalu, which is a very small country consisting solely of atolls. Therefore, issues confronting the respective countries shall not be considered comprehensively, but rather specifically as individual countries.

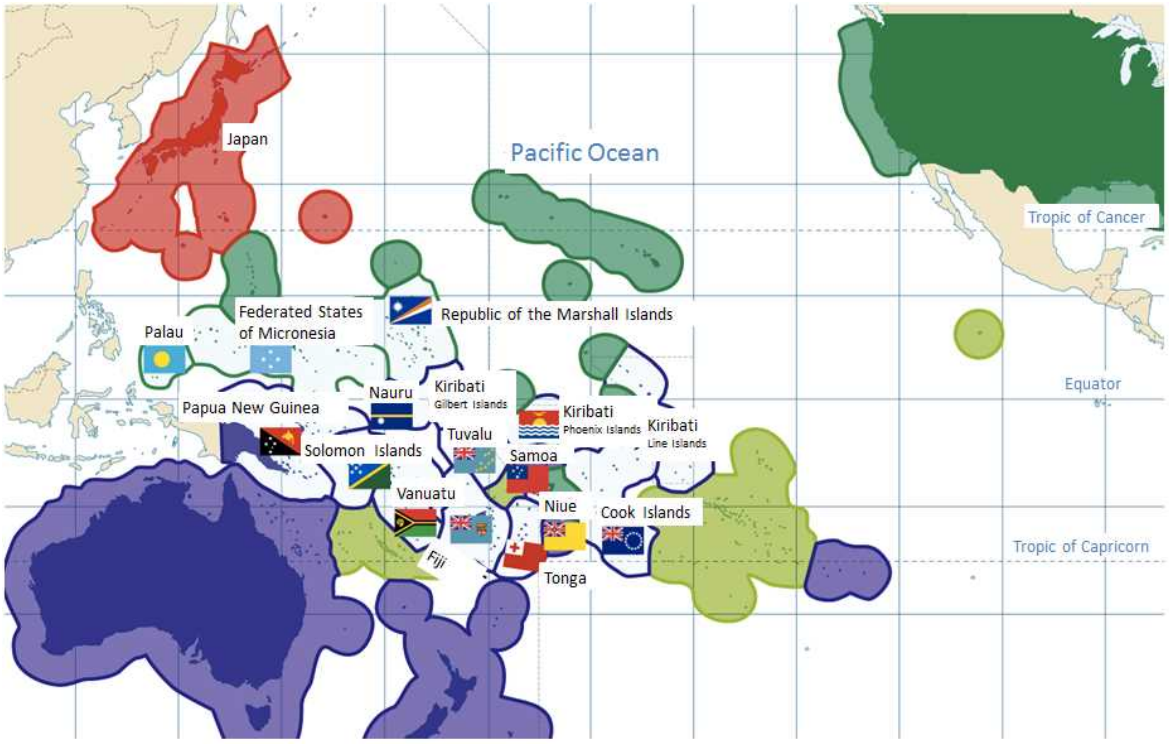



**Figure 24 : Small island countries in the Pacific and their exclusive economic zones (Kayanne / Kagami, 2015)**

(1) Socioeconomic perspective

(a) Trend in the economic affairs

- Social disparity by differences in income was noted, particularly in urban areas.
- Generally speaking, a trend in island countries, concerning the drainage of skilled workers overseas, and there are indications that such population movement has a negative impact on the economy.
- Many island countries face autonomous issues, with reliance on import for the procurement of various basic supplies. Regarding autonomous, problems in remote islands may lie in different areas to urban areas. Many areas in remote islands are capable of maintaining a autonomous system. In urban areas, a sufficient level of autonomous cannot be maintained due to a rapid increase in population and an underdeveloped domestic production and distribution system, resulting in the reliance on import from Australia and the United States. As a result, a negative impact in trade balance occurs.

(b) Urban areas

- There are cases of new influx of population into urban areas in island countries. (In Funafuti Island, Tuvalu, for example, areas which previously had a population of several hundreds now have a population of over 5000). By means of such urbanization or increased concentration, living environment which made self-sustenance originally possible has changed drastically, resulting in accumulation of wastes in urban areas and an increased demand in daily necessities such as water, etc. Through such environmental changes attributed to population influx, an environmental load has resulted, contributing to national fragility.
- Changes to the construction methods of housing, etc., due to urbanization, may at times contribute to the increase in urban fragility. For example, houses which were

formerly thatched prior to urbanization, could be reconstructed quickly despite suffering damages from cyclones. However, with the post-urbanization construction methods using concrete blocks, recovery from cyclones requires time, including time to procure the materials.

- Social transformation accompanying urbanization may also be a factor that increases in fragility. In island countries, urbanization began in the 20th century. Prior to urbanization, a land-based mutual-aid system in villages existed. However, along with urbanization, urban residents cut off from the traditional mutual-aid system increased. Such social transformation may also be a contributing factor to the feeling of insecurity toward social stability in island countries.
- Regarding phenomena which are thought to be the causes of fragility from climate change, consideration should be given not only to direct factors of climate change such as global warming and sea level rise, but also to socioeconomic aspects. For example, in Funafuti Island, Tuvalu, there is a salinity intrusion issue, which is thought to have been caused from sea level rise due to climate change. However, environmental changes caused by urbanization must also be taken into account at the same time. Funafuti is a marshland with partially uninhabited areas. Nevertheless, owing to progress in urbanization, population influx into such areas by certain classes of people resulted. Such environmental changes through urbanization is one aspect of damages incurred from salinity intrusion which is worthy of consideration.

(c) Agriculture, fishery

- Agriculture in island countries is fragile to damages from drought and floods, etc. For example, in Viti Levu Island, Fiji, sugar cane cultivation and super-manufacturing industry are thriving. However, due to drought and floods, there has been a decrease in production, and particularly on the west side of the island, ongoing damages have been observed for the past five years.
- Regarding fishery, potential for changes exist in the volume of the catch, etc. due to changes in the ocean pattern.
- Voices have already been raised regarding the decrease in fishery resources around the island countries, and regulations have been imposed for tuna catching. Decrease in such fishery resources have already been acknowledged by those engaging in fishery in the island countries.

(d) National land conservation in atoll countries

- Atolls in island countries are constantly experiencing erosion, causing changes in shape. Thus, changes from climate change are complex.
- Issues currently confronting atoll countries include expansion of habitation in vulnerable areas of the capital, deterioration of the coral reef ecosystem due to domestic wastewater and wastes, obstruction of the transportation of sand ascribed to causeways and wharfs, inhibition of sand deposition due to upright seawalls, loss of the seashore stabilizing mechanism caused by the loss of coastal vegetation, etc. (Figure 25) These problems weaken the islands' resilience against sea level rise which will inevitably continue to increase in the future. To simplify these complex problems surrounding small island countries into merely submersion due to sea level rise is losing the essence of the problem, leading to implement appropriate measures in the long term (Figure 26).


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**Figure 25 : Loss of island formation and maintenance process due to human activity（Kayanne, H. et al., 2014）**

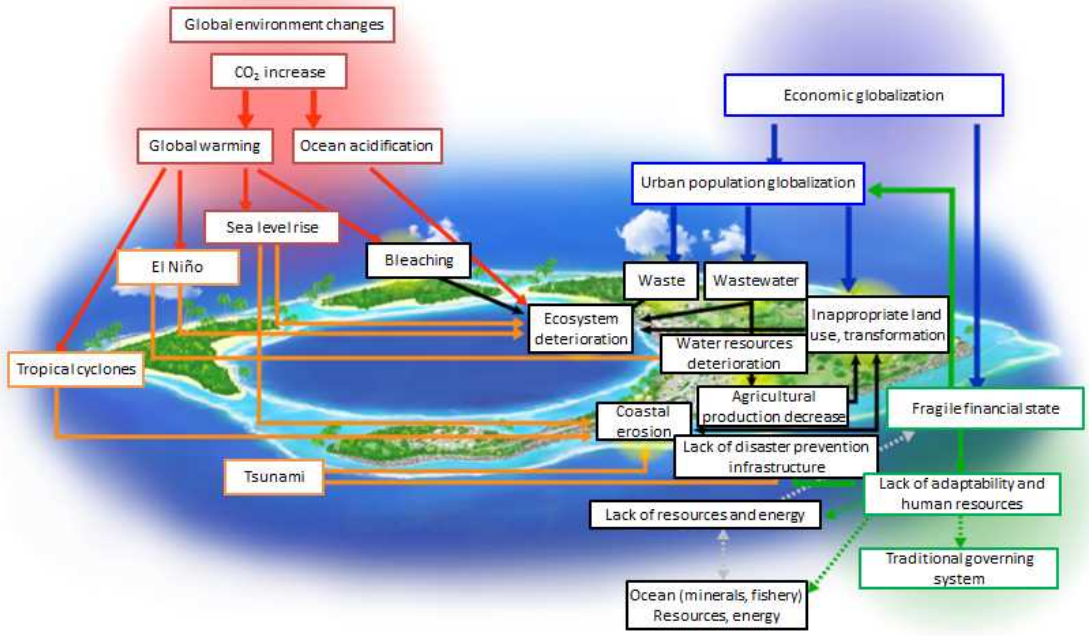


**Figure 26 : Problems surrounding atoll countries (Kayanne, H. et al., 2014)**

- Atoll countries consist of islands formed from the deposition of organisms such as coral and foraminifera. From the perspective of enhancing the restoring force of the

land, ecosystem-based measures are required. Regarding this point, conversation and rehabilitation of the habitat of coral and foraminifera by means of regeneration of coral and proper wastewater treatment and adequate management of domestic wastewater (including prevention of algae growth), and making full use of green technology such as utilizing design which promotes the deposition of gravel and sand along the coast, etc. If such measures are insufficient, engineering measures (shore protection by seawalls, artificial nourishment and offshore breakwater) such as the implementation of shore protection works are desirable.

- In the design and execution of such projects, adequate management of support from various countries worldwide and mutual cooperation therewith are also essential. Not only with regard to the management of coral and foraminifera but also regarding shore protection measures and beach nourishment, instead of executing individual tasks on a one-off basis, mutual coordination is required. With respect to this matter, the lack of execution ability of island countries is also an issue.
- On the other hand, making a direct connection of ecosystem-based measures with sea level rise is difficult, and a short-term effect cannot be anticipated. Thus, the reality is that shore protection measures are chosen. In such cases any coastal protection works must not conflict with and had better enhance natural process of coastal sedimentation.
- In cases where it has been determined that the population density is high and urbanization are required, executing shore protection works and constructing an infrastructure which is hygienic and conducive to industrial activities may be the preferred choice.

(f) Innovation of information technology

- Exchange of information through the widespread use of the internet has made a significant impact on island states. The presence of island states in climate change issues has become more distinct not only because their present conditions became to be known to the world, but island states that are affected by climate change have obtained the way to send out their messages through the Internet.
- Due to the establishment of high-speed communications network, island states possess potential to create new business industries in future. However, simply educating human resources with information technology may only motivate them to move to advanced countries. It is preferable to nurture human resources together with building infrastructure for communication network.
- On the other hand, regarding the innovation of information technology, it has been observed the gap has been expanded between the people who can obtain and use the information and those who cannot, resulting to create social instability. Under this condition, those who can obtain information become sensitive to the movement outside of the area and choose to move out to outside of their environment to look for better economic and social condition. People in island states are not exceptions.

(2) Demographic movement

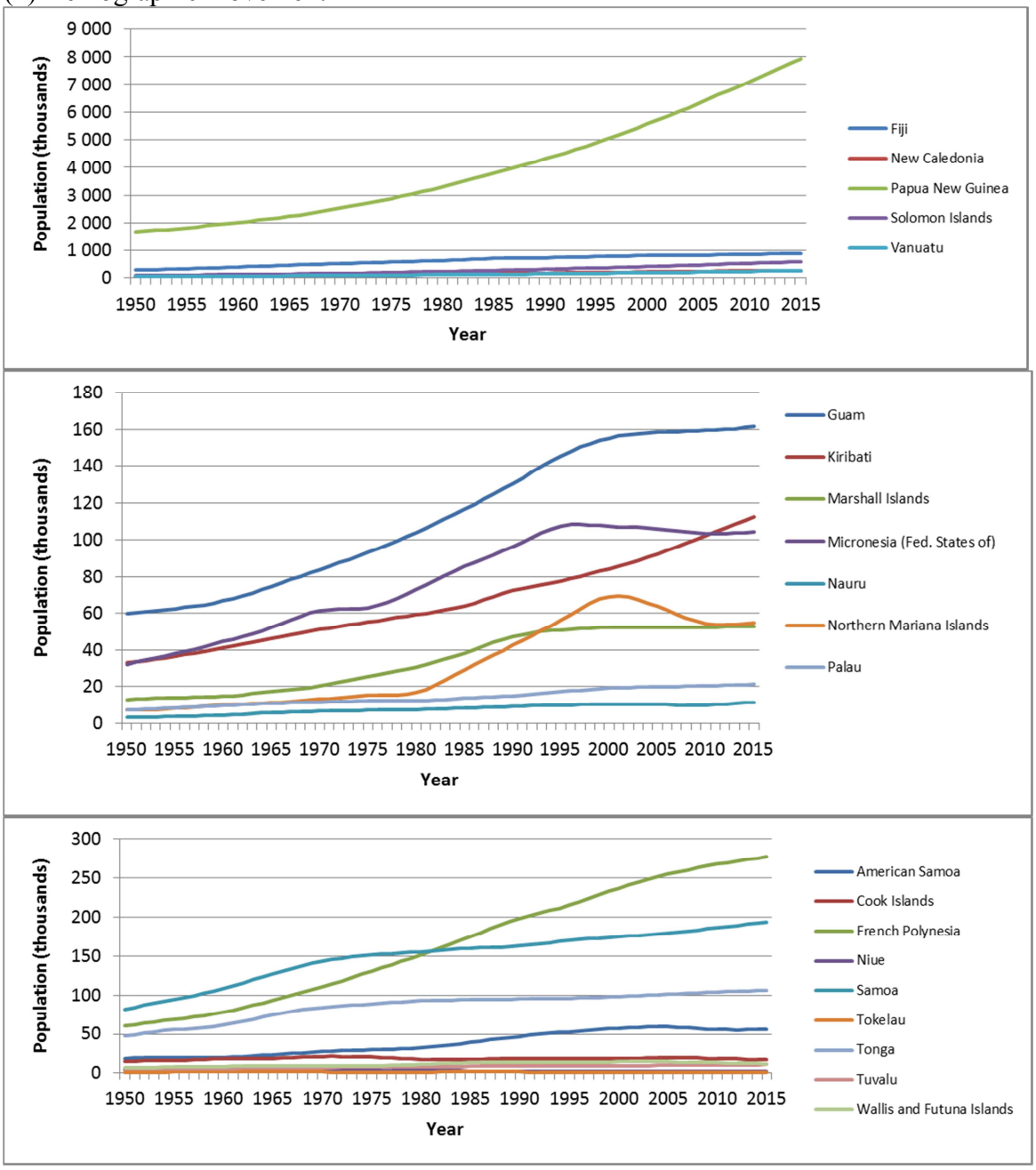


**Figure 27 : Changes in population (Top: Melanesia, Middle: Micronesia, Bottom: Polynesia) (From United Nations' World Population Prospect, 2017)**

- Large population outflow from rural area to urban area has been observed in many island states.
- Population outflow from rural area to urban area causes environmental change, which is a factor to increase instability caused by urban area.
- Demographic shift is not only caused by economic incentives. For example, in Fiji, taking into account the lessons learned from the big damage suffered from the cyclone Winston in 2016, residents moved their residency to upland.
- Population transfer to other countries has been internationally observed phenomenon and island states are not exceptions. There are some cases of population transfer between island states. It is necessary to give attention to the fact that the issue has

become a big internal affair. However, it is noteworthy that Kiribati secured land in Fiji for immigration, preparing for disappearance of their land in future.

(3) Support from overseas countries, impact of foreign economy
- Aids from International organizations, donor countries and NGOs to island countries must consider maintenance costs after implementing equipment.
- Island states producing primary commodities and raw materials mainly import machines and electric appliances from advanced countries.
- There are many countries relying on importing petroleum from other countries and interested in establishing renewable energy with aid to cut down their import cost. Since energy grid is not sufficiently developed, safe energy supply is still a big issue in many countries.

(4) Political perspective
- When a strong political leader exists, the political climate becomes stable and the same goes for island states. For example, in Samoa, stable political management has been maintained for 20 years since Prime Minister Tuilaepa took his position in 1998.
- There are countries maintaining stable government by introducing advanced political system. In 2013, the first election was conducted with the voting register based on abolished ethnic categorization in Fiji. Currently, nation's approval rating for the government is high and no social problems have risen to the surface.
- On the other hand, when foreigners continue to flow in and settle in, they may become unstable factors in the society. This can be said in island states, too.
- Racial clash, conflict with people from other countries, and confrontation with people with historically different identities are the matters one must consider when examining political stability in island states.

(5) Climate change/Geopolitical influence
- When the Paris Agreement was negotiated, island states established High Ambition Coalition with Africa, Caribbean countries, EU, U.S., Mexico, and Brazil to show high consciousness to climate change and actively stating their opinions in the international society.
- Sea level rise and shore erosion are widely known as serious issues to island states. People of island states feel increasing number of tropical cyclones have become larger.
- Draught and flood are also large problems to island states, regardless of their relationships with climate change. In atoll countries, there are very little amount of fresh water that can be used as groundwater. Therefore, the reality is that they have to rely heavily on rain water. International cooperation has been made in a way such as donating seawater desalination units, but it has continued to be a social issue.

3. Perspective of conflict prevention/peacebuilding (Efforts made by JICA)

In their independent report from G7, A New Climate for Peace, elements of risk assessment based on the perspective of climate change and fragility (opposing elements over resource allotment and movement of people) have many common points with the elements of risk assessment conducted for conflict prevention and peacebuilding. One can see the similarity in the purposes of these two assessments as they are trying to secure long-lasting peace and stability in countries and regions, though their approaches are different.

To examine the risk of fragility in each region/country/community, it is indispensable to fully understand and comprehend the elements that can be various

political, economic and social divisive factors in each country/region affected by conflict (countries/region in conflict and surrounding countries/region). Such risk assessment in each region has already been conducted in the field of development and has provided an important perspective to provide socioeconomic development aid. These assessments are conducted with the idea that factors of conflicts are different in each region, including characteristics of the country affected by conflict, background and model of the conflict, form of ending the war, governance system after end of the war, and support system of international society. For example, Japan International Cooperation Agency (JICA) uses following problem consciousness and technique to practice PNA (Peacebuilding Needs and Impact Assessment) depending on the level of impact caused by the conflict and in the level suit to the country or region and the project.

(1) Background and necessity of PNA

It has been confirmed that there are common issues in countries/regions affected by conflict:

- Public order, government, and social condition are fluid and unstable.
- Conflicting emotions and hatefulness exist among parties in dispute and at the community level.
- Public administration fails their function and residents lose faith to their government.
- Factors to recur conflict are remaining/Arising new factors of instability.

Based on these issues, JICA considers following should be taken into account when one implements a project in a country/region affected by conflict

- Contents and challenge level of cooperation differ depending on the timing to conduct cooperating projects, subject area, and their counterpart.
- Development aid can possibly increase the risk for recurrence of conflict by unintentionally facilitating unstable and/or conflict factors.
- It is necessary to control negative impact caused by unstable government and public order.
- It is possible to decrease unstable and/or conflict factors through implementation of development aid.
- Use stable factors (factors that can contribute to peacebuilding and regional stability).

(2) PNA at the country/region level

(a) Purpose

Country/region level PNA analyses are conducted as part of grasping conditions at the time of starting or resuming new cooperation in a country/region affected by the conflict or reviewing the cooperating project when conflict becomes exacerbated. The results of analyses are used to find out the content of the cooperative development, sequence and introduction plan for the cooperative development, and examination of the program contents (agenda for support, subject area to cooperate). Additionally, the results of analyses are also used to establish and renew aid implementation policy, project development plan, and program tactics for each country.

(b) Aid recipient countries/regions

Especially in the countries/regions that are likely to face recurrence of conflict, aid recipient countries/regions are determined based on following reference:

- Country/Region with many issues attributed to unstable factors and/or conflict in politics, society and public safety fields, and highly possible that conflicts recur.

- Country/Region is on the road to nationhood and building framework of the nation.
- Country/Region is under the condition that national reconciliation has not been proceeded.
- As a guide, it has been within 10 years after the conflict was concluded.

(3) Project-level PNA

The purpose of conducting project-level PNA is to make each project useful to form and implement matters that promote peace without stimulating insecure factors. Project-level PNA is the process that the project further contributes to peacebuilding. Results of project-level PNA analyses are used to determine the proper timing to start the project, select subject area(s) and/or target group(s), examine and/or review contents of activity, examine implementation system, and review implementing process.

In the process of conducting risk assessment and implementing measures, it can be beneficial to consider longer risk elements with the standpoint of permanent peacebuilding. In doing so, there is a room to examine the aspects of other factors, for example, how climate change affects the project (transferring domicile, agricultural change, livelihood change, increase of poverty, enlarged economic disparity, change of inhabitable areas, water resource distribution, decrease of natural resources, etc. caused by aggravated natural disaster). JICA has already been taking into consideration of the elements of climate change in their aid for socioeconomic development, and it is possible that each country examines the elements related to climate change towards contributing the results to prevent conflicts, to sustainably maintain peace for long period, and to promote human resources.

## IV. Suggestions Obtained

The purpose of these examinations contained in this report was not conducted in purpose of forecasting or identifying causal link between long-term climate change and its impact on political, economic and social fragility in Asia-Pacific region. On the other hand, certain propositions were obtained to present preparation measures for mitigating social instability in future by overlapping the latest academic and scientific knowledge about the impact of future climate change and contemporary social instability. These issues are described in the following paragraphs.

In order to make a more definitive assessment on how much impact climate change has as an attributional factor to the fragility in each area, more detailed and comprehensive examinations are required. Needless to say, the suggestions obtained in these examinations are neither conclusive nor proposition to implement certain political measures.

Also, as shown in following suggestions, there are several specific cases and projects examining both climate impact in each region and socioeconomic issues in a balanced manner. The utility of these projects and their approaches are not limited to the ones carried out by Japan and can be implemented by other countries. Determining and sharing these approaches and cases will be important in conducting climate control measures with consideration of both long-term impact from climate change and issues raised by socioeconomic development.

Furthermore, when long-term impact from climate change and changes of society in each region were analyzed, proposals not limited to the issue of climate change were obtained. The report also introduced some elements that prompt conducting examination of impact from technology innovation on the society in each region and yet in the entire international society.

It will be important to consider how to reflect these individual and detailed proposals obtained in this report to evaluate, plan, and design diplomatic measures in each country and region. To proceed such examination, policymakers need to consider which political measure tool or tools they should use including bilateral cooperation, development aid, and regional cooperation as well as how to relate short-period issues and medium- to long-term issues such as climate change. In this context, the following findings will expedite the reviewing process.

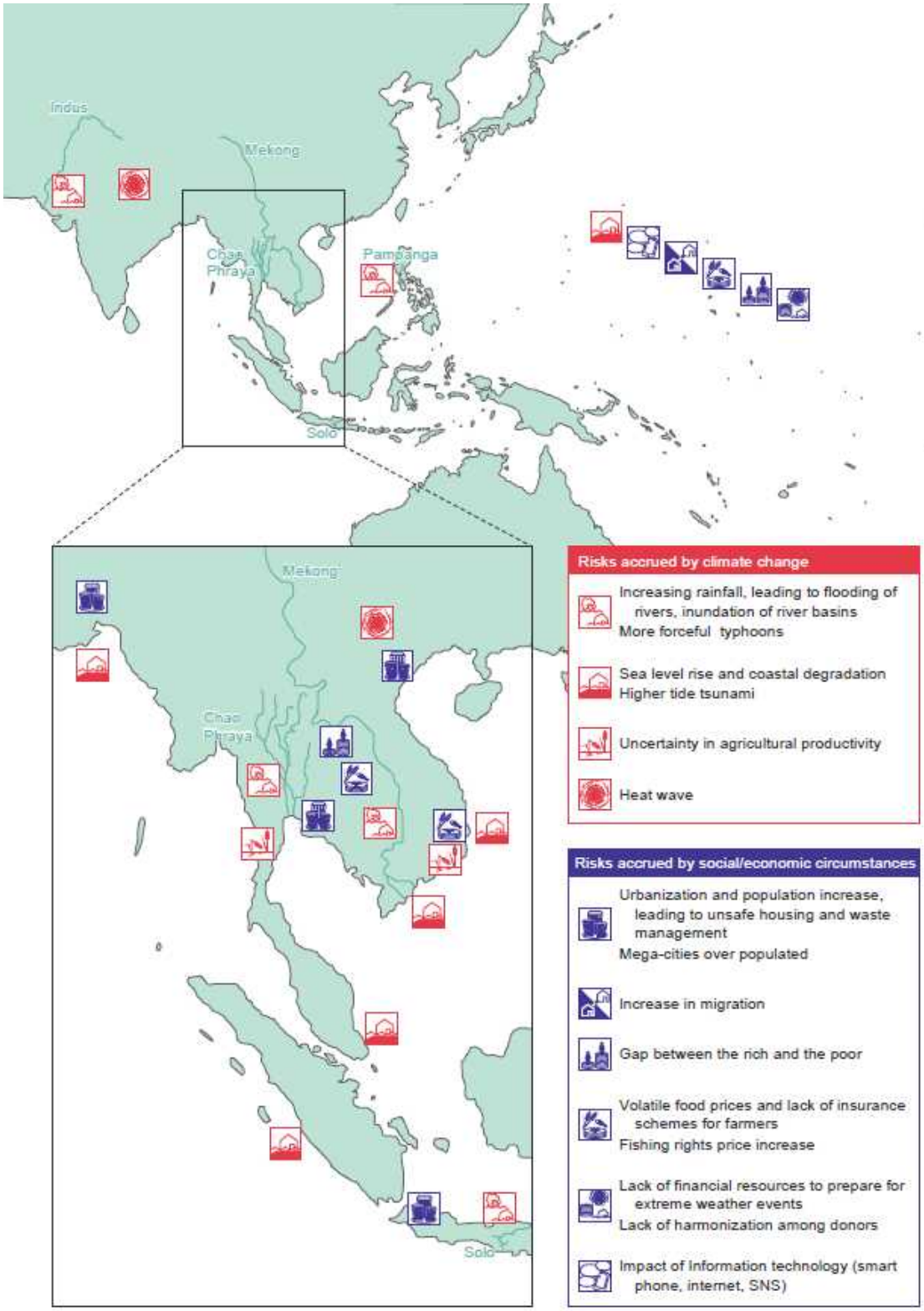


**Figure 28 : Climate change and socioeconomic fragility in Asia-Pacific region**

Figure 28 displays a mapping on risks accrued by climate change and social/economic circumstances deprived from the studies and interviews introduced in this report. Further studies are required to see correlations among the risks in order to better understand the nexus between climate change and socioeconomic fragility.

1. Ideas that Facilitate Future Examination

(General matters)

- Impact caused by climate change varies from single, direct and visible ones to long-term, indirect and not surfaced ones. The most significant issue is how to deal with long-term and difficult to visualize impact through various policy measures we have when connecting climate change and planning diplomatic measures. In practice, it is possible to determine effectiveness and assignments of current policy measures to some extent by making connections between long-term scenario and current regional affairs, and further elaboration may lead us to more effective policy scheme.
- Even if the factors of socioeconomic change in each country/region are not directly attributed to climate change, individual element shown below indicates impact from medium- to long-term climate change has the impact as a threat multiplier that amplifies these changes. Elements including urbanization, widening of economic discrepancy, and intensification of the damages from natural disasters are connected to compromise recovery of people who do not have economic measures and their adaptive capacities. Taking advantage of such social fragility to complement problems with bilateral cooperation and/or regional cooperation becomes the issues on diplomatic policy. Seventeen goals of Sustainable Development Goals (SDGs), in which climate change is placed as an important pillar, are beneficial in purpose of understanding the relationship between climate change issue (goal 13) and other political and developmental goals, and to associate them to detailed policy measures.

(Assessment by each region)

- In Asian region, temperature is expected to rise further if no sufficient mitigation measures were taken. Although population increase has stopped in some countries, population inflow and concentration in urban areas are expected to continue. Therefore, when infrastructure development is implemented in those countries, it is necessary to aim to establish low carbon city with mitigation measures and to design the city with the viewpoint of adaptation such as avoiding heat accumulation.
- Regarding concentrated downpour and typhoon, increasing number of river basins in the Asian region is expected to suffer from swollenness and flooding. On the other hand, funds for basic infrastructure development in many countries in the area may not be sufficient to address such natural disasters. Other than providing assistance for improving the infrastructure for swollenness, it is necessary to promote know-how of land utilization plan such as making areas with high risks of river flood be non-residential area.
- In the Asian region, impact of climate change on yield of agricultural products is uncertain. Maintenance of irrigation facilities, breed improvement responding to climate change, and compensation system in case that crops receive damage from natural disaster is important. There are more than a few countries in the Asian region that value industrialization for further economic development. However, farming policy incorporating the impact of medium- to long-term climate change is important not only as an adaptation plan for climate change but as measures for securing socioeconomic stability.
- In island states, the past decisions allowing unfitted land to be used as residential areas due to rapid population growth and concentration in cities even before people started to consider the impact of climate change increased the future risk. The impact of climate change therefore should be examined within government's general national land planning such as urban development projects.

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(Cross-regional aspect)

- In the Southeast Asia and Pacific region, it is also necessary to sufficiently examine not only medium- to long-term risks that climate change cause but the impact brought by economic and social changes such as urbanization and shift in demographics. One should separately examine how each economic and social factor affect political, economic and social stability, and how climate change affect such stability. Also, it is important to examine how climate change affects as a multiplier of such impact.
- One must assume various scenarios to examine the impact toward local political, economic and social elements, (for example, economic growth, demographics, and current various aids from other countries,) based on long-term model of climate change. The flow of people including demographics and worker migration can be a major factor regardless of the location.
- In urban areas, it is necessary to examine the capacities of facilities (sewer system, etc.) to discharge rain and ocean water as much as possible at the time of torrential rain and tidal wave as well as the ability to deal with deterioration of hygienic environment after flooding. Such examination on the capacity of infrastructure and local authority should be conducted after incorporating the long-term impact of climate change in that area.
- Economic disparity occurring in various places in the world brings larger impact to the strata of society that cannot respond to sudden change once the effect of climate change becomes so strong. The difficulty to deal with such sudden change shows the risk of fragility, which can affect the stability of entire society. Adequate social capital improvement for the residents who cannot sufficiently enjoy the benefit of economic growth not only contributes to stabilizing politics and society but also is effective as adaptation measure in the context of climate change policy.
- Sufficient attention should be given to the common aspect of the risk assessment involved in climate change and fragility and the risk assessment involved in conflict prevention and peacebuilding. By connecting these two risk assessments, one can better understand and grasp factors of instability in each region in more detailed manner. With the standpoint of building lasting peace, it can be beneficial, for example, to consider what kind of impact climate change (agricultural change, change of inhabitable area, distribution of water resources, etc.) cause, or, to examine how climate control affect local residents, economy and society with the standpoint of reallocation of income, employment, and movement of people, and study if they become risk factors.
- As a specific response to deal with the impact that climate change brings to natural disaster, disaster response and international cooperation have high potential as one of the visible outcome. In Southeast Asia, for example, ASEAN Regional Disaster Emergency Response Simulation Exercises (ARDEX) is conducted as a disaster measure and ASEAN Defence Ministers' Meeting + Military Medicine/HADR Expert Working Group (ADMM+-MM/HADR EWG) joint training is conducted. Examining various scenarios reflecting risks associated with climate change can contribute to create more realistic equipment plan and other response measures.

(Impact brought by technological innovation/and change of values)

- Development of information technology including the Internet, SNS and smart phones has brought significant changes in the perspectives of people living in the Asia-Pacific region. As citizens understand the impact caused by climate change more accurately, they are expected to prepare for the impact properly.
- The possibility of achieving future society should be considered in the forms beyond

our traditional sense of value and perception advancement and innovation of technology. It implies the possibility that the argument based on the society in extension of current form may not be relevant anymore. For example, when people in their forties and fifties talk about travelling, they mean an actual trip to the destination; however, younger generation can experience travelling through virtual technology without going there and worry about public order and safety. It may give the same level of appreciation and enjoyment of the travel as the actual trip and help to save energy (and carbon emission) as well. This implies the need for reconsidering current technologies and premises taken for granted in order to see a future form from future's perspective, not from the current standpoint, since the societal values may shift fundamentally.

- Once technological innovation progress, it does not regress. Even if the technology has not been developed as a countermeasure to the climate change, introduction of new technologies advanced in various fields can inadvertently be useful to reduce greenhouse gas and to adaptation measures. Regarding vehicles, for example, the main purpose of automatic driving and car sharing is to establish convenience and safety, but expansion of these ideas can contribute to reduce greenhouse gas. In this respect, technological innovation itself is important to tackle climate change issues. Technological innovation will reduce the cost for solar energy, and furthermore, it will lower the threshold of introducing them.

2. Examples of detailed measures

When reducing long-term impact from climate change in each region, it is indispensable to examine the adaptation plans with sufficient consideration not only about the aspect of climate change but also about socioeconomic issues such as urbanization, and sustention and recovery of ecological system. Followings are the cases introduced through this examination as example cases that have already been worked on.

Various aids were proposed by developed countries and international organizations to small island states facing the risk of sea level rise. As a measure, bank protection is easy to be conducted. However, upright bulkhead blocks natural deposition and causes erosion. When implementing engineering measures, it is preferable that these encourage the process of formation and preservation of the island and do not block them. With that viewpoint, gravel nourishment was conducted at Fongafale Island of Tuvalu with technical cooperation from JICA (See Figure 29).

**Figure 29 : Gravel nourishment at Fongafale Island of Tuvalu. Before nourishment (left) and after**

**nourishment (right) (Photographs provided by Nippon Koei Co., Ltd.)**

Additionally, it is important to rehabilitate deteriorated coral reef ecosystem, eliminate the factors that disturb sand production, transportation, and sedimentation processes, and revive ecological mechanism. Artificial structures such as revetments, bridges, and causeways should be designed in a way not disturbing ecological process. Along with that, coastal management plan should be developed based on monitoring of landform and ecosystem.

A number of problems have been arisen in many island states in the Pacific Ocean due to concentration of population in capitals in the globalized society and economy. With understanding of these conditions, it is necessary to consider plans for comprehensive national land policy based on the standpoint that preservation and restoration of ecosystem will be led to those of national land. It is also necessary to introduce land utilization plan, environmental management including drainage and waste treatment, and wisdom of traditional ecosystem management (See Figure 30).


**Figure 30 : Time scale and technical development level of ecotechnological measures (Kayanne, H . et al., 2014)**

## V. Further Issues to Study

An analysis with an emphasis on current regional affairs contained in this report was conducted to better understand the impacts of climate change on present political/social/economic affairs in respective regions using the latest scientific data. The analysis falls short of examining the specific manner climate change incur damages to political/social/economic affairs in each region. Moreover, in regards to long-term climate change models of each region, hardly any review has been conducted on the link with factors that instigate vulnerability in a region, aside from factors such as flood damages and impacts on agriculture. For example, connections to future demographic trends and the forecast on economic growth has not been made.

Henceforward, it may be worth researching and analyzing the following points as examples of specialized areas of focus.

- Detailed review on short-term and medium to long-term climate change impacts on socioeconomic development.
- Particularly on the subject of socioeconomic development, the correlation of medium to long-term shift in climate change with medium to long-term trends such as changes in migration, transition of number employed according to industry and emigration of the working class.
- Review on the correlation between the capacity to recover/rehabilitate from a natural disaster and stable economy, politics, and society. (Inversely, the factors that engender fragility)
- Proposal of a comprehensive national land policy against climate change (sea level rise) in island states. To this end, to select ecological/engineering countermeasure works, or alternatively, a suitable mix of choices coupled with adequate plans for international aid for their realization.
- Review concerning health hazards caused by climate change (e.g. Malaria, Dengue fever), which was not included this time but is already being underlined in discussions, such as at the international round table seminar held in Tokyo in January. Additional study to understand possibly relevant international healthcare policies and to increase opportunities to cooperate with medical organizations
- Verification whether climate change forecast was calculated in the individual forecasts in political, economic, and social fields (so called Scenarios in 2050). Review whether climate change forecasts can be included in aforementioned forecasts.
- Review and identification of issues regarding methods required for analysis in risk mapping in economic, political, and social domains. Selecting existing data for this purpose and review on the necessity to collect and analyze new data.
- Study whether human security issues incited actions by state/non-state actors affect the environment.

The advancement of these specific works would facilitate research in natural sciences specialized in climate change and research devoted to regional affairs. This, in turn, expedites reviews of foreign policy planning at a broader level. Such active interaction between scientific researches and policy planning process would enable more focused work on both sides, this raising questions for further consideration: The ways changes in various climate conditions may impact socioeconomic affairs in each region; ways to respond to these changes in advance or to devise preventative strategies to prepare for these changes; and types of opportunity/requirement for bilateral, multilateral, regional cooperation.

## VI. Appendix

### 1. Representative Concentration Pathways (RCPs) in IPCC AR5

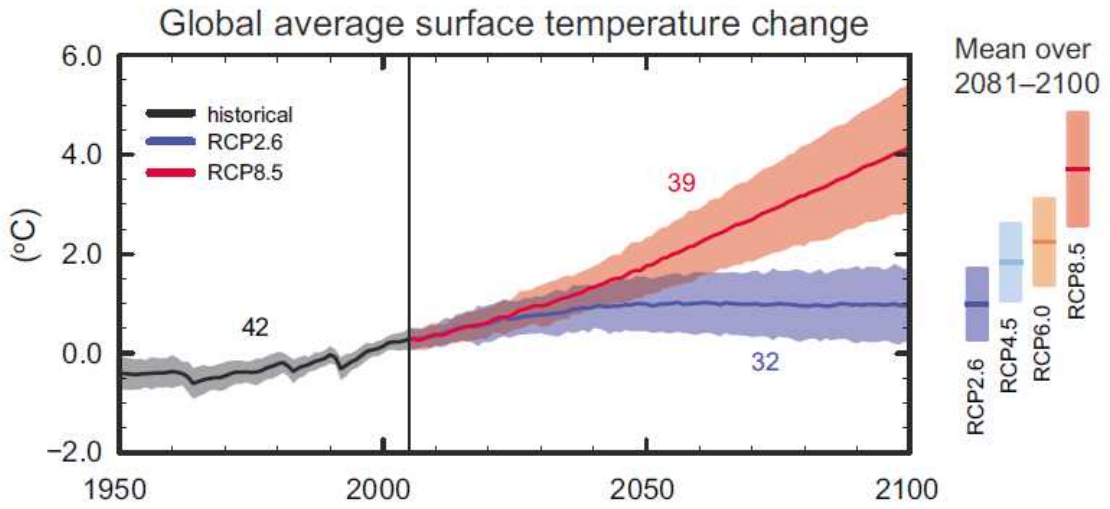


**Figure 31 : CMIP5 multi-model simulated time series from 1950 to 2100 for (a) change in global annual mean surface temperature relative to 1986–2005（IPCC, 2014）**

Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red) on Figure 31. Black (grey shading) is the modelled historical evolution using historical reconstructed forcings. The mean and associated uncertainties averaged over 2081−2100 are given for all RCP scenarios as colored vertical bars. (IPCC, 2014)

For RCP8.5 and RCP2.6 scenarios, temperatures are estimated to increase 4°C and 1.5°C, respectively by 2100.

### 2. SSP (Shared Socio-economic Pathway) scenarios

A set of SSPs was chosen to characterize the range of uncertainty in mitigation efforts required to achieve particular radiative forcing pathways, in adaptation efforts that could be undertaken to prepare for and respond to the climate change associated with those pathways, and in residual impacts. This will allow assessment of scenarios along two axes: socioeconomic challenges to mitigation, and socioeconomic challenges to adaptation. Five SSP scenarios are: The world is reasonably well suited to both mitigate and adapt in SSP1 (Sustainability); SSP2 (Middle of the Road) would be an intermediate case between SSP1 and SSP3; large challenges to both mitigation and adaptation in SSP3 (Regional Rivalry), where mitigation might be relatively manageable while adaptation would be difficult; vulnerability high in SSP4 (Inequality); large challenges to mitigation but reasonably well equipped to adapt in SSP5 (Fossil-fueled Development). (IPCC Workshop on Socio-Economic Scenarios, 2010)

## 3. Special Report on Emissions Scenarios (SRES) in IPCC Fourth Assessment Report

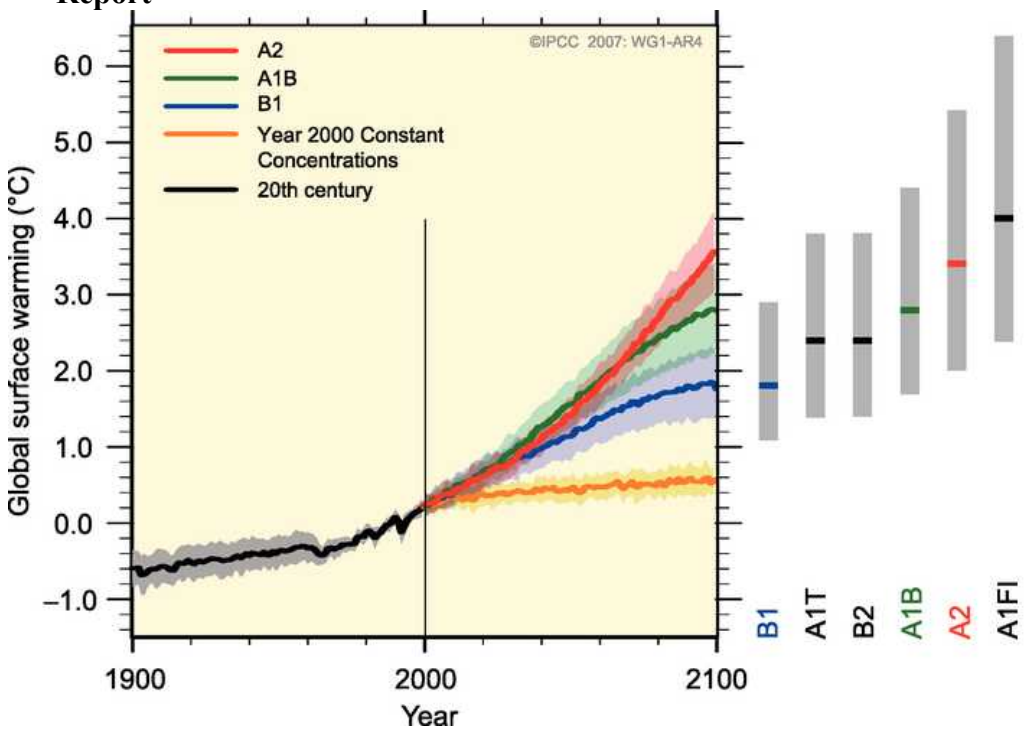


**Figure 32 : Multi-Model Averages and Assessed Ranges for Surface Warming (IPCC, 2007)**

Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the twentieth century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. (IPCC, 2007)

## 4. II. 1. (2) Changes in intensity and occurrence frequency of tropical cyclones

25-year span simulation experiments were conducted for two periods; the present-day climate (11 members, 1979-2003) and the future global warming climate (29 members, 2075-2099) based on IPCC A1B scenario. The experiments used models consisting of various versions of MRI-AGCM3, with horizontal resolution 60km and 20km, and with three different convection schemes. The geographical distributions of the changes in occurrence frequency per decade in each 5˚ x 5˚ grid box in various intensity categories are shown in Figure 2. (Sugi et al., 2016)

## 5. II. 1. (3) Changes in storm surge and wave heights

Future changes in storm surge and wave heights are assessed in Chapter 13 of Working Group I (WGI) and Chapter 5 of Working Group II (WGII) of IPCC AR5. WGI discusses future changes of storm surge and wave heights as sea level extreme together with sea level rise. The report concluded as follows: it is very likely that there will be a significant increase in the occurrence of future sea level extremes in a number of regions by 2100, with a likely increase in the early twenty-first century, it is likely (medium confidence) that annual mean significant wave heights will increase in the Southern Ocean

as a result of enhanced wind speeds, and it is likely (medium confidence) that annual mean of significant wave heights will increase in the Southern Ocean as a result of enhanced wind speeds.

**6. II. 1. (5) Transition of agricultural production: details on Figure 5**

The average is weighted by the current crop area. SSP2 scenario is used for the estimation. '$CO_2$ Constant' indicates the results when the $CO_2$ concentration is constant at $CO_2$ value in 2000. 'Adapt' refers to results when the crop cultivars can be changed according to the climate change. 'Change Planting Day' is defined by the results when planting days are appropriately chosen in each year. 'Maximum Irrigation' presents the results when the irrigation is exercised to its maximum capacity. 'GDP Constant' refers to the results when assuming the GDP is constant at its value in 2000 and agricultural technology will not be improved (i.e. the GDP values link to agricultural technologies).
(The figure of 'ICA-RUS report 2017' is modified.)

**7. II. 1. (6) Transition of agricultural production: details on Figure 6**

Here, RCP8.5 scenario was used for the estimation. The average of multiple GCM was shown on Figure 6. The left column illustrates the results where no-adaptation was assumed. The right column shows the results where adaptation was assumed. In situations where adaptation was assumed, the truncation of growing day due to an increase in temperature is inhibited by the change of crop cultivars. The shading indicates the area where the current harvested area is very small. In such area, the accuracy of the estimates are low.
(The figure of 'ICA-RUS report 2017' is modified.)

**8. II. 2. (2) Temperature projections: details of Figure 8**

Figure 8 (Probability map of temperature change in the late 21 century in East Asia) was calculated with a probability model based on regression method developed by National Research Institute for Earth Science and Disaster Resilience and The Institute of Statistical Mathematics (Ishizaki et al., 2017) using all 21 scenarios of Global Climate Models (GCMs)[1] under Phase Three of Coupled Model Intercomparison Project (CMIP3)[2] and high economic growth scenario under low population growth (SRES-A1b scenario, 2069 to 2098).

**9. II. 2. (3) Precipitation projection (South China): details of Figure 9**

Figure 9 shows the frequency distribution of the average annual maximum daily precipitation (mm/day) in South China calculated for the d4PDF experiment for the past day experiment (60 years x 100 members) and for the 4$^{o}$C increase experiment (60 years x 90 members). The result was normalized by dividing with net sample number of both experiments. (NIES, 2017)

**10. II. 2. (4) Precipitation projection (Southeast Asia): details of Figure 10**

Average annual precipitation in Figure 10 was calculated after carrying out the bias correction of daily precipitation of the present-day climate experiment where 20-km

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1 Global Climate Models (GCMs) are representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations (ipcc-data.org)

2 Phase Three of Coupled Model Intercomparison Project (CMIP3) is a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs).CMIP3 included realistic scenarios for both past and present climate forcing and used in IPCC Fourth Assessment Report. (cmip-pcmdi.llnl.gov)

mesh MRI/JMA atmospheric general circulation model was used and of the global warming climate experiment where 4 SST distributions were used.

In bar charts and the change rate of the future climate under RCP8.5 scenario, the degree of uncertainty of climate prediction is shown. The uncertainty is resulting from the difference in SST and other parameters used as boundary conditions in the future climate experiment. It is apparent in the figures that the degree of difference resulting from the gap of SST distribution against ensemble average is relatively small in Indus River, Chao Phraya River, and Mekong River; however, the difference of SST distribution strongly affects the change rate of annual precipitation in the future in Pampanga River and Solo River. Especially in Pampanga River, it does not necessary imply the annual precipitation in the future changes 0.5 % from the present-day climate, but it indicates that the annual precipitation could not only increase but it could also decrease depending on the difference in SST distribution; hence, the impact of the uncertainty of climate prediction is considered to be high in Pampanga River. (ICHARM, 2017)

**11. II. 2. (5) Assessment of water-related disaster: Mekong River, Chao Phraya River, Solo River, and Pampanga River: details of Figure 11**

The past day climate experiment and the experiment on the future climate under RCP8.5 scenario were conducted over 6000 years and 900 years, respectively. For the future climate experiment, the SST future change pattern was calculated using MRI-CGCM3 (MR). (ICHARM, 2017)

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