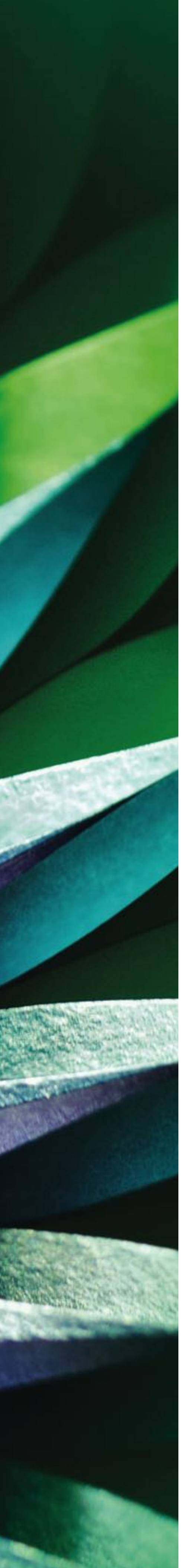

BACKGROUND PAPER

Climate Change and Agricultural Insurance in the Asia and the Pacific Region

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CLIMATE CHANGE AND AGRICULTURAL INSURANCE IN THE ASIA AND PACIFIC REGION

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Abstract

Expanding the coverage and effectiveness of agricultural insurance schemes in low- and middle-income countries has received significant interest over the last decade. This has led to proliferation of multitudes of initiatives on insurance and climate change through collaborations between national governments, international organizations, private insurers, and multilateral organizations. While low coverage and penetration of crop insurance schemes, especially among the poor and vulnerable population, has remained a concern, recent efforts have increased both in terms of research to understand different dimensions of the issue and, in practice, with increasing number of pilot schemes with new product designs and innovations and funding, to address the challenges. Considering new recent evidence on crop insurance and climate change scenario in Asia, this paper aims to (i) review existing literature and summarize the projected impact of climate change on agriculture in the Asia and Pacific region; (ii) present findings from recently collected secondary data on crop insurance coverage in countries of Asia and the Pacific, trends, status, and types; and (iii) examine the limitations and advantages of agricultural insurance schemes as a climate change adaptation strategy, and discuss its policy implication.

Key words

climate change, crop insurance, Asia and Pacific region

JEL Codes

Q54, G22, G52

I. INTRODUCTION

Increasing impacts from climate change, coupled with rising global population and higher food demand, are already negatively affecting the most vulnerable farming populations of the world ([Intergovernmental Panel on Climate Change] IPCC 2019, 2014). However, as climate change progresses, impacts are projected to adversely affect Asian countries which account for more than half of the people on the planet and where about 263 million people were living under extreme poverty in 2015 (IPCC 2019 and [Asian Development Bank] ADB 2020). Effects of increased frequency and intensity of extreme events including more extreme heat and precipitation events, tropical cyclones, higher intensity storms, and extended droughts are further likely to worsen in the future.

With a large share of population still dependent on agriculture and related activities, developing countries of the Asia and Pacific region (APR) are likely to face detrimental impacts on agricultural potential because of climate change, which could undermine the long-term development goals in the region. For example, recent estimates show that the largest impacts from climate change on extreme poverty will be realized through higher food prices and, on average, 61 million additional people could be pushed onto poverty globally because of these higher food prices (Jafino et al 2020). In addition, globally economic losses from production attributed to climate change in the recent past for three major crops (wheat, maize, and barley) are estimated at about United States (US) $5 billion per year (Lobell et al 2007). Disasters and extreme weather events in Asia and the Pacific from 1989 to 2018 have affected more than 5.2 billion people, claimed one million lives, and caused total direct physical losses of US$843.6 billion. These economic damages could amplify substantially for countries of Asia and the Pacific at higher global warming. Further, novel, compounding, and interconnected risks such as coronavirus disease (COVID-19) could dampen the current efforts to achieve Sustainable Development Goals and climate change adaptation in the region. COVID-19 could reverse the trend of poverty reduction and economic growth in Asia (ADB 2020 and World Bank 2020).

Existing evidence suggests that countries with higher dependence on livelihoods derived from agriculture and natural systems are particularly vulnerable to multiple shocks arising from climate change stressors (Hallegate et al. 2016, Field et al. 2014, and Easterling et al. 2007). Designing and implementing effective adaptation response for the agriculture sector has inevitably become an essential part of managing climate risks. Insurance is increasingly seen as an important instrument in agricultural climate risks management in the global south and epically in low- and middle-income countries of the world (Panda et al. 2013, Cole et al. 2013, and Platteau et al. 2017). The increasing emphasis on use of insurance instruments can be assessed from the fact that between 2008 and 2017, a total of US$136.15 million of multilateral climate funds has been given in grants and concessional loans to projects that entail an insurance component (Climate Funds Update 2018). Further, new initiatives and programs have been launched to deal with financial impacts of climate-related disasters: the Insu-Resilience Global Partnership for climate and disaster risk finance and insurance solutions and Global Index Insurance Facility which aims to increase the number of poor and vulnerable people and smallholder farmers in developing countries benefiting from direct or indirect insurance.

However, despite many new initiatives and projects and promising potential of agricultural insurance in helping climate change adaptation, the uptake of agricultural insurance has largely been unsuccessful in its widespread use and application, especially in the countries of Asia and the Pacific. Low level of insurance penetration in these countries limits the benefits that insurance instruments can provide at the micro level for climate change adaptation. For example, recent evidence on uptake of insurance in 126 developing countries of Asia and Africa shows only 16.30% of sample households being insured with any formal insurance (Panda et al. 2020).

II. BACKGROUND: AGRICULTURE, CLIMATE RISKS, AND CROP INSURANCE

APR comprise[1] of 49 low- to middle- and higher-income countries. The region comprises of 9 high-income countries, 2 low-income countries, 17 upper middle-income countries, and 20 lower middle-income countries. Demographic features vary between countries, comprising of both highly populated countries of the People's Republic of China (PRC) and India with 2019 population of 1.4 billion and 1.34 billion, respectively, to countries of the Pacific with less-populated countries such as Niue, the Cook Islands, and Palau. In terms of gross domestic product (GDP) at constant 2010 US dollar, these 49 countries range from about US11,785 billion in the

[1] In this document unless otherwise stated, Asia and Pacific countries consist of 49 member countries of the Asian Development Bank (ADB) in the APR.

PRC in 2020 to about US$0.187 billion in the Marshall Islands in 2019.

Agriculture continues to be very important in many of the lower middle-income and low-income countries in the APR although agriculture sector's relative contribution to overall economy of the region shrank from 26.6% in 1970 to 7.9% in 2017 (FAO 2019). Combined value added of agriculture, forestry, and fishery as a share of GDP in 2019 ranges from 28.61% in Kiribati to 0.02% in Singapore. In many countries such as Afghanistan, Nepal, Uzbekistan, and Vanuatu, it still accounts for nearly one-fourth of GDP. On average, agriculture accounted for 18.08% of total GDP in 2019 among the low-income and lower middle-income countries and 7.37% of total GDP for high-income and upper middle-income countries of Asia and the Pacific.

In the APR agriculture continues to hold an extremely important role in poverty reduction, food security and reducing greenhouse gas (GHG) emissions. In 2019, close to 750 million—or nearly 1 in 10 people in the world—were exposed to severe levels of food insecurity (FAO 2020) and still a large section of working adults (65%) is making a living through agriculture globally (World Bank 2020). In the Asia and Pacific countries, on average, 30% of population were employed in agriculture in 2017 and about 37% of land were agricultural land in 2015 signifying the important role agriculture still plays in the region. However, climate risks in the region such as droughts, floods, cyclones, typhoons, and landslides are leading to high crop loss, livelihood, and economic damages. For example, while island nations such as the Cook Islands, the Federated States of Micronesia, Kiribati, the Marshall Islands, and Samoa are expected to incur loss on average about US$26.2 million because of various natural disasters such as tropical cyclones and earthquakes, flooding in Afghanistan, Armenia, Azerbaijan, Cambodia, and the Kyrgyz Republic is causing about US$524 million of average annual economic damages. In the PRC, since 2000, 38.86 million hectares of crop have experienced a yield loss of at least 10% from natural disasters every year. Climate change is likely to increase the severity and intensity of these events in the future, jeopardizing the livelihoods of millions of farmers in the region.

Agricultural insurance as an intervention tool has a long history in the APR. Japan introduced the earliest government-subsidized cooperative crop and livestock insurance program in the region through the Crop Insurance Act in 1938. Countries such as New Zealand and Australia have a long history of private commercial crop and livestock insurance program. Since the 1970s, other countries such as the PRC, India, and the Philippines have started crop and livestock insurance schemes either though public sector initiatives or public–private partnerships. In recent years, there has been major changes to crop insurance schemes in the region, including (i) introduction of new product types such as Weather Index Based Insurance; (ii) increased involvement of private players in the agricultural insurance market; (iii) increased efforts to mainstream climate change and disaster risk concerns, while designing new agricultural insurance products; and (iv) greater involvement of global and regional humanitarian community and donors to expand the reach of crop insurance to small and marginal farmers in the region.

With likely negative climate change impacts on the agriculture sector in the coming decades, reducing and managing financial impacts from climate-related disasters and extreme events is becoming increasingly important in the APR (Surminski et al. 2019 and Panda et al. 2020). Agricultural insurance can support building resilience to climate change in the region by increasing financial resilience among the poor and vulnerable. Although insurance market is predominantly concentrated in the agriculture sector, the penetration and coverage have remained low in many countries. For example, in Asia, Bangladesh is the country with the least insurance penetration at 0.2% of GDP; in comparison to Japan, where insurance penetration is 2.3% of GDP (Lloyds of London 2018). The discussion on climate change and insurance is not new. The first assessment of the IPCC noted that insurance could serve a double function, both providing signals about risks and offering an 'effective means of reducing the economic impact of losses' (IPCC 1990). In the past decade, initiatives relating to insurance and climate change have rapidly increased, often through collaborations between national governments, multilateral organizations, nonprofits, and private insurers.

In the above context, this paper reviews existing literature and summarizes the projected impact of climate change on agriculture in the APR; presents findings from recently collected secondary data on crop insurance coverage in countries of APR: trends, status, and types; and examines the limitations and advantages as a climate change adaptation strategy and discusses policy implication.

III. METHODS AND DATA

This paper uses an extensive review of literature method and secondary data collection to summarize and synthesize the findings for the three major objectives of the paper: (i) review existing literature and summarize the projected physical and economic impacts of climate change on agriculture in APR; (ii) present findings from crop insurance coverage in countries of APR—trends, status, and types; and (iii) examine the role of crop insurance as climate change adaptation strategy and its advantages and challenges in the APR.

To summarize the projected physical and economic impacts of climate change in the APR, this paper uses various IPCC reports and selected peer reviewed papers on physical impacts of climate change in the APR between 2015 and 2020 identified from Web of Science with key words "climate change impacts and Asia and the Pacific", "climate extremes and Asia and the Pacific", and "agriculture and climate change in the APR".

To summarize data on crop insurance coverage, trend, and types, this paper uses recent secondary online sources, annual reports, and government websites update on crop insurance data in all the 49 countries of the APR. As there is no credible and accepted single source of data on status of crop insurance schemes, this paper relied on google search to visit department of agriculture and other departmental websites of the governments of these countries, compiled data from earlier reports, and present the findings. Data gaps were observed for many indicators such as number of farmers and livestock benefited, country-wise premium subsidy amount, insurance penetration, and coverage. Data were not available for many countries where crop insurance schemes are new or many of them are in pilot and preparation phase. The paper excluded data on pilot crop schemes that have stopped operating. The aim here was to gather data on national or regional level crop and livestock schemes in the APR.

IV. IMPACTS OF CLIMATE CHANGE IN THE ASIA AND PACIFIC REGION

This section presents review and discussion of the observed and protected impacts of climate change in the APR based on the current scientific evidence. To estimate and assess the impacts of climate change, climate models often make assumptions about the nature and speed of reduction of GHG emissions at different future time slices represented through various scenarios. Although climate modeling has evolved over the years (Hausfather et al. 2020), recently climate modeling community has developed four representative concentration pathways (RCPs), which span a large range of future global warming scenarios. More generally, RCP 2.6 presents a future with low emission scenario (compatible with Paris Agreement targets) and RCP 8.5 with a high emission scenario or business as usual.

The 2015 Paris Agreement on climate change sets a target of limiting average global temperature increases to 2°C (3.6°F) relative to preindustrial levels. However, global average temperature has already warmed by about 1°C (1.8°F), above pre-industrial levels, and could exceed the goal of the Paris Agreement of limiting the increase to 1.5°C (2.7°F) as early as 2030 if emission continues at the current rate (IPCC 2018). Recent analysis shows that almost 75% of the climate pledges are partially or totally insufficient to contribute to reducing GHG emissions by 50% by 2030, and some of these pledges are unlikely to be achieved (UEF 2019). A rapid warming has dramatic implications on how countries of the APR will adapt to the changing climate and manage financial risks to agriculture and allied sectors. Even with major mitigation efforts, adaptation to the current climatic impacts and building resilience to future climatic risks especially among the vulnerable population of the APR is extremely important. Major projected impacts of climate change in the APR have been summarized below.

A. Temperature and Heat Extremes

The global mean annual temperature from 1986 to 2005 had warmed by 0.61°C since the preindustrial level (IPCC 2013). Regional and local temperature can vary from the global averages. There has been observed increase in frequency and duration of warm spell lengths in large parts of Asia and Australia and, at 1.5ºC, it is very likely that there will be global-scale increased intensity and frequency of hot days and nights, and decreased intensity and frequency of cold days and nights (IPCC 2018).

Increasing annual mean temperature trends at the country scale in East Asia and South Asia have been observed during the 20th century. Between 1950 and 2010, western Afghanistan and southwestern Pakistan have experienced the largest increases in annual average temperatures rising by 1.0°C–3.0°C (1.8°F–5.4°F). Southeastern India, western Sri Lanka, northern Pakistan, and eastern Nepal have all experienced increases of 1.0°C–1.5°C (1.8°F–2.7°F) over the same period.

(Mani et al. 2018). Many studies on projections on temperature in the APR show a likely increase in mean temperature over Asia under the business-as-usual scenarios (ADB 2017, Xu et al. 2017, Mc Kinsey 2020, and Mani et al. 2018).

Changes in mean and extreme temperature because of climate change is already having impacts on the trends and patterns of heat waves in many countries and likely to aggravate in the future with further warming. The global mean annual temperature from 1986 to 2005 had warmed by 0.61°C since the preindustrial level (IPCC 2013). Extreme heat can have potentially negative impacts for both human health and for crops and agricultural production. High temperatures affect different crops in different complex ways through photosynthesis, soil moisture, weather conditions, and canopy properties causing lower grain number and grain weight (Seibert et al. 2014). The impacts of heatwaves and extreme temperature on human health is often defined as human survivability threshold based on wet bulb temperature. Accordingly, 35°C is considered an upper limit on human survivability in a natural environment for most people (Sherwood and Huber 2010).

Among many parts of APR, the Southeast Asian countries are particularly projected to be highly vulnerable to heat waves by many studies (Dosio et al. 2018, Gasparini et al. 2017, Li et al. 2020, and Russo et al. 2017). While, across Southeast Asia, temperature has been increasing at a rate of 0.14°C–0.20°C per decade since the 1960s (Xu et al. 2017), heat waves are projected to become more frequent, longer lasting, and more intense (Li et al. 2020). Under 2°C warming, Southeast Asia is likely to face extreme heat waves at least once every 20 years in 57.6% of land area (Dosio et al. 2018). In South Asia, large cities in parts of Bangladesh, India, and Pakistan could be among the first places in the world to experience lethal heat waves that exceed the human survivability threshold. Under RCP 8.5, by 2050, between 600 million and 1 billion people in Asia will be living in areas with a nonzero annual probability of lethal heat waves, on average, between $2.8 trillion and $4.7 trillion of GDP in Asia annually will be at risk from an effective loss of outdoor working hours because of increased heat and humidity (McKinsey 2020). Similarly, while upward temperature trends are notable and robust in recent past in West Asia, the number of heat waves per person is projected to increase in Central Asia (Perkins et al. 2012).

In one of the first studies at the global scale on impacts of extreme heat on crop production Deryng et al. (2014) projected impacts of extreme heat stress on maize, spring wheat, and soybean yields for the 21st century. Results indicated maize to face progressively worse impacts under a range of climate scenarios while spring wheat and soybean will improve globally through to the 2080s because of carbon dioxide fertilization effects, even though parts of the tropic and subtropic regions could face substantial yield declines. Gao et al. (2014) projected wheat crop to experience a greater number of high-temperature episodes during their reproductive period, posing a threat to crop production. Examining the impacts of extreme weather disasters on crops between 1964 and 2007, estimates show that droughts and extreme heat significantly reduced national cereal production by 9%–10% across the globe (Lesk et al. 2016). While there is less research and evidence on agricultural impacts of heat waves in APR, evidence indicates towards negative impacts of heat waves both on crop production and human health in the region.

B. Precipitation and Floods

Millions of farming households and many micro, small, and medium-sized enterprises (MSMEs) directly or indirectly depends on monsoon rainfall in the APR including the Indian monsoon, the Australian monsoon, and the East Asian monsoon for agriculture-related activities. Changes in the rainfall and precipitation patterns from climate change impacts could significantly alter the agricultural productivity, cropping patterns, livelihood outcomes, and resulting economic consequences in the region. Studies on impacts of climate change on monsoon rainfall predicts a higher increase in precipitation in 21st century for Indian monsoon, East Asian monsoon, South Asian monsoon, and Indo-China peninsular monsoon and moderate increase for Australian monsoon (Wang et al. 2014, Mishra et al. 2020, Moon et al. 2020, and Burke et al. 2017).

Although there is strong regional variability on impact of climate change on flooding globally, recent projections on flood risk indicates an increased risk in APR under accelerated warming conditions. While for South Asia, climate models predict an increase in average monsoon precipitation of 6.4% under the RCP 8.5 by 2050 (Mani et al. 2018), large increase in precipitation have been projected for foothills of Himalayas, Tibetan Highlands, Myanmar Region, and India. In general, dry regions are projected to get drier and wet to get wetter with increase in warming in South Asia (Bhowmick et al. 2019). Similarly, annual precipitation is projected to increase in most parts Central Asia during 2011–2100 (Huang et al. 2014 and Jie et al. 2020). Climate change is exacerbating the flood risk situation globally and scientific evidence indicate a likely rise in extreme flash floods and river floods (Dankers et al. 2014, Arnell et al. 2016, and Alferi et al. 2017). The likelihood of extreme precipitation events and floods could increase in areas of eastern Japan, central and eastern PRC, parts of the Republic of Korea, Indonesia, South Asia and Southeast Asia, and Brahmaputra River in Bangladesh (McKinsey 2020, Doll et al. 2018, Mohammed et al. 2017, and IPCC 2018).

Likely increase in flooding events because of climate change carries a huge economic cost for many low- and middle-income countries in the APR. Globally, flooding accounts for some 40% of all loss-related natural catastrophes since 1980, with losses worldwide totaling more than US$1 trillion. For example, floods and landslides in Thailand in 2011 resulted in highest flood losses of all time totaling US$43 billion (Munich Re 2021). Flood risk and associated human and material losses are heavily concentrated in India, Bangladesh, and the PRC (IPCC 2014). Flood frequency and flood-induced mortality are the largest in Asia, specifically in the PRC, India, Indonesia, and Philippines (Hu et al. 2018). An estimated 73% of the total population exposed to river flooding are living in Asia, with the largest total value of assets in river flood hazard areas (US$17 trillion) (Jongman et al. 2012). Recent estimates show that about $1.2 trillion in capital stock in Asia is expected to be damaged by riverine flooding each year by 2050 (McKinsey 2020). The impacts of floods also depend on the preexisting socioeconomic and infrastructure conditions that's contributes to the outcome of the flood events. Winsemius et al. (2016) estimated that basins in heavily urbanized regions and emerging economies (for example, Yangtze and Mekong basins) are projected to face an increase in the economic impacts of river flood.

C. Sea-Level Rise and Coastal Flooding

Sea-level rise (SLR) and related coastal flooding is one of the well-known impacts of climate change. Socioeconomic factors such as coastal population, infrastructure, and megacities on the coast makes these knowledges critical for informing decision-making directions. Many of these physical and socioeconomic factors make APR vulnerable to the impacts of SLR and coastal flooding. SLR risk is expected to increase virtually in all low-laying coastal areas of APR over this century, despite the differences in nature economic and geographic characteristics (IPCC 2019).

Globally, increase in global mean temperature has caused a global mean SLR of about 0.19 meters

(m) during the last century (IPCC 2013). While there is little consensus between the reported ranges of global mean sea level rise, projections vary in the range of 0.26 m–0.77 m and 0.35 m–0.93 m for 1.5°C and 2°C respectively (IPCC 2018). Future SLR will depend on the additional warming caused by GHG emissions and their impact on ice sheet and glacier. Global mean sea level will rise between 0.43 m (0.29–0.59 m, likely range; RCP 2.6) and 0.84 m (0.61–1.10 m, likely range; RCP 8.5) by 2100 (medium confidence) relative to 1986–2005 (IPCC 2019).

Regional variations of SLR rise also exist and are because of the land ice loss and variations in ocean warming and circulation (IPCC 2019). Under RCP8.5 scenario, there will be a likely increase of 48% of the world's land area, 52% of the global population, and 46% of global assets at risk of flooding by 2100. A total of 68% of the global coastal area flooded will be caused by tide and storm events with 32% because of projected regional SLR (Kirezci et al. 2020). Regionally in APR, the mean sea level for the Pacific Commonwealth islands for 2080–2100 is expected to be from 0.4 m to 0.8 m higher compared to 1986–2005. The rate of SLR is expected to increase to reach values 6 millimeters per year and 12 millimeters per year by 2100 for RCP 8.5. Further, extreme sea level events are projected to increase in the Pacific region because of impacts of climate change. For example, an extreme event which currently happens once a century will become a yearly occurrence by 2050 (Wahl et al. 2017, Viteusek et al. 2017, and IPCC 2014).

For other countries of APR, assuming no coastal protection, under RCP 8.5 in 2100, projections show that Southeast Asia and East Asia are likely to experience significant increase in coastal flooding (Kirezci et al. 2020). Many Asian countries such as the PRC, Bangladesh, India, Viet Nam, Indonesia, Thailand, the Philippines, and Japan are highly vulnerable to SLR and coastal flooding by the end of the century (Kulp et al. 2019). Without adaptation, risk is expected to significantly increase in many places such as the river deltas in Asia, which are providing agricultural services to a large population at the risk of coastal flooding, erosion, and salinization.

D. Cyclones and Storms

There has been considerable uncertainty on the question of whether impacts of climate change have discernible effects on patterns/intensity/frequency of cyclones (Knutson et al. 2010 and Christensen et al. 2013). Globally, the annual number of global tropical cyclones exhibits no clear trend and has remained steady at about 86 since 1980 (Murakami et al. 2020). However, studies have suggested that human-induced GHGs have very likely influenced the nature and patterns of cyclones and storms (Gillet et al. 2008, Webster et al. 2005, Knutson et al. 2010, and Murakami et al. 2020). Few studies have found an increase in frequency and percentage of observed categories 4 and 5 hurricanes during the last part of the 20th century. While Webster et al. (2005) suggest increase in both the frequency as well as the percentage of observed categories 4 and 5 hurricanes during 1970–2004 with largest increase in northwest Pacific, the Indian Ocean, and the South Pacific, Klotzback et al. (2015) found insignificant upward trend between 1990 and 2014 for frequency of categories 4 and 5 hurricanes. Kossin et al. (2013) finds increasing trend of lifetime maximum intensity of tropical cyclones) in North Atlantic and South Pacific and the South Indian basins. Walsh et al. (2019) found that consensus projections of future tropical cyclone behavior continue to indicate decreases in tropical cyclone numbers, increases in their maximum intensities, and increases in tropical cyclone-related rainfall.

APR is particularly vulnerable to storms and tropical cyclones with five existing tropical storm seasons i.e., Arabian Sea, Bay of Bengal, Northwest Pacific, South Pacific, and Australia. Murakami et al. (2020) demonstrate an increase in the frequency of extremely severe cyclonic storms over the Arabian Sea and a decreasing trend of tropical cyclones and severe tropical cyclones over the Bay of Bengal for 1961–2010. The number of tropical cyclones originating in central Pacific has increased over the past four decades, while fewer have occurred in the southern Indian Ocean and western North Pacific. The study projects decrease in total number of tropical cyclones and more frequent occurrence of most intense (categories 4 and 5) cyclones at higher warming levels.

Overall, the most recent IPCC review (2019) concluded with medium confidence that the average intensity of tropical cyclones, the proportion of categories 4 and 5 tropical cyclones and the associated average precipitation rates are projected to increase for a 2ºC global temperature rise. Rising mean sea levels will contribute to higher extreme sea levels associated with tropical cyclones (very high confidence). Coastal hazards will be exacerbated by an increase in the average intensity, magnitude of storm surge, and precipitation rates of tropical cyclones. There are greater increases projected under RCP8.5 than under RCP2.6 from around mid-century to 2100 (medium confidence). There is low confidence in changes in the future frequency of tropical cyclones at the global scale.

E. Drought and Water Stress

The extensive impacts of droughts on agriculture are well documented. Globally, 3.2 billion people live in agricultural areas with high to very high-water shortages or scarcity, of whom 1.2 billion people—roughly one-sixth of the world's population—live in severely water-constrained agricultural areas. About 520 million of such people live in Southern Asia and 460 million live in Eastern Asia and Southeastern Asia (FAO 2020). Globally, studies have already indicated towards increased frequency and intensity of droughts and increased water stress in the future because of impacts of climate change (Sheffield et al. 2012 and Dai et al. 2010) and it is expected that drought events will become more frequent and more severe in future. Globally, between 1980 and 2008, area percentages of high and very high agricultural drought hazard zones were about 23.57 % and 27.19% of the total agricultural area and these zones includes east central and southwest PRC, Southeast Asia, and eastern Australia of APR (Zeng et al. 2016). More recent studies have projected increased water stress and droughts in APR under accelerated warming condition (Kraaijenbrink et al. 2017, Liu et al. 2018, Gao et al. 2018, Wang et al. 2014, Naumann et al. 2018, and Cook et al. 2020).

While projections show likely increase of the global median drought length with increased warming, a progressive and significant increase in frequency of droughts is projected with warming in West Asia, Southern Asia, and Oceania, where droughts are projected to happen 5–10 times more frequently even under ambitious mitigation targets and current 100-year events could occur every 2–5 years under 3°C of warming (Naumann et al. 2018). While severe drought-affected populations are projected to increase in urban areas of East Asia, West Asia, and Southeast Asia in 1.5°C warmer world compared to 1985–2005 (Liu et al. 2018), less rural population in South Asia, Tibetan Plateau, and Central Asia for the 1.5° C and 2 °C warmer worlds would be exposed to severe drought.

Available scientific evidence projects risk of future agricultural drought in mainland Southeast Asia from 2020 to 2029 under RCP8.5 (Amnuaylojaroen et al. 2019), an increasing drought frequency and intensity over East Asia, mainly in Southeastern Asia (Zhang et al. 2015), northwest South Asia (Zhai et al. 2020), dry conditions under the 1.5°C/2.0°C global warming scenarios for Kazakhstan and Northwest PRC (Miao et al. 2020), increasing drought severity and frequency in north India (Gupta et al. 2018), and increase in severe and extreme drought durations in western and central India after 2030s (Shresta et al. 2020).

Along with droughts, water stress is also projected to increase in APR. For example, an estimated additional 200 million people are under threat of facing at least heavily water-stressed conditions from climate change and socioeconomic growth mostly in the PRC and India (Gao et al. 2018). Climate change is projected to increase water shortages in many parts of Indus and Ganges basins by the end of the century, affecting freshwater availability in the region (Wang et al. 2014). Similarly, glaciers of high mountains of Asia, which provides water to millions of people in the region, is warming more rapidly that global average and much of the glaciers ice is projected to disappear under RCP 8.5 scenario by the end of the century (Kraaijenbrink et al. 2017).

F. Climate Change and Food Security

Food production and food security in the region is likely to be adversely affected because of the impacts of climate change. For example, climate change will generally reduce South Asian rice production in the medium term to 2040. India is likely to be the most negatively affected, losing up to 5% of its rice output potential from the historical trend. Similarly, Bangladesh, India, and Pakistan are clearly predicted to be the losers to climate change in the future foregoing 5%–10% of their wheat output potentials (Cai et al. 2016). Maize yield in eastern India is projected to reduce in the 21st century in irrigated conditions, while its shows positive yield in rained conditions (Srivastava et al. 2021).

However, studies have also shown that some regions might get higher output under increased carbon dioxide concentration in the future. Horie et al. (2019) find that rice yields in the regions surrounding the equator (Indonesia and Malaysia) will increase under all climate scenarios. Namely, rice cultures in southeast India, northwest India, Southeast Asia, central PRC and south-central to southwestern Japan are likely to suffer significant yield reductions by the projected global warming, mainly through increased spikelet sterility and shortened growth duration.

Central Asia is likely to be severely affected by impact of climate change (Reyer et al. 2017). In Tajikistan, crop yields could drop by up to 30 % by 2100 because of water stress in some parts of the country. In Uzbekistan, without implementing adaptation measures and technological progress, yields for almost all crops are expected to drop by as much as 20%–50 % (in comparison to the 2000–2009 baseline) by 2050 with 2°C warming because of heat and water stress (World Bank 2020). In central Asia, positive income gains is projected for many large-scale commercial farms in the northern regions of Kazakhstan and negative impact in small-scale farms in arid zones of Tajikistan (Boboojonov et al. 2014).

In Southeast Asia, agriculture is a major source of livelihood and about 115 million hectares of land are devoted to the production of rice, maize, palm oil, natural rubber, and coconut (ADB 2009). Rice has been the major crop in the region since a long time. Climate change is likely to affect food production in Southeast Asia (Raghavan et al. 2019). Recent studies indicate that that future crop choice could be quite different with more Southeast Asian farmers choosing to grow rice and oilseeds. Farmers are likely to adapt to future climate change by growing more rice and oilseed crops, planting more often from November through March, and relying more heavily on groundwater irrigation for water short seasons (Reed et al. 2017).

V. CROP INSURANCE IN THE ASIA AND PACIFIC REGION

Agricultural insurance, defined here as crop and livestock insurance, has been an important economic instrument in many countries to cope with losses from weather and agricultural risks. Based on product type, insurance can address a wide range of risks arising from climatic and non-climatic factors and help farmers cope with risks. Traditionally, farmers have been using broadly formal (market based, i.e., private crop insurance, formal credits, and savings) and informal (nonmarket, i.e., savings at home, community crop sharing, asset sale) which can be ex-ante (before the shock) and ex-post (after the shock). For many poor small and marginal farmers of APR, informal risk management practices had been a norm without access to market based on public sector agricultural insurance. However, with the recent expansion of agricultural insurance in APR, the insurance landscape is fast evolving and changing in the last two decades. Earlier study estimated that, globally, 104 countries had some form of agricultural insurance in 2008, and that the total premium collected that year was $20 billion (Mahul and Stutley 2010). More recently, Hess and Hazell (2016) estimated number of farmers covered under index-based agricultural insurance program and found that globally 198 million farmers were insured in 2014 and from these about 194.2 million were in Asia—of which 160 million were in the PRC and 33.2 million in India. The global insurance market for agricultural risks is currently thought to be worth about US$33 billion and is growing at a rate of about 5% each year (Krauer, 2018).

However, despite the recent increase in focus on agricultural insurance, there remains considerable gap in terms of insurance coverage, uptake, and demand in APR, which is primarily dominated by agricultural insurance markets of the PRC, India, Japan, and the Philippines. Earlier assessment of agricultural insurance in the APR by FAO (2011) shows that, in 2010, agricultural insurance was present either in a pilot form or a fully mature national-level program in 20 (45%) of the 44 countries, territories and areas in the APR. Based on recently collected secondary data, this paper assesses the agricultural insurance market in the APR.

A. Agricultural Insurance in the Asia and Pacific Region: Status and Trends

To review the status of crop insurance, the APR is defined as 49 member countries of the Asian Development Bank (ADB) within Asia and the Pacific. However, for analysis, 46 countries of the APR were included as mentioned in table below. Lack of publicly available data constraints the analysis on insurance coverage and penetration in all countries of APR. The paper finds publicly available data for only 14 countries of APR on area and farmers covered under agricultural insurance. There are only few earlier estimates on different indicators of agricultural insurance. While Mahul and Stutley (2010) provided and estimation on different aspects of premium, subsidy, type of products, etc., the latest estimates by Hess and Hazell (2016) provide estimation on number of farmers covered under different index insurance. However, Hess and Hazell (2016) provided data from eight countries of Asia and with a time span from 1999 to 2013. This study provides and updated estimates based on data from recent years from 14 countries. The findings of the analysis are presented below.

In 2017–2018, it is estimated that agricultural insurance was being implemented either on a pilot basis or under a fully operational program in 24 countries (52% of total of the 46 countries) in the APR. However, after removing countries in PPP (pilots/planning/preparation) phase only 17 (or 36%) have fully operational agricultural insurance schemes. Out of the 46 countries, in 7 countries are in PPP stage. These countries are namely Azerbaijan, Armenia, Bangladesh, Cambodia, Myanmar, Malaysia, and Viet Nam. The paper did not find any existing agricultural insurance schemes in any of the 14 Pacific countries in APR.

In South Asia except Afghanistan and the Maldives, all the countries have some form of agricultural insurance. In Southeast Asia, four countries have no form of agricultural insurance namely Brunei Darussalam, the Lao People's Democratic Republic, Singapore, and Timor-Leste. However, Cambodia, Viet Nam, Myanmar, and Malaysia are under PPP phase to launch agricultural schemes soon.

In 2017–2018, it is estimated that about 251 million farmers and 228 million hectares of land were under any form of agricultural insurance in the APR.

Very few countries in APR today have only one form of insurance model. There has been a major expansion of PPP in recent years in APR for agricultural insurance. With increased focus, investments and initiatives related to agricultural insurance in almost all countries, in some form for private players, are operating in the insurance sector. Our estimations show that, in 2017–2018, in about 34% of countries in APR there were PPPs, while the public sector operated in four countries. Further, the paper finds that agricultural insurance is largely subsidized in many countries of SAR (32%) and, in 19% of the countries, agricultural insurance is voluntary.

Recently few countries have shifted back to voluntary insurance as opposed to earlier mandatory insurance schemes such as India which recently approved the revamping of Pradhan Mantri Fasal Bima Yojana and Restructured Weather Based Crop Insurance Scheme, making enrollment under both schemes voluntary. Similarly, Kazakhstan is planning to make agricultural issuance voluntary

B. Agricultural Insurance: Demand and Uptake in the Asia and Pacific Region

The uptake and coverage of agricultural insurance globally has remained unequal and low, especially among the low- and middle-income countries (Panda et al. 2020 and Surminski et al. 2019). In APR, the status is not very different with agricultural insurance being available in 24 countries and the distribution of number of farmers covered, livestock covered, and area covered under agricultural insurance is concentrated in few countries such as the PRC, India, the Philippines, and Sri Lanka. Many countries still largely lack any available schemes and a widespread coverage and demand for agricultural insurance products. Extreme weather, catastrophe losses amplified by climate change and chronic climate risks have significant potential to undermine the current efforts to increase the uptake of agricultural insurance among poor and vulnerable farmers in the region.

Understanding barriers and challenges to operation of insurance market has been a major topic of research in microeconomics. Seminal works have identified the adverse selection and moral hazard as endemic to insurance arrangements under conditions of asymmetric information (Rothschild and Stiglitz 1978). Spatially correlated risk, moral hazard, adverse selection, and high administrative costs are important barriers for agricultural insurance market to function properly. (Hess et al. 2005). Much of the agricultural risk management approach in developed countries are not suitable in low- and middle-income countries because of limited fiscal capacities and limited access to global reinsurance market. This has led to introduction of various improved insurance products over the years to boost demand in developing countries, including increased focus on parametric agricultural insurance. Index-based agricultural insurance program has seen expansion in many countries of APR, for its potential to overcome difficulties of adverse selection and moral hazard with traditional insurance and potential for increasing inclusion of private sector in managing agricultural risks (Hess and Hazzel 2016 and Clarke and Dercon 2016).

However, although index insurance theoretically has many benefits, its expansion and uptake has remained minimal in many countries of APR. Studies examining the demand for index-based insurance in developing countries through household surveys, randomized control trials, and choice experiments have made an important contribution to this debate (Cole et al. 2013, Giné Townsend and Vickery 2008, ~~Dercon et al. 2018~~, and Bjerge and Trifkovic 2018). These studies have highlighted various factors for low uptake of demand for insurance such as high premium prices, low income, trust in the insurer, previous experience with insurance, level of education, financial literacy, liquidity constraints, and the effect of past shocks. The prevailing low demand for micro-insurance services has also been analyzed from supply-side perspectives by examining the role of basis risk, price, transaction costs, contract design, and quality of services (Karlan et al. 2013, Jansen et al 2016, Norton et al. 2014,). Few studies have also investigated the interconnected nature of the demand for formal savings, credits, and insurance among households in developing countries (Bendig et al. 2009) and found that, in developing countries, poor are less likely to participate in formal financial services as compared to their better-off counterparts.

In the case of India, Matsuda et al. (2019) investigated the demand for temperature and rainfall index insurance in India and found that price has a strong impact on the insurance quantity demanded, and farmers respond less to the price of a rainfall insurance scheme in the monsoon season after a temperature insurance scheme in the previous dry season. Gaurav et al. (2020) suggest basis risk significantly reduces farmers' willingness to buy index insurance products. Similarly, Ghosh et al. (2021) find that farmers value the assurances that they will receive timely payouts when they incur losses and may not have a strong preference for the method with which losses are assessed. Jin et al (2016) in the PRC find that subsidy provided by the government is the major reason for farmers to participate in insurance program and shows that farmers' risk aversion significantly increases the probability of their decision to buy weather index-based crop insurance. Liu et al (2021) find that demand for livestock insurance increases when the price premium decreases or the expected payout increases. While the study by Fadhliani et al. (2019) in Indonesia find that incomplete coverage with relatively low premium subsidies is the best policy to minimize the impact on yield, Dewi et al (2018) examine the farmers willingness to pay for Asuransi Usaha Tani Padi crop insurance and finds that significant factors influencing farmer's decision to participate in the crop insurance program were farm size, land status, and farmer's income.

While index-based agricultural insurance in the APR has received increasing attention, at best it has remained a work in progress and overall uptake has remained low. In APR, only India and the PRC have achieved some scale in area yield index insurance and weather index insurance, largely based on heavily subsidized schemes. Most low- and meddle-income countries in the region have hardly achieved any scale in implementing index-based agricultural insurance schemes. Research has focused on various problems related to low uptake of index-based schemes such as lack of demand because of availability of other low-cost risk management systems in place compared to insurance, prevalence of basis risk, lack of liquidity to pay premiums among poorer farmers, high transaction costs, degree of risk aversion, lack of understanding of insurance products, lack of trust with the insurers, low correlation between index, and agricultural risks because of lack of weather data in many countries (Hess and Hazell 2016).

Based on the current evidence, we summarize the major challenges for expansion of agricultural insurance in the APR.

(i) One of the major challenges in the wider uptake of agricultural insurance coverage in APR is the lack of affordability. Public subsidies have been often used to achieve the objective of stimulating demand as evident from India and the PRC in achieving some scale in area yield index insurance and weather index insurance, largely based on heavily subsidized schemes. Although insurance demand is price-sensitive, it is likely to be difficult to achieve universal coverage through subsidies alone.

(ii) There is a need to decide between targeted and universal subsidies and how premium subsidies will be more effective at increasing coverage among low-income populations. The question of inclusiveness of agricultural insurance is important to avoid mistargeting in APR. Poorly designed insurance schemes might lead to moral hazard and maladaptation.

(iii) Low correlation between index and agricultural risks because of lack of weather data in many countries of APR needs to be addressed by developing better availability of weather data.

(iv) A good monitoring and evaluation (M&E) system that tracks the performance agricultural insurance schemes is paramount for the success of these schemes.

(v) Agricultural risk insurance schemes should be embedded in the comprehensive risk management strategy rather than a stand-alone product.

(vi) Agricultural insurance for MSMEs are largely missing in the region. There is a need to promote insurance of MSMEs in the region.

While index-based agricultural insurance in the APR has received increasing attention, at best it has remained a work in progress and overall uptake has remain low. Overall, despite many promising pilots and projects in the region by initiatives such as Global Index Insurance Facility and Insuresilience global partnerships and other private players, the scale of the uptake is very small. Whether the current projects and pilots will lead to successful outcomes remains to be seen. Lastly, one of the major problems in assessing the effectiveness of pilots and initiatives has been the lack of M&E of these projects and with a lack of consensus on what indicators to use and what information to collect. A particular challenge is how to measure performance and impact (Panda et al. 2020 and Hess et al. 2016).

In recent years, there has been increasing efforts from development organizations to introduce new kinds of products and strengthen crop insurance for smallholder farmers in APR. For example, the International Water Management Institute, with private and government players, is testing the use of satellite technology to bring index-based flood insurance to farmers in India and Bangladesh. Similarly, the International Food Policy Research Institute is testing the use of smartphone camera data to strengthen insurance products in India. More recently, pilots on block chain climate risk crop insurance aim to increase the resilience of farmers by providing more accessible inside insurance products. In this system, each insurance policy is plugged into smart contracts on a blockchain and indexed to local weather. During an extreme weather event, the policies are automatically triggered on the technology platform, which facilitates timely and fair payouts (Micale et al. 2019). Further, initiatives such as the rice crop monitoring initiative—Remote Sensing-based Information and Insurance for Crops in Emerging Economies—has been helping governments and farmers in Southeast Asia and India to better forecast harvests in the face of an increasing number of extreme weather events. The initiative has been collecting satellite-based data for land under rice cultivation in Cambodia, India, the Philippines, Thailand, and Viet Nam. The data collected is also used by insurance systems to make crop insurance more efficient and payouts more transparent.

C. Agriculture and Disaster Risk Insurance in the Asia and Pacific Region

Despite a decade of experimentation with index-based insurance, the challenges of low demand, high basis risk, moral hazard, adverse selection, and other institutional and governance issues have recently led to change in programming of the schemes and to shift responsibilities to higher organizational levels. There has been an increasing focus towards 'meso' and 'macro' scales in terms of implementing agricultural insurance in the context of climate change. This is reflected in the recent interest in macro level or sovereign level disaster insurance schemes.

Climate change is likely to increase the intensity and frequency of extreme weather events in the future and countries of APR need to address their limited capacity to finance climate change and disaster risks. While agricultural insurance serves as one way of protecting the millions of farmers in the region from climate change risks at the micro and meso levels, there is an urgent need to supplement these efforts by incorporating climate and disaster risk insurance (CDRI) and other risk financing instruments at national and regional level.

Insurance has been widely recognized as an important tool for climate change adaptation. While the costs of adaptation in developing countries could range from US$140 billion to US$300 billion per year by 2030 (UNEP 2020), every US$1 invested in adaptation could result in US$2–US$10 in net economic benefits (GCA 2019). With increasing evidence that countries with widespread market-based insurance coverage recover faster from the financial impacts of extreme events (Golnarghi 2018), governments are increasingly recognizing the role of market-based insurance for adaptation. One important example is the growing number of disaster insurance schemes in developing countries as a climate risk management tool. A recent study identifies 25 intervention that qualify as CDRI in the Asia and Oceania region covering directly or indirectly more than 212 million people (GIZ 2020). Recently, many countries of the APR are moving towards proactive and alternative planning for financing disaster risks. Although it is still in its initial stages, this is evident from increasing participation of countries in sovereign risk transfer pools and catastrophe risk insurance pool in APR. In sovereign catastrophe risk pools, countries can pool risks in a diversified portfolio, retain some of the risks through joint reserves and capital, and transfer excess risk to the reinsurance and capital markets. (World Bank 2020). Currently, there are two sovereign risk transfer /catastrophe risk pools arrangements in APR: (1) Southeast Asia Disaster Risk Insurance Facility involving the Lao People's Democratic Republic, Myanmar, and Cambodia. Southeast Asia Disaster Risk Insurance Facility is a regional platform that that strengthens financial resilience against disasters through rapid and predictable disaster relief funding and access to international reinsurance and capital market through regional risk pooling. (2) Pacific Catastrophe Risk Assessment and Financing Initiative aims to provide the Pacific Island countries with risk modeling and assessment tools to enhance disaster risk reduction and provide disaster risk management and financial solutions to help build resilience in the Pacific islands. The current members include the Cook Islands, the Marshall Islands, Samoa, Tonga, and Vanuatu. However, despite the increasing number of macro level schemes, a recent study finds that even though 68 countries participate in these four regional risk pools, only about a third (32%) purchased insurance coverage in 2019, with almost half (46%) of the eligible countries not deploying any disaster risk finance instruments at all (Act Alliance 2020).

In addition to sovereign risk pools, there are also few examples of new national risk pooling such as The Philippine City Disaster Insurance Pool, which aims to address the need for rapid access to early recovery financing for cities in the Philippines that typically face particularly high disaster risk. The Philippine City Disaster Insurance Pool will offer parametric insurance cover against typhoons and earthquakes in its first phase. In addition, there are also existing examples of use of catastrophe bonds in the case of the Philippines and Catastrophe Deferred Drawdown Option in the case of the Maldives. In addition, there are few other recent regional initiatives such as the

Asia–Pacific Climate Finance Fund established in 2017. The Asia–Pacific Climate Finance Fund identifies and pilots innovative, scalable, and commercially viable financial risk management products alongside development projects that support climate change mitigation and adaptation in ADB's developing member countries. Overall, CDRI in APR is still in its infancy, and it is essential to put greater emphasis on how CDRI supports resilience to climate change. CDRI and broader risk financing does not automatically reduce risk, but it can help to finance and manage it, thus reducing vulnerability to climate change impacts. However, CDRI is only sustainable in the medium term and long run if it is underpinned by strong disaster risk reduction and resilience actions.

VI. DISCUSSION

Climate change is likely to increase the severity and intensity of extreme natural disasters events in the future jeopardizing the livelihoods of millions of farmers and MSMEs dependent on agriculture. Extreme weather exposures and losses amplified by climate change risks have the potential to reverse economic gains of past decades and increase poverty levels, especially in the APR. Our analysis of climate change and crop insurance in the region reveals some important observations and suggestions. First, both supply and demand bottlenecks need to address to close the protection gap in agricultural insurance in the APR. While much focus has been on solving demand side problems of uptake of insurance, there has been little attention on solving supply side bottlenecks in improving affordability of agricultural insurance schemes. Many of the low- and middle-income countries of APR micro-insurance remains as the prime focus. However, with increasing systemic risks from climate change, there is need to increasingly support scaling up from micro to meso and sovereign level agricultural insurance schemes. Second, agricultural insurance in APR is largely in few countries only. For example, many countries of Central Asia and Southeast Asia lack any kind of large-scale agricultural insurance schemes. Third, there is an increasing need to focus on insurance for MSMEs in the agriculture sector. So far, most of the focus has been on designing insurance products at the micro level in the APR. Fourth, sovereign disaster risk insurance has significant potential in the region to reduce macroeconomic costs of disasters arising from climate change and supplementing agricultural insurance schemes by pooling risks. However, so far, these are concentrated in a few countries of the Pacific region. Fifth, while there are many ongoing pilot and fully operational insurance schemes in the region, lack of M&E and publicly available data on agricultural insurance schemes remains a concern for analysis. There is a need to promote institutional arrangements to create data platforms for public use and sharing. Finally, agricultural insurance will only be sustainable in the medium term and long run if it is underpinned by strong disaster risk reduction and resilience actions. Currently, most agricultural insurance schemes lack strong disaster risk reduction component in product designs.

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APPENDIX: TABLES AND FIGURES

Table A1: Status of Crop Insurance in the Asia and Pacific Region

Region	Countries	Yes/No	Indemnity Based/Index Based	Type of Market	Mode of Inclusion	Premium Subsidy	Farmers Insured (million)	Livestock Insured (million)	Area Insured (million hectare)
Central Asia	Armenia	⊶	Indemnity based	PPP	NA	NA			
	Azerbaijan	⊶	Indemnity based	PPP	NA	NA			
	Georgia	√	Indemnity based	PPP	Mandatory	Yes	0.049		0.714
	Kazakhstan	√	Indemnity based	PPP	Mandatory	Yes			
	Kyrgyz Republic	√	Indemnity based	PPP	Voluntary	Yes			
	Tajikistan	χ							
	Turkmenistan	√	NA	PPP	Voluntary	No			
	Uzbekistan	√	Indemnity based	Public	Voluntary	No			
East Asia	Hong Kong, China	√							
	Mongolia	√	Index based	PPP	Voluntary	No	0.028	7.1	1.22

Region	Countries	Yes/No	Indemnity Based/Index Based	Type of Market	Mode of Inclusion	Premium Subsidy	Farmers Insured (million)	Livestock Insured (million)	Area Insured (million hectare)
	People's Republic of China	√	Both	PPP	Voluntary	Yes	195	21480	166.23
	Republic of Korea	√	Indemnity based	PPP	Voluntary	Yes	0.9		
	Taipei,China	√	Indemnity based	PPP	Voluntary	Yes	0.047		0.078
South Asia	Afghanistan	χ							
	Bangladesh	⊶	Both	Private	Voluntary	Yes	0.0196		
	Bhutan	χ							
	India	√	Both	PPP	Voluntary	Yes	47.32	0.74	51.93
	Maldives	χ							
	Nepal	√	Indemnity based	Public	Voluntary	Yes	0.0014	0.068	
	Pakistan	√	Both	PPP	Mandatory	Yes	1.13	0.258	0.23
	Sri Lanka	√	Both	Public	Mandatory	Yes	1.5		1.06
Southeast Asia	Brunei Darussalam	χ							

Region	Countries	Yes/No	Indemnity Based/Index Based	Type of Market	Mode of Inclusion	Premium Subsidy	Farmers Insured (million)	Livestock Insured (million)	Area Insured (million hectare)
	Cambodia	⚩	NA	NA	NA	No			
	Indonesia	√	Both	PPP	Voluntary	Yes	1		0.806
	Lao People's Democratic Republic	χ							
	Malaysia	⚩				No			
	Myanmar	⚩	Index based	PPP	Voluntary	No			
	Philippines	√	Both	Public	Voluntary	Yes	2.27		1.84
	Singapore	χ							
	Thailand	√	Indemnity based	PPP	Mandatory	Yes	1.9		4.51
	Timor-Leste	χ							
	Viet Nam	⚩	Both	PPP	Voluntary	Yes			
Total	**Yes=17** **No=22** **PPP=7**						**251.16**	**21488.16**	**228.61**
Others									

Region	Countries	Yes/No	Indemnity Based/Index Based	Type of Market	Mode of Inclusion	Premium Subsidy	Farmers Insured (million)	Livestock Insured (million)	Area Insured (million hectare)
	Australia	√	Both	Private	Voluntary				
	New Zealand	√	Both	Private	Voluntary				
	Japan	√	Both	PPP	Both		1.54	10.86	1.75
Total							**252.7**	**21499.02**	**230.36**

NA = not applicable, PPP = public–private partnership.

Sources: Author's estimates.

Table A2: Studies on Projected Changes in Monsoon in the Asia and Pacific Region

Monsoon	Projected Changes	Studies
Indian Monsoon	Indian summer monsoon (5.0 %/°C) under RCP 4.5	Wang et al 2014
	The frequency of extreme dry (SPEI ≤ −1) monsoon seasons are projected to increase over the coming century, especially after the 2030s. Extreme hot monsoon seasons are likely to become normal after the 2040s	Mishra et al 2020
	The percentage change in precipitation per one-degree Celsius warming in the long term SSP5-8.5 scenario is +3.6 %	Moon et al 2020
Indo-China Peninsula Monsoon	The percentage change in precipitation per one-degree Celsius warming in the long term SSP5-8.5 scenario is +6 %	Moon et al 2020
East Asian Monsoon	East Asian summer monsoon (6.4 %/°C) rainfall under RCP 4.5	Wang et al 2014
	Future monsoon projections from the CMIP6 models show an increase in precipitation in the East Asian monsoon (EA) (SSP 8.5)	Moon et al 2020
	Under anthropogenic forcings, the model predicts that in the People's Republic of China, there is, on average, a decrease in the total monsoon rainfall, an increase in the number of dry days. This gives a picture of a generally drier monsoon. (People's Republic of China)	Burke et al 2017
Australian Monsoon	Australian summer monsoon rainfall will increase moderately by 2.6 %/°C under RCP 4.5	Wang et al 2014
	Australian monsoon (AU) precipitation will slightly increase by about 2% °C in the long term with high confidence	Moon et al 2020
South Asian Monsoon	South Asian monsoon will carry 5% more rainfall under the RCP 4.5 warming scenario.	Wang et al 2014

Source: Author.

Table A3: Impacts of Natural Disasters in Selected Countries of the Asia and Pacific Region

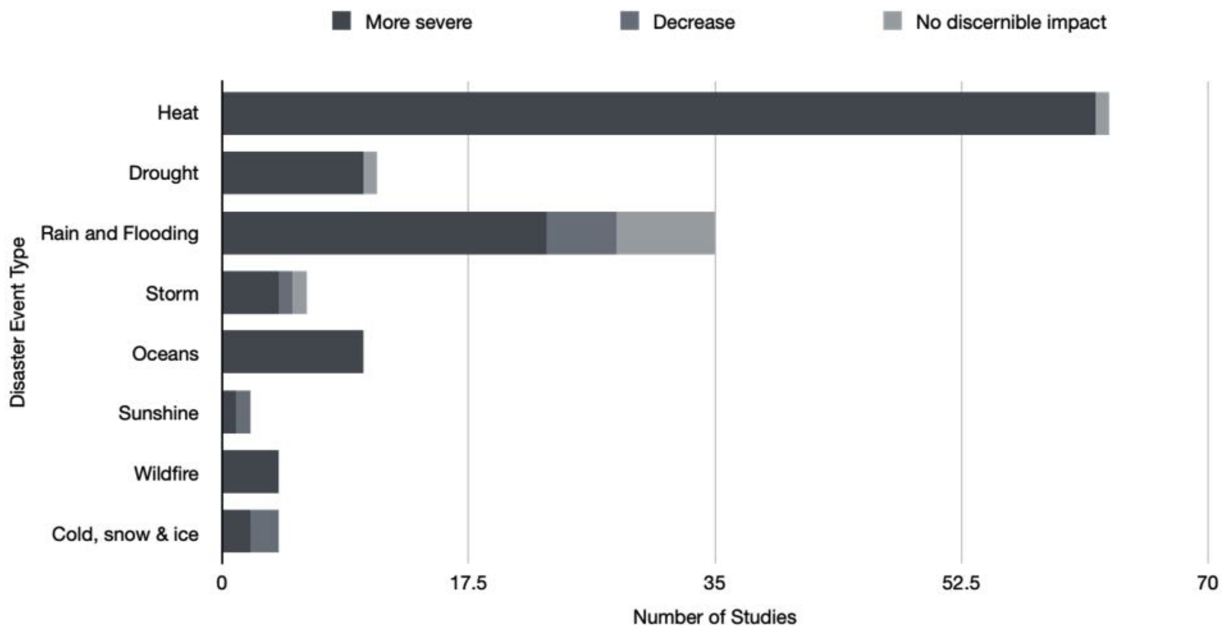
Country	Frequent Disasters	Examples of Economic Impacts of Disasters
Afghanistan	F, D, LS, EQ	Flooding causing average annual damage of $54 million
Armenia	EQ, F	Annual average flooding loss to gross domestic product (GDP) about $100 million.
Australia	HA, F, CY, FF	Cost of natural disasters in Australia over the 10 years to 2016 averaged $18.2 billion per year.
Azerbaijan	EQ, F	The annual average affected GDP by flooding is about $300 million.
Bangladesh	C, F, SS, D, SLR	Tropical cyclone in Bangladesh since 1900 have resulted in US$4.7 billion–US$$9.0 billion in damages.
Cambodia	F, S, D	Annual flooding is causing estimated losses of US$100–US$170 million
Cook Islands*	TC, E	It is expected to incur, on average, about US$4.9 million of losses per year because of tropical cyclones.
Micronesia, Federated States of	TC, TY, SLR,	It is expected to incur, on average, US$8 million per year in losses because of earthquakes and tropical cyclones.
Fiji	C, F, EQ, TSU	Between 1980 and 2016, annual economic damages caused by disasters have been estimated at about to US$16.3 million.
Georgia	EQ, F, LS, D, AV	Between 1995 and 2013, loses from natural disasters is estimated at GEL2.7 billion.
India	F, D, EQ, CY, D	India suffered US$79.5 billion economic loss because of climate-related disasters in the last 20 years.
Indonesia	F,D,LS,TS, EQ	Total costs in 2050 by climate change in these three areas of agriculture, health, and gradual sea level rise are estimated at Rp132 trillion. The greatest financial impact of climate change will be because of decreased agricultural output, which accounts for 53% of this cost.
Kazakhstan	F, EQ	The annual avenge GDP affected by floods about $3 billion.
Kiribati	TC, EQ	Kiribati is expected to incur, on average, about US$0.3 million per year in losses because of earthquakes and tropical cyclones.
Kyrgyz Republic	EQ, F	The annual avenge affected GDP by flooding is about $70 million.
Lao People's Democratic Republic	F, D	Annual expected losses for the Lao People's Democratic Republic from flood events range between 2.8% and 3.6% of GDP
Malaysia	F, LS	9% of the total land area under flood risk, potentially affecting 2.7 million people.
Marshall Islands	TC, EQ	The Marshall Islands is expected to incur, on average over the long term, annual losses of US$3 million because of earthquakes and tropical cyclones.
Mongolia	Dzuds, F, WF	Disasters in the last 10 years have caused a total economic loss of about US$321.3 million.
Myanmar	F, LS, C, D	Myanmar faces average costs of US$9 million for just emergency response to floods alone.
Nepal	F, D, LS	The estimated direct cost of these events is equivalent to 1.5%–2% of current GDP/year (about US$270 million–US$360 million/year in 2013 prices).
Pakistan	F, ST, HW, D	The climate-only disaster losses are measured at 1% of GDP for the period 2005–2013.
Papua New Guinea	EQ, F, LS,	It has been estimated that an average of US$85 million annual losses occur as a result

		of earthquakes and tropical cyclones in Papua New Guinea,
People's Republic of China	F, D, C, EQ	Between 1989 and 2018, natural hazards caused direct physical losses valued at about US$1,698 billion (in 2018 values) Since 2000, 38.86 million hectares of crop have experienced a yield loss of at least 10 percent from natural disasters every year,
Philippines	TY, F	Between 2000 and 2016 natural disasters caused average annual damages of $1.2 billion.
Korea, Republic of	TY, F, LS, EQ	The maximum annual damage costs from natural disasters through 2060 are estimated to be US$20.9 billion, which would be 1.03% of future GDP.
Samoa	CY, TSU, EQ	Samoa is expected to incur, on average over the long term, about US$10 million per year in losses because of earthquakes and tropical cyclones.
Sri Lanka	F,CY, D, LS	Precipitation flooding causes Sri Lankan households to have US$78 million per year in asset losses and US$119 million per year in wellbeing losses. recorded damages of nearly U$ 7 billion between 1990 and 2018.
Tajikistan	F, EQ	The annual average affected GDP about $300 million because of earthquakes.
Thailand	F, LS, ST, D	Flood disasters in Thailand between 1989 and 2018 have caused more than US$5.1 billion in damage.
Turkmenistan	EQ, F	The annual average affected GDP about $2 billion because of earthquakes.
Uzbekistan	F, EQ	The annual average population affected by flooding in Uzbekistan is about 400,000 and the annual average affected GDP about $800 million.
Viet Nam	TY, F, SS	Natural shocks cause private and public asset losses worth an average of US$8.1 billion in power purchasing parityterms each year; that is US$2.7 billion in real terms

F = flood, D = drought, TY = typhoon, LS = landslide, EQ: = earthquake, CY = cyclone, TS = tsunami, TC = tropical cyclone.

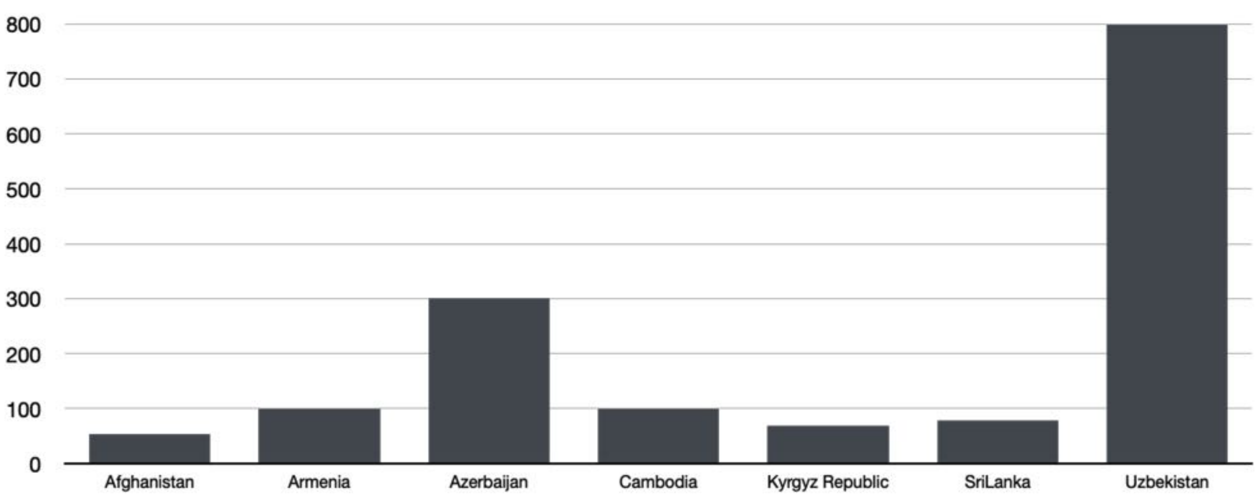
Source: Author.

Figure A1: Number of Studies Attributing Increase in Natural Disasters Because of Anthropogenic Climate Change, 2001–2019.



Source: Author's estimates using Carbon Attribution Database.

Figure A2: Estimated Average Annual Flood Damage in million US$



Sources: Author's estimates based on various studies.

Table A4: Examples of Past Climate Extreme Events in Asia and Projections

Extreme Event	Year	Country	Event	Future Projections
Asia "anomalously warm" seasonal temperatures, 1961–2008	Trend		Heat	More severe or more likely to occur
Republic of Korea summer heatwave, 2013	2013	Republic of Korea	Heat	More severe or more likely to occur
Japan heatwave, 2013	2013	Japan	Heat	More severe or more likely to occur
Central eastern PRC hot summer, 2013	2013	PRC 24°–33°N, 102.5°–122.5°E	Heat	More severe or more likely to occur
Eastern PRC record hot summer, 2013	2013	Eastern PRC	Heat	More severe or more likely to occur
Republic of Korea record hot spring, 2014	2014	Republic of Korea	Heat	More severe or more likely to occur
Northern PRC hot spring, 2014	2014	Northern PRC 30°–55°N, 105°–135°E	Heat	More severe or more likely to occur
Record warmth in India, 2015	2015	Southern India and Sri Lanka	Heat	More severe or more likely to occur
Deadly heat & humidity in India & Pakistan, summer 2015	2015	India and Pakistan	Heat	More severe or more likely to occur
Northwest PRC record heat, July 2015	2015	Northwest PRC, Xinjiang Autonomous Region	Heat	More severe or more likely to occur
Western PRC extreme high temperatures, 2015	2015	Western PRC, West of 105°E	Heat	More severe or more likely to occur
Japan heatwave, August 2015	2015	Japan	Heat	More severe or more likely to occur
Republic of Korea earliest summer onset, 2017	2017	Republic of Korea	Heat	More severe or more likely to occur
Northeast PRC hot and dry spring/summer, 2017	2017	Northeast PRC (80°–120°E and 40°–70°N)	Heat	More severe or more likely to occur
Central eastern PRC heatwave, July 2017	2017	Central eastern PRC	Heat	More severe or more likely to occur
Yangtze river delta summer heatwave, 2017	2017	Yangtze river basin	Heat	More severe or more likely to occur

Extreme Event	Year	Country	Event	Future Projections
Asian heat extremes, 2016	2016	10°S–90°N, 55°E–170°W	Heat	More severe or more likely to occur
Thailand hot and dry April, 2016	2016	Thailand	Heat	More severe or more likely to occur
China heatwave, July 2017	2017	Central Eastern PRC	Heat	More severe or more likely to occur
Japan high temperature event, July 2018	2018	Japan	Heat	More severe or more likely to occur
Northeast PRC summer extreme heat, 2018	2018	Northeast PRC (110°E-130°E, 35°N-50°N)	Heat	More severe or more likely to occur
Northeast Asia summer heatwave, 2018	2018	Northeast Asia (34°–40°N, 120°–143°E)	Heat	More severe or more likely to occur
Northeast PRC nighttime heatwave, summer 2018	2018	Northeast PRC (34°–55°N, 105°–135°E)	Heat	More severe or more likely to occur
Republic of Korea "summer longest heatwave", 2018	2018	Republic of Korea	Heat	More severe or more likely to occur
Japan record low sunshine, August 2017	2017	Japan	Sunshine	Decrease, less severe or less likely to occur
Tibetan Plateau severe drought, autumn 2009	2009	Tibetan Plateau	Drought	More severe or more likely to occur
South PRC late spring drought, 2018	2018	South PRC (22°–29°N, 105°–120°E)	Drought	More severe or more likely to occur
Record-breaking consecutive dry days in Beijing, winter 2017-18	2017-18	Beijing	Drought	More severe or more likely to occur
Northern India severe rainfall, June 2013	2013	Northern India	Rain and flooding	More severe or more likely to occur
Southeast PRC extreme rainfall, May 2015	2015	PRC	Rain and flooding	More severe or more likely to occur
Northeast Bangladesh extreme pre-monsoon rainfall, 2017	2017	Northeast Bangladesh (90.5°–92.5°E, 24°–25.5°N)	Rain and flooding	More severe or more likely to occur
Southeast PRC record June rainfall, 2017	2017	Southeast PRC (24°–32°N, 107°–124°E)	Rain and flooding	More severe or more likely to occur
Extreme rainfall in Yangtze-Huai, PRC, June-July 2016	2016	PRC, Yangtze–Huai region (27.5°–35°N, 107.5°–123°E)	Rain and flooding	More severe or more likely to occur

Extreme Event	Year	Country	Event	Future Projections
Wuhan extreme rainfall, July 2016	2016	PRC, Wuhan City	Rain and flooding	More severe or more likely to occur
Yangtze river extreme rainfall, summer 2016	2016	PRC, Yangtze River	Rain and flooding	More severe or more likely to occur
Central western PRC daily rainfall extremes, summer 2018	2018	Central Western PRC (30°–38°N, 100°–110°E)	Rain and flooding	More severe or more likely to occur
Japan heavy rainfall event, July 2018	2018	Japan	Rain and flooding	More severe or more likely to occur
Central western PRC persistent heavy rainfall, summer 2018	2018	Central Western PRC (30°–38°N, 100°–110°E)	Rain and flooding	Decrease, less severe or less likely to occur
Upper Yellow river basin extreme floods, 2018	2018	Upper Yellow River basin in the PRC	Rain and flooding	Decrease, less severe or less likely to occur
Eastern PRC recod cold event, January 2016	2016	Eastern PRC	Cold, snow, and ice	Decrease, less severe or less likely to occur
Eastern PRC "super cold surge", 2016	2016	Eastern PRC	Cold, snow, and ice	Decrease, less severe or less likely to occur
Himalayan snowstorm, 2014	2014	Nepal	Storm	More severe or more likely to occur
Extreme accumulated cyclone energy in western North Pacific, 2015	2015	Western North Pacific	Storm	More severe or more likely to occur

PRC = People's Republic of China.

Source: Adapted and modified from Carbon Brief Attribution Database 2020.