Working Paper No.112

Technological Innovation for Enhancing Agricultural Resilience to Natural Disasters and Climate Change

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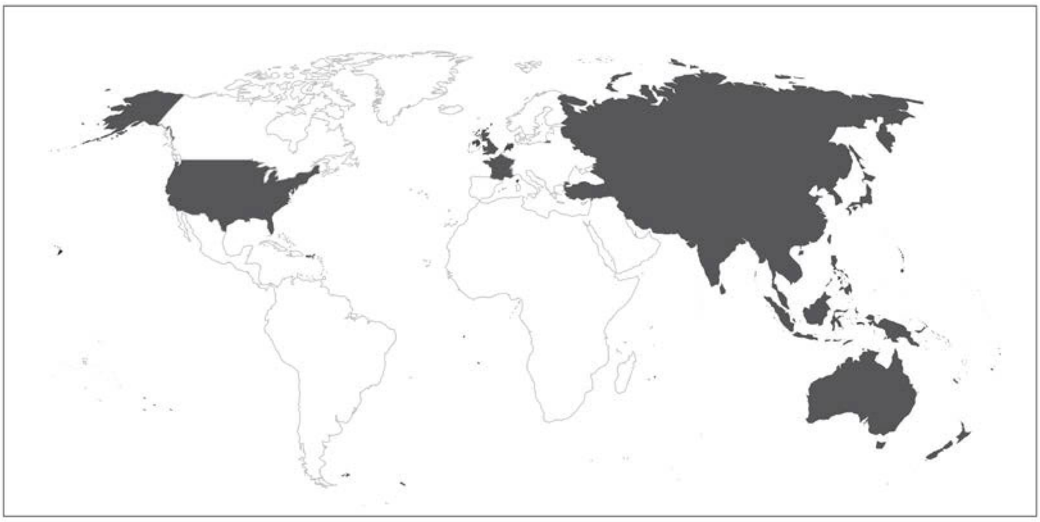
UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

CAPSA
Centre for Alleviation of Poverty through Sustainable Agriculture



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The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 Member States and 9 Associate Members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. ESCAP's research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries' sustainable and inclusive development ambitions.

CAPSA-ESCAP

The Centre for Alleviation of Poverty through Sustainable Agriculture (CAPSA) is a subsidiary body of UNESCAP. It was established as the Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT Centre) in 1981 and was renamed CAPSA in 2004.

Objectives

- Enhanced national capacity for socioeconomic and policy research on sustainable agriculture for poverty reduction and food security
- Enhanced regional coordination and networking to successfully scale up and scale out research findings that have implications for policy design and implementation related to sustainable agriculture and rural development
- Enhanced capacity of policymakers and senior government officials to design and implement policies to achieve rural development, poverty reduction and food security through sustainable agriculture in Asia and the Pacific

**The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city of area or of its authorities, or concerning the delimitation of its frontiers or boundaries.*

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CAPSA-ESCAP
Jalan Merdeka 145, Bogor 16111
Indonesia

ISBN 978-979-9317-90-2

Cover photos by: Kaikoro / Shutterstock.com
Cover design and lay out by: Fransisca A. Wijaya

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Abbreviations

ADB	Asian Development Bank
CAPSA	Centre for Alleviation of Poverty through Sustainable Agriculture
CEDAC	Centre d'Etude et de Développement Agricole Cambodgien/Cambodian Center for Study and Development in Agriculture
CH_4	Methane
CO_2	Carbon Dioxide
CRED	Centre for Research on the Epidemiology of Disasters
CSA	Climate Smart Agriculture
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EIDs	Emerging Infectious Diseases
EM-DAT	Emergency Events Database
EPIS Korea	Korea Agency of Education, Promotion & Information Service in Food, Agriculture, Forestry and Fisheries
ESCAP	Economic and Social Commission for Asia and the Pacific
EWS	Early Warning Systems
FAO	Food and Agriculture Organization of the United Nations
FFTC	Food and Fertilizer Technology Centre
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
ICT	Information and Communication Technology
IEG	Independent Evaluation Group
IFAD	International Fund for Agricultural Development
IFRC	International Federation of Red Cross and Red Crescent Societies
IFS	Integrated Farming System
IRRI	International Rice Research Institute
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPR	Intellectual Property Right
IT	Information Technology
LDCs	Least Developed Countries
LLDCs	Landlocked Developing Countries
N_2O	Nitrous Oxide

NGO	Non-Governmental Organization
RNA	Ribonucleic Acid
R&D	Research and Development
SATNET Asia	Sustainable Agricultural Technologies and Improved Market Linkages in South and South-East Asia
SDG	Sustainable Development Goal
SDI	Subsurface Drip Irrigation
SIDS	Small Island Developing States
SLR	Sea Level Rise
SMS	Short Message Service
SRI	System of Rice Intensification
UNIDSR	United Nations International Strategy for Disaster Reduction
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UN-RCO	United Nations Resident Coordinator Office
USD	United States Dollar

Foreword

The Centre for Alleviation of Poverty through Sustainable Agriculture (CAPSA) has a mandate to promote sustainable agriculture to reduce poverty and enhance food security in Asia and the Pacific. The aim is to strengthen South-South dialogue and intraregional learning on poverty, food insecurity and sustainable agriculture through research, advocacy and networking, capacity development and policy advice. Specifically, CAPSA engages in the following activities:

- **Policy research**: identify, coordinate and promote research on emerging and successful policy options in areas related to CAPSA's mandate and of relevance to the current needs of the member states, synthesize those findings from across the region and translate them into policy recommendations
- **Capacity development**: develop capacity of governments, experts, practitioners and civil society for the adoption and implementation of effective policy initiatives and good practices
- **Knowledge sharing, advocacy and networking**: establish networks for exchanging and disseminating relevant knowledge and experience, and promoting intraregional learning among policymakers, opinion leaders and other stakeholders
- CAPSA also provides tailor-made **policy advice** upon request from member states.

This working paper identifies the types of technological innovations at every stage of disaster risk management, particularly on information and early warnings, prevention, mitigation, response and recovery, which can support stakeholders in pursuing resilience agriculture in relation to food security, community welfare and achievement of sustainable development goals (SDGs). Disaster risk reduction (DRR) agriculture intervention plays a significant role in improving agricultural resilience to natural disasters and climate change. It has been well documented that investments in preparedness can result in significant savings in aid and rehabilitation costs. Studies concluded that for every dollar spent on DRR is about equal to 4 dollars returned in avoided damage or losses and costs.

This publication, *Technical Innovation for Enhancing Agricultural Resilience to Natural Disasters and Climate Change* aims to build a practical learning, information and reference resource for all DRR agriculture professionals, especially in Asia and the Pacific. It emphasizes the role of DRR agriculture in ensuring sustainable food production systems and sustainable agriculture practices.

Masakazu Ichimura
Director, CAPSA-ESCAP
December 2017

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Acknowledgements

The initial draft of this working paper was developed by Le Huu Ti, CAPSA consultant with additional contributions from Nobue Amanuma, Programme Officer of CAPSA. The draft was then processed further and finalized by Ita Sualia, CAPSA consultant, under the overall direction and guidance of Masakazu Ichimura, Director of CAPSA-ESCAP. Collaborative efforts by the CAPSA supporting team are also acknowledged. This working paper would not have been completed without their contribution.

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Executive Summary

Records since 1900 show that Asia and the Pacific region experiences over 40 per cent of global natural disaster events, making it the most disaster-afflicted region in the world. In the last two decades, the number of natural disaster events, such as floods, droughts, tropical cyclones, landslides and earthquakes have increased sharply. Along with this increase, the Asia-Pacific region also experiences extreme weather variability. The combination of these creates an adverse impact on agriculture systems, including failure of crops, higher demand for inputs and support services, slashes in the ability of farmers to repay loans and disruption of supply chains between farmers, buyers, processors and consumers.

The impact of natural disasters on agricultural sectors is particularly high in developing countries, reaching 22 per cent of total damage and losses. Various studies have shown that a lack of integration of disaster risk reduction (DDR) into agricultural development plans and actions (and vice versa) has contributed to this damage and losses (FAO, 2015b). As the number of natural disaster events in the Asia-Pacific region has increased sharply, particularly in the last two decades, there is an urgent need to reduce vulnerability and to foster resilient livelihoods, farming systems, ecosystems and infrastructure to reduce the risks and minimize the costs of damage from future disasters in Asia-Pacific region. Godschalk *et al.* (2009) estimated that the investments of 1 dollar in DRR could save about 4 dollars in avoided future losses.

This working paper demonstrates 'technological innovation' as a crucial intervention to improve agricultural resilience towards natural disasters and climate change. Innovation plays significant roles in all five stages of disaster management: (1) institutional and frameworks development; (2) disaster risk management (DRM) strategy setting and DRR planning; (3) information and early warning; (4) prevention and mitigation; and (5) response and recovery. This working paper will focus on how technological innovation could help in DRR management in stages 3-5 of DRM.

Information and early warning

Farmers and communities need early warning of natural hazards, as a well-functioning early warning system (EWS) with accurate information can help farmers and communities decide which DRR measures should be undertaken. Vulnerability and risk assessment to determine the level of vulnerability and adaptive capacity of communities and agricultural systems is needed by the government and other development agencies as a basis for determining priority locations and actions in a disaster management plan. The availability and collation of this information is vital. Hazard information obtained from various geographical locations could be used to create prediction and risk distribution maps at different spatial scales across farming areas. The predictions could be site specific, based on administrative areas or landscapes, depending on what coverage is required.

Experiences from various Asia-Pacific countries revealed that dissemination of disaster risk and early warning information should be built through a 'risk communication mechanism' (Coffey *et al.*, 2015). This could be a mix of direct verbal, printed and electronic dissemination. The mechanism targets a range of stakeholders, including government, farmers, disaster management agencies and other members of the agriculture chain.

Current technology, such as smartphones, allows community-based data gathering, hazard information and early warnings to be distributed via SMS or social media quickly and effectively. At a higher level, the use of telemetry technology, such as satellite images, drone observation and other sensor technologies for monitoring, has made the management of large-scale farms (plantations) much easier. The information presented may include climate projections, weather forecasts, soil segmentation, rainfall cluster analysis, elevation analysis, crop condition and forecasting, and early warning of natural disasters. A critical consideration in using the hazard risk information in an early warning system is how to follow up the information and disseminate it to multisectoral and interdisciplinary stakeholders across the geographical landscapes.

Prevention and mitigation

Disaster prevention and mitigation are defined as the measures designed and implemented to reduce the impact of disaster events. Agriculture-specific prevention and mitigation measures cover various activities, including improvement of land use and land management, improvement of water management and pest management, and the use of plants and crops which are resistant to extreme conditions.

Experience of various types of disasters across the Asia-Pacific region has shown the need to invest in technological innovation for disaster prevention and mitigation in agriculture, particularly in the following mitigation practices:

- Integrated farming systems: through the combination of crop and livestock components
- Crop diversification and rotation: through the reduction of farmer dependency on single crops to distribute disaster risk
- System of rice intensification (SRI): through a single seed planting method to enable individual rice plants to be grown in larger space than usual
- Water efficient farming: through the improvement of rainfall infiltration and irrigation, reduction of run-off and maintenance of soil moisture
- Improved soil management: through slow-forming terraces, conservation tillage and strip cropping
- Integrated pest management: through biological control

Response and recovery

Our knowledge on various types of natural hazards and disasters is still insufficient. Therefore, even with sophisticated DRR strategies, there is always a need for emergency response and recovery interventions. Rapid impact assessment, as the first response, followed by livelihood assessment could significantly support effective recovery after a severe natural disaster. In the Asia-Pacific region, immediate support to recover the community's agricultural system is an essential part of the comprehensive post-disaster emergency response. Since agriculture is the primary livelihood of communities across the region, the recovery measures will not only boost the morale of the community after the devastation but will also help to quickly re-establish economic activities in the disaster-affected areas.

Based on experience from various countries and disaster events in the region, the most needed technological innovations for disaster recoveries are land remediation, agricultural inputs and the rebuilding of damaged agriculture infrastructure. The recovery intervention should also include rebuilding social and market support for agricultural products and, in some cases, providing agriculture policy reform allowing better agriculture practices. Some recovery efforts in preparing the farmland include natural succession, ecological restoration, managing weeds, pests and invasive species, desalinization and decontamination of chemicals and radioactivity.

Policy support

The critical part of fostering technological innovation for agriculture DRM is enabling strong policy support to provide the right conditions for research and development in agriculture DRR, including infrastructure and skills, availability of financial resources for research and development, and effective implementation of regulations. The infrastructure includes facilities, tools and instruments. Skills refer to human resources, knowledge services and networks that support the process of developing new technologies. The specific policy support needed by Asia-Pacific countries to encourage technological innovations in DRR agriculture include:

- Integrating DRR into the agriculture sector and vice versa
- Integrating agriculture and DRR into spatial planning
- Accelerating innovation
- Investing in research and development
- Capacity-building and institutional arrangements
- Providing access to information and knowledge-sharing

Ultimately, technological innovation in preventing, mitigating and responding to natural disasters in agriculture can evolve through a strong multi-sectoral, interdisciplinary and regional cooperation in data and information exchange. Therefore, every country in Asia and the Pacific should continuously improve their mechanisms for information exchange in order to lead to a better understanding of disasters, how they develop, what their impacts on crops are and how they hamper the growth of the agriculture sector.

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1 Introduction

1.1 Background

The CAPSA Annual Governing Council Session is held to gain input on programmes that have been implemented in the past year, as well as to gather feedback on specific thematic ideas to plan activities for the following year. The eleventh session, held in February 2015, recommended a focus on agricultural innovation. Affirming this direction, the twelfth session, held in February 2016, further requested a focus on resilience to natural disasters and climate change. In the same year, dialogues with potential donors echoed that technological innovation to enhance agriculture's resilience to natural disasters should be a potential area for future cooperation.

These recommendations aim to address the high degree of hunger in Asia and the Pacific, which affects 513 million people and constitutes 65 per cent of total global hunger. Part of the aim of Sustainable Development Goal 2 (SDG 2) is to end hunger by 2030. Attempts to achieve this goal are hampered by a projected population increase from 7.5 billion in 2017 to 8.5 billion people by 2030 and the increasing frequency of natural disasters. Disasters weaken all aspects of food security, by reducing food supplies and cutting the income of the poor community. Projected rises in temperatures, changes in precipitation patterns, changes in extreme weather events and reductions in water availability result in reduced productivity. Climate change adds to the severity and frequency of disasters.

Since those recommendations are well in line with their mandates on promoting knowledge sharing for sustainable agriculture, food security and inclusive rural development, CAPSA decided to take up the issue of "Technological Innovation for Agricultural Resilience to Natural Disasters and Climate Change" as a theme of its analytical research and to publish it as a working paper.

1.2 Objective

This research is a stocktaking and issue mapping exercise, to provide a broad overview on how technological interventions can play a role in every phase of disaster management, what technologies are being developed and applied to enhance the resilience of agricultural systems to natural disasters and climate change, and what areas hold promise for future innovation.

The knowledge compiled in this working paper is expected to: (1) help key players in technological innovation, such as national agricultural research centres and other institutes, to better focus and design their programmes for research and development (R&D); (2) assist agriculture practitioners and other stakeholders with available knowledge and emerging technologies for reducing risks and enhancing adaptive capacity to climate-related and other natural disasters; and (3) support evidence-based policymaking for sustainable and resilient national development with improved rural livelihoods and food security.

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2 Natural Disasters and the Threat to Sustainable Development

A natural disaster is defined as a natural process that severely interferes the functioning of a community or society, causing widespread human, material, economic and environmental losses, which exceeds their ability to cope using their resources (IFRC, 2000). Furthermore, the International Federation of Red Cross and Red Crescent Societies (IFRC) stated that a natural hazard can be caused by either the rapid or slow onset of events. This working paper divides natural disasters into three categories:

- geophysical: earthquakes, landslides, tsunamis and volcanic activity
- hydro-meteorological: extreme temperatures, drought and wildfires, avalanches and floods cyclones and storms/wave surges
- biological: diseases, epidemics and pests

Many disasters are not sufficiently anticipated in development planning, particularly in developing countries. Thus, their sudden onset creates unprecedented adverse consequences to the progress of sustainable development. In order to anticipate disasters in development planning sufficiently, understanding the nature of each disaster, mitigation responses and recovery approaches become of paramount importance to minimize the risk of disruption in achieving sustainable development.

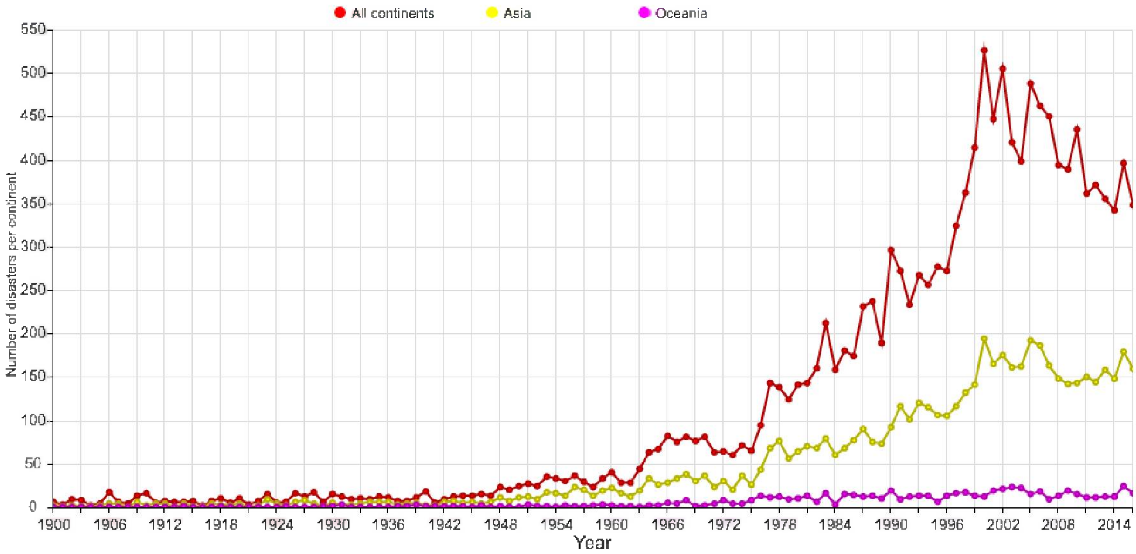
For instance, the Asia-Pacific region is geographically rich with islands, mountains, extensive coastlines, forests, deltaic plains and desert that makes it more prone to disaster than other regions of the world (ESCAP, 2015). The following sub-chapters describe some important aspects of natural disasters in the Asia-Pacific region.

2.1 Characteristics of natural disasters in Asia and the Pacific

In between 2005 and 2014, the Asia-Pacific region experienced over 40 per cent of global natural disasters, resulting in 60 per cent of the total number of deaths globally and 45 per cent global damage. Five types of natural hazards - flood, drought, tropical cyclone, landslide and earthquake - create most damage to the region. Data collected on natural disasters since 1900 indicates that they have increased sharply during the past two decades (Figure 2.1). Since 2000, climate-related disasters have been highest in frequency (over 67 per cent). The situation can be seen in Figure 2.2, there were almost 3,100 natural disaster events, of which about 40 per cent were flood and 27 per cent were storm.

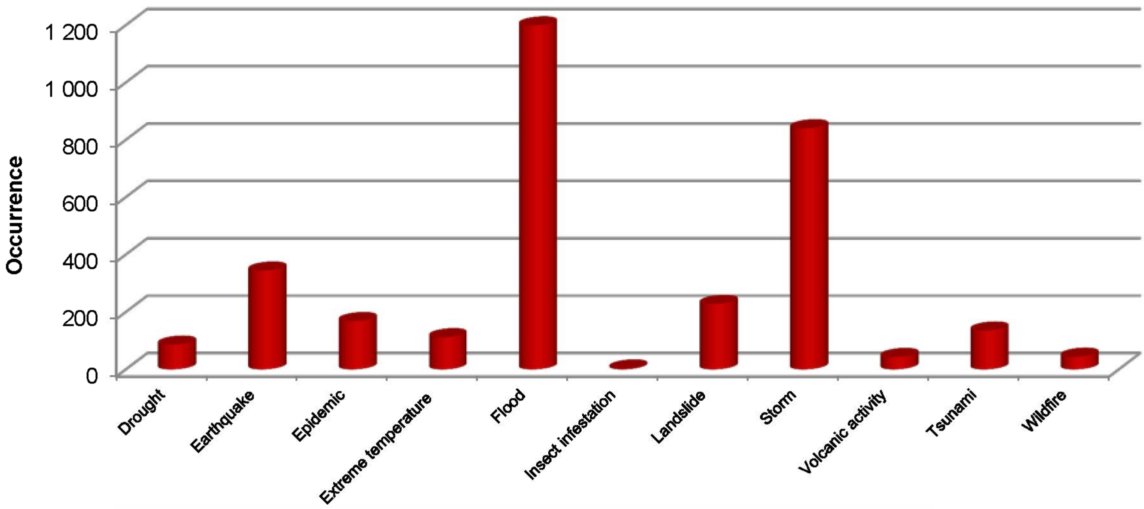
In terms of regional characteristics, the Indian Ocean and Pacific Ocean climate systems regularly produce tropical cyclones and typhoons that directly affect coastal and island countries around the two oceans. On the mainland of Asia, monsoon variability and snow cover dynamics are major contributors to the frequency and severity of floods and droughts. Several major rivers flow through this area, crossing several national borders, and a huge number of people live in the fertile valley of the river. Most floods and storms occurr in China, followed by India, with the most flood cases, and the Philippines with the most storm cases (Figure 2.2).

Figure 2.1 Natural disaster occurrence trend in Asia-Pacific region (1900-2016)



Source: Data compiled from EM-DAT (n.d.): www.emdat.be. Accessed 22 August 2017.

Figure 2.2 Type and occurrence of natural disasters in Asia-Pacific region (2000-2017)

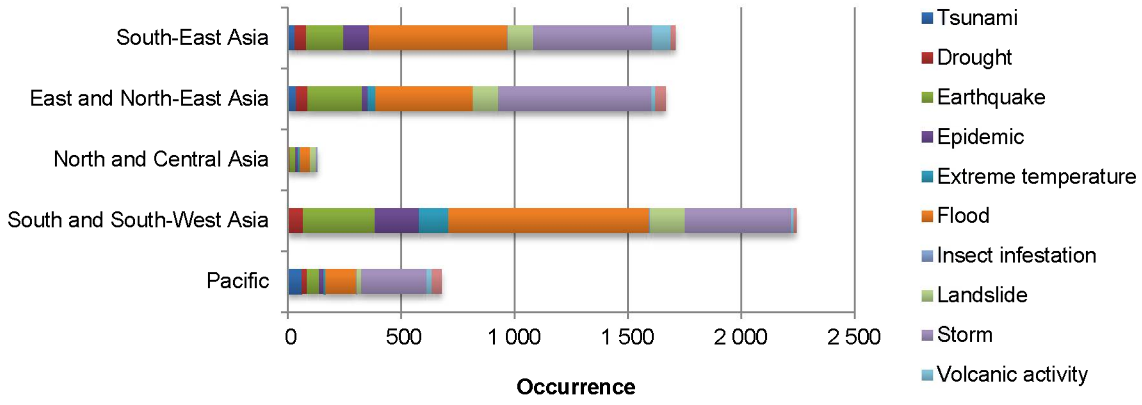


Source: Data compiled from EM-DAT (n.d.): www.emdat.be. Accessed 22 August 2017.
For tsunami, data compiled from: https://www.ngdc.noaa.gov/hazard/tsu.shtml. Accessed 3 October 2017.

Geological disasters also profoundly impact the Asia-Pacific region. The region has many young mountains that are particularly prone to earthquakes, landslides, avalanches and glacial lake outburst floods (GLOFs). The situation is exacerbated by active tectonic plate movements along the Pacific and the Indian Ocean, which are the source of major earthquakes and tsunamis (ESCAP, 2015).

Further analysis of the occurrence of disasters since 1900 in each subregion revealed that South and South-West Asia experienced the most significant number of natural disaster events, more than 2,200 out of 6,300 events for the whole region (Figure 2.3). The second place is shared equally by South-East Asia (1,700 events) and East and North-East Asia (1,600 events). Floods are common in most of the subregion, while storms are most prevalent in East and North-East Asia.

Figure 2.3 Occurrence of natural disasters according to subregion in Asia and the Pacific (1900-2017)



Source: Data compiled from EM-DAT (n.d.): www.emdat.be. Accessed 22 August 2017.
For tsunami, data compiled from: https://www.ngdc.noaa.gov/hazard/tsu.shtml. Accessed 3 October 2017 (data of tsunami is available from 2000 until 2017).

2.2 Threats to sustainable development

Asia and the Pacific have suffered substantial economic losses due to natural disasters of more than USD 0.5 trillion over the last decade, nearly half of total global losses (ESCAP, 2015). Approximately 1.4 billion people from this region have been affected by these natural disasters, constituting 80 per cent of global victims. Therefore, achieving sustainable development in the Asia and the Pacific will be difficult without integrating disaster management into the development plan.

To put disaster into the context of daily life in Asia and the Pacific, here is an example of a cross-country natural disaster that occurred while this paper was being written. A vast flood due to excessive rain washed across Nepal, India and Bangladesh on 10 August 2017. The torrential monsoon rains unleashed floods and landslides. They caused more than 800 human deaths and 40 million people were affected following widespread floods across South Asia (UNOCHA, 2017). According to the UN-RCO (Resident Coordinator Office), in Nepal, the floods killed at least 140 people, destroyed 65,000 homes and displaced 460,000 people.

The countries most vulnerable to natural disasters including small island developing states (SIDS), least developed countries (LDCs) and landlocked developing countries (LLDCs). They tend to be in marginal areas and most of the communities rely on livelihoods that are at high risk of being affected by natural disasters; for example, rain-fed agriculture. Moreover, these countries face many sources of economic vulnerability, including ageing and inadequate physical infrastructure. Between 2005 and 2015, SIDS in Asia and the Pacific recorded damage of around USD 500 million, with 830,000 people affected by cyclones, floods and tsunami (ESCAP, 2016).

Natural disasters have also laid tremendous economic burdens on SIDS, devastating their hard-earned development gains. LDCs have lost almost 1 per cent of GDP per year since 1970, while LLDCs have lost over 0.5 per cent. In 2015 in Vanuatu, Cyclone Pam caused damage and losses equivalent to 64 per cent of the country's GDP (ESCAP, 2016).

There are several major challenges to achieving SDG targets, namely ending hunger, achieving food security and improving nutrition, and promoting sustainable agriculture, in the region. They include the increasing intensity of natural disasters compounded by climate change, rapid economic growth, rising populations, emerging cities and the subsequent impact of these interconnected processes on environmental services. Furthermore, natural disasters are a global barrier to achieving sustainable development, as they are a source of profound social upheaval and economic losses.

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3 Natural Disasters and Damage to Agriculture

A recent assessment by FAO (2015a) found that the agriculture sector suffers about 22 per cent of total global damage and losses caused by natural disasters. These are climate-change related and include increases in temperatures, low humidity, high winds, rainfall variation, and an increased frequency and intensity of extreme weather events that directly damage crops. Furthermore, high rainfall with strong winds causes floods, landslides and erosion, which can further destroy agricultural land, crops and other infrastructure. In lowland coastal areas and small islands, the impacts include the loss of agricultural land, infrastructure and crops due to salinity intrusion and inundation of seawater (FAO, 2013).

3.1 Impact on agriculture

The immediate impacts of natural disasters on the agriculture sector are in the form of physical damage to crops. Within hours of the occurrence, agricultural facility buildings and equipment, transportation, agriculture land, irrigation works and dams, and the crops themselves can be destroyed. There is also indirect damage, which refers to the loss of potential production due to disruption in the flow of goods and services, loss of production capacity and increased production costs.

The long-term impacts of natural disasters include prolonged drought that contributes significantly to land degradation and water shortages, which erode traditional coping mechanisms, especially for the poorest people who live on the most degraded land. In the long term, environmental degradation and infrastructural damage will reduce production, causing food scarcity, increases in the price of goods and ultimately threaten the food security of low-income communities or countries. The potential impact of climate change on agriculture is presented in Table 3.1.

Table 3.1 Climate phenomena and impact on agriculture

Climate phenomena	Impact on agriculture	Probability
In most terrestrial areas, days and nights will be warmer, less frequently cold and more frequently very warm	Better harvest in cold environments; worse in warm environments; insect pests more frequent	Almost certain
More frequent heat waves and warm periods	Impoverishment of the crops in warmer regions due to heat stress; increased risk of uncontrolled wildfires. In currently cold mountain climates, yield increases	Very likely
More frequent intense precipitation events in most regions	Damage to crops, soil erosion, inability to cultivate the land due to waterlogging	Very likely
Increase in areas affected by drought	Lower yields, crop damage and even crop failure; significant livestock losses; increased risk of uncontrolled wildfires	Likely
Increased intensity of tropical cyclones	Damage to crops, uprooting the trees	Likely

Source: Intergovernmental Panel on Climate Change Working Group II (IPCC, 2007).

Data on natural disaster occurrences between year 2000 and 2016 from the Emergency Events Database (EM-DAT) show that, in the last two decades, the highest damage to the agriculture sector due to natural disasters was caused by floods (up to the USD 41.5 billion), followed by storms (up to USD 32.2 billion), tsunamis (up to USD 30 billion), droughts (up to USD 21.2 billion) and earthquakes (up to USD 8.7 billion). This data shows a correlation in the magnitude of loss and the number of disasters. As presented in Table 3.2, flood resulted in the highest costs, as it was the most common disaster, followed by storms and tsunamis, see Table 3.2 and Figure 2.2.

Table 3.2 Estimated damage to the agriculture sector in Asia-Pacific region (2000-2016)

Type of damage	Cost of damage in billion USD	Percentage of total annual damage*
Flood	41.5	4.36%
Storm	32.2	3.38%
Tsunami	30.8	3.24%
Drought	21.2	2.23%
Earthquake	8,.8	0.92%
Total	**134.6**	**14.14%**

* Total annual damage to agriculture sector in the Asia-Pacific region is estimated USD 952 million

Source: Data compiled from EM-DAT (Le Huu, n.d.).

Box 3.1 Key risks to agriculture resilience*

a. Hydro-meteorological hazards

Agriculture is highly exposed to hydro-meteorological hazards, such as floods, drought, hurricanes, cyclones and typhoons. Climate change, including variability and extremes, is a pervasive source of risk to agriculture. Climate-related hazards, including extreme weather, impacts adversely on agriculture systems, including crop production, farmers' demand for inputs and support services, and ability to repay loans. It may also have an impact on the upstream buyers and processors in the supply chain.

b. Geophysical hazards

Earthquakes and volcanic eruptions, wherever they occur, will hit vulnerable agricultural infrastructure, which leads to direct/indirect loss and disruption in production, processing and distribution. Natural disasters typically result in significant short-term yield reductions, subsequent market price increases and asset destruction that interfere with the flow of goods, services and information. For example, earthquakes can damage irrigation systems and crop fields, eventually leading to harvest failures due to shocks in the water supply.

c. Biological and environmental hazards

The agriculture sector is also subject to a wide range of biological and environmental hazards. Crops are exposed to diseases (bacteria and fungus), pests and toxic substances. Biological risks are associated mostly with yield and quality reductions, but they can also disrupt the flow of goods and services. In contrast, environmental hazards for agriculture include contamination and degradation of natural resources and the environment, and the contamination and degradation of production processes and processing. Environmental degradation (e.g. soil erosion, pesticide or factory effluent run-off into water supplies) could adversely affect future productivity, worker health and downstream market access. Mass or over-fertilization results in increased air, soil and water pollution with consequent impairment of agricultural ecosystem services.

*Adopted from Mia et al. (2015)

3.2 Non-natural disaster challenges for agriculture

Despite the magnitude of threats from natural disasters and climate change, the public expectation that the agriculture sector maintains its critical role is very high at both national/regional (macro) and community (micro) level. At the macro level, agriculture is expected to provide national food security for a growing population and increase its contribution to the GDP, fulfilling the need for employment and foreign exchange. While at the micro level, agriculture is the main source of income for millions of families in rural areas and provides important resources for social infrastructure and development.

Macro level

a. National food security

The challenge of feeding 8.5 billion people by 2030 is heightened by competition for land, water and energy that will affect the ability to produce food. Currently, 65 per cent of the 795 million undernourished people in the world live in the Asia-Pacific region. At the same time, population growth in certain countries/regions results in increasing wealth and higher purchasing power, thus increasing consumption and demand for processed food, meat, dairy and fish. This situation will generate pressure on the food supply system. Figure 3.1 shows examples of the food supply system: rice stockpiling in Cambodia (left) and the rice market in Indonesia (right).

Figure 3.1 Organic rice stock at the Centre d'Etude et de Développement Agricole Cambodgien (CEDAC) Cambodia (left); rice stock at a local market, Indonesia (right)

b. Raw material supply for manufacturing

Various industries require agriculture products; for example, the textile industry, furniture, wood fibre, leather and biofuel industries. This is turning the agricultural sector from food suppliers into non-food suppliers. This is illustrated in Figure 3.2, where the coconut plantations that used to supply coconut milk for food, are being cut to supply the manufacturing industry.

The actual size of the inputs needed for energy and manufacturing supplies is still uncertain, but it is likely will create major competition in land use and the use of resources either for food or for non-food. There is an increasing need to develop new industrial crops and improve traditional crops, particularly neglected and underutilized crops. Technically, many non-food biomass-derived chemicals from agriculture could potentially replace petroleum-derived chemicals.

Figure 3.2 Coconut timber for the manufacturing industry

c. Contribution to GDP and employment

Agricultural growth has significantly contributed to the Asia-Pacific food supply and economy. East Asian countries, in particular, have seen remarkable economic growth due to agricultural development. This has reduced poverty in the region by two-thirds in last three decades (IFAD, 2002). Furthermore, Barichello (2004) showed that, between 1980 and 2000, economic growth in East Asia was 7.5 per cent, much higher than developing countries at other regions. The closest regions in terms of growth over these years were Latin America and the Middle East/North Africa, growing at about 2.5 per cent per year on average.

In Asia and the Pacific, about 40 per cent of the 4.5 billion population work in the agriculture sector in rural areas. Ironically, the most food-insecure communities are those living in rural areas with agriculture as their primary source of livelihood (FAO, 2017a). Based on the World Bank database, the agriculture sector's contribution to country GDP varies from 3 per cent up to 50 per cent (Figure 3.3). This shows the importance of investment in rural agriculture to reduce poverty and eradicate hunger.

Figure 3.3 Agriculture's contribution to GDP

Source: World Bank (n.d.): http://databank.worldbank.org/data/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country= Accessed 1 September 2017.

d. Foreign exchange

A country can boost economic growth and provide the capital formation for economic productivity through international trade. One of the challenges to international trade is fluctuation in the currency exchange rate between the trading countries. Rate changes will affect the competitiveness of the agricultural sector due to changes of production cost and prices, especially if many of the agricultural inputs are imported. Increased currency value of the producer country will make their agricultural product more expensive in the international market, while a declining currency will make their produce more competitive.

Community level

a. Source of income and employment

Poverty is still a big issue for Asia-Pacific countries; there are around 560 million people with an income of under USD 1.95 per day, 55 per cent of the total number of poor people globally. The number of poor people in the Pacific countries is about 26.6 per cent, South Asia is 16 per cent, South-East Asia is 17 per cent, Central and West Asia is about 9 per cent, and East Asia about 2 per cent (ADB, 2017). Most of them (76 per cent) live in rural areas and are highly dependent on agriculture-based livelihoods.

Figure 3.4 A group of women in Lao PDR employed in sorting the corn harvest

Agriculture employs rural people on a large scale (e.g. Figure 3.4), but does not always play a successful role in rural poverty alleviation. A study conducted by IFAD (2016) showed income from non agriculture employment have grown speedly and in some countries it has larger share compare to agricultural income. Despite that, agriculture indirectly contributes to rural economic growth through its linkages with other sectors.

b. Maintaining social infrastructure in rural community

Social infrastructure is defined as "a relation linkage and causality between facilities, places, spaces, programs, projects, services and networks that maintain and improve community's standard of living and quality of life" (Perrine, 2013). Transformation of rural people is not only about reducing poverty in the short term but also about how to integrate social development, technology and policy in a sustainable development concept. For most countries in Asia and the Pacific, agriculture is a part of their social identity including a social structure in the community.

Public investment in the social infrastructure in agriculture-based countries not only increases agricultural productivity but also reduces poverty. The importance of social infrastructure cannot be neglected, as proven by a study in Punjab India (Nadeem *et al.*, 2011). Rural primary education increased productivity by improving the technical efficiency of the farming community. In addition, the proper availability of health facilities at village level provided a sense of mental satisfaction, reduced health expenses and saved farmers' time in maintaining their health.

3.3 Importance of resilience in agriculture

Controlling the occurrence of natural disasters is nearly impossible. Therefore, the agriculture system should be managed to make it resilient by enhancing its adaptive capacity and reducing vulnerability. Resilience in agriculture can be loosely defined as the ability of farmers and agriculture systems to absorb and recover from various shocks and stresses to regain their agricultural productivity and livelihoods. During and after disasters, agriculture plays a critical role in ensuring that affected people have access to food and livelihoods. It also has a role in building resilience over time.

It is commonly recognized that disaster prevention and disaster risk mitigation are more advantegous than managing the damage after a disaster. Resilience agriculture contributes to food security in maintaining food supply and maintaining the economic stability of a country, especially for agrarian countries. In addition, Godschalk *et al*. (2009) revealed that 1 dollar spent on disaster risk reduction is about equal to 4 dollars returned from cost damage or losses. A recent study by FAO (2017b) demonstrates that the adoption of good DRR practices could create agricultural resilience and bring an additional socioeconomic benefit 2.5 times higher than usual practices in hazard conditions.

4 Disaster Risk Reduction in Agriculture

Disaster risk is a key obstacle to poverty reduction, food security and sustainable livelihoods. Therefore, it is crucial to integrate disaster risk reduction (DRR) into agricultural and rural development plans and vice versa. The aim of DRR in agriculture is to prevent the occurrence of disasters, minimizing the risks and providing support after disasters have occured. Prevention and mitigation measures are adopted before disasters occur. Prevention involves stopping the event from happening, for example, eradicating pests. Mitigation attempts to limit the risk, for example by growing pest-resistant varieties or diversifying crops for a certain period of time. A coping strategy is how the agricultural system (households and infrastructure) adapt to the post-disaster situation, for example, by starting to farm with commodities that suit to the conditions and available resurces. Disaster risk management (DRM) in agriculture will be discussed further in sections 5.2 and 5.3.

4.1 DRR framework for agriculture

A DRR framework describes how the whole community can work together to prevent and mitigate disaster risks through the implementation of an integrated, exclusive policy that prevents or reduces hazard exposure and vulnerability to disasters, increases preparedness for response and recovery, and enhances capacity. In line with the Sendai Framework for Disaster Risk Reduction, the following framework of five stages is considered:

1. Institutional and frameworks development
2. DRM strategy setting and DRR planning
3. Information and early warning
4. Prevention and mitigation
5. Response and recovery

Each of these steps is described as follows:

1. Institutional and frameworks development

This stage addresses the institutional arrangements needed to establish an overall strategy for managing disaster risks in the given administrative areas, often at the national scale. The framework could include, inter alia, the definition of legal positioning of DRR actions at different levels in overall national development planning and governance, the demarcation of responsibilities of relevant organizations with a central coordination body, identification of relevant stakeholders and modalities for their participation and partnerships, and mobilization of necessary resources. This contributes to the achievement of robust economic and social development at a national scale, and the consistency and long-term sustainability of the ecosystems.

2. DRM strategy setting and DRR planning

Within the overall institutional framework, a sectoral DRR plan should be developed for agriculture, to ensure that DRR in agriculture is an integral component of national development planning, with clear objectives, priority actions and targets. The implementation plans should take into account local conditions. In addition, strategy and planning information would be a helpful tool for all concerned parties in evaluating the actions and lessons learned in post-disaster situations.

3. Information and early warning

The aim of an information and early warning framework is to improve capacity in collecting hazard information through the production of climate forecasts, vulnerability risk assessments, and disseminating and interpreting early warnings to increase awareness before disasters occur. Understanding the risks makes it possible to develop strategies and plans to manage them. These measures are expected to improve the preparedness of agriculture for natural disasters and climate change. The framework will also be a reference for parties in developing early warning systems, especially researchers who have hazard information to be disseminated.

4. Prevention and mitigation

The cornerstone of the DRR framework for agriculture is the implementation of prevention and mitigation strategies. This requires studies to produce crop varieties that are resistant to environmental stress resulting from natural disasters and climate change, and sustainable agriculture practices, including soil, water, pest and plant management. The DRR agriculture framework, in addition to providing guidance on the planning and implementation of mitigation prevention, also gives guidance on budgeting and the 'who is doing what' in the national scope of the DRR system. An effective implementation of the DRR agriculture framework hinges on the inclusion and understanding of the whole community in implementing prevention and mitigation measures.

5. Response and recovery

In the emergency phase, the DRR agriculture framework leads to improved disaster response through national networks to rescue and save lives in imminent danger. The national response framework is expected to be built on scalable, flexible and adaptable concepts to align with the situation. The DRR agriculture recovery framework is a guide that enables effective recovery support to agriculture in disaster-impacted areas, including support on how best to recover, redevelop and revitalize agriculture-based livelihoods. It is expected that the response and recovery framework will provide guidance on core response and recovery principles, a coordinating structure that facilitates communication and collaboration among all stakeholders, and guidance for pre- and post-disaster recovery planning.

Box 4.1 Sendai Framework of disaster risk reduction in the context of resilience agriculture and SDGs *

Disaster risk reduction (DRR) and climate change adaptation are closely intertwined, and in agriculture, they should be addressed in an integrated way. Disasters impede sustainable development and must be prevented or mitigated to achieve the SDGs by 2030. The Sendai Framework priorities indicates a paradigm shift for agriculture - from reducing risk to managing risk for disaster prevention - and identifies the significance and extent of slow onset disasters, such as drought, and the impacts of climate variability and drought that year after year erode the livelihoods of smallholders.

The following is the Sendai Framework of disaster risk reduction and its priorities for agriculture based on the United Nations International Strategy for Disaster Reduction (UNISDR, 2016).

Priority 1: Understanding disaster risk in the agriculture sector with the following requirements

- Capacities for the multi-threat assessment of risks and vulnerabilities especially those related to weather and climate in the agriculture sector
- Information systems that gather, monitor and share, periodically, information on disaster risk for the agriculture sector

Priority 2: Strengthening risk governance in the agriculture sector with the following key activities

- National legal frameworks, policies, strategies and plans for DRR that include the different subsectors of the agriculture sector
- Participation of the agriculture sector in the governmental mechanisms for intersectoral coordination for DRR and resilience

Priority 3: Investment in DRR for the resilience of the agriculture sector

- Systematic planning of the use of natural resources and promotion of sustainable production systems in all government interventions in the agriculture sector
- Availability of formal mechanisms for risk retention and transfer (funds, insurance and social protection) adapted to the needs of the different types of smallholders

Priority 4: Response preparedness and 'build back better' in the agriculture sector

- Risk monitoring systems and multi-hazard early warning systems adapted to the different subsectors: agriculture, livestock, forestry, fisheries and food security
- Inclusion of risk prevention and mitigation aspects in programmes and plans for the rehabilitation of livelihoods and development, as well as for sustainable development programmes.

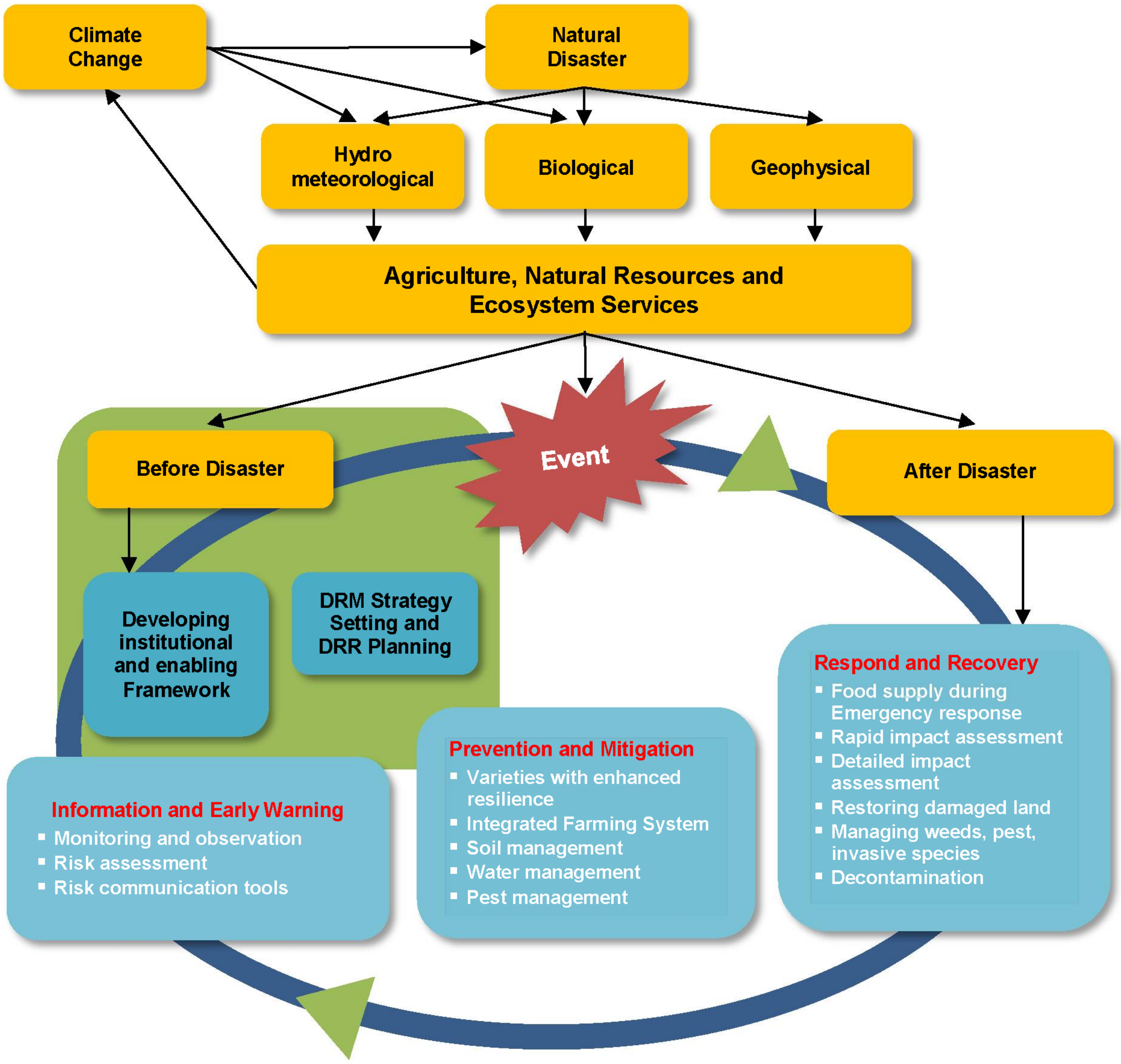
* Source: FAO (2017c).

4.2 Role of technological innovation

Agriculture is facing new and huge challenges, including population growth, increased disaster events, and the negative impacts of climate change and environmental degradation. Without technological innovation, agricultural productivity will continue to decline. Technological innovation enhances agricultural resilience to biotic and abiotic stresses, maintaining the stability of, and even boosting, agricultural production. The types of technological innovation that can be applied in disaster management include physical infrastructure, machinery, equipment, biotechnology and software covering knowledge and skills, crop varieties and farm practices, as illustrated in Figure 4.1.

The 2030 Agenda for Sustainable Development recognizes the importance of technology for the achievement of 17 goals of SDGs. About 14 out of 169 of SDG targets explicitly refer to 'technology' as the way to achieve the indicators, including agriculture sector targets. Technology is considered a critical means of implementation of sustainable development. In line with the DRR framework in agriculture presented in section 4.1, technological interventions may play a particularly significant role in information and early warning, prevention and mitigation, and response and recovery.

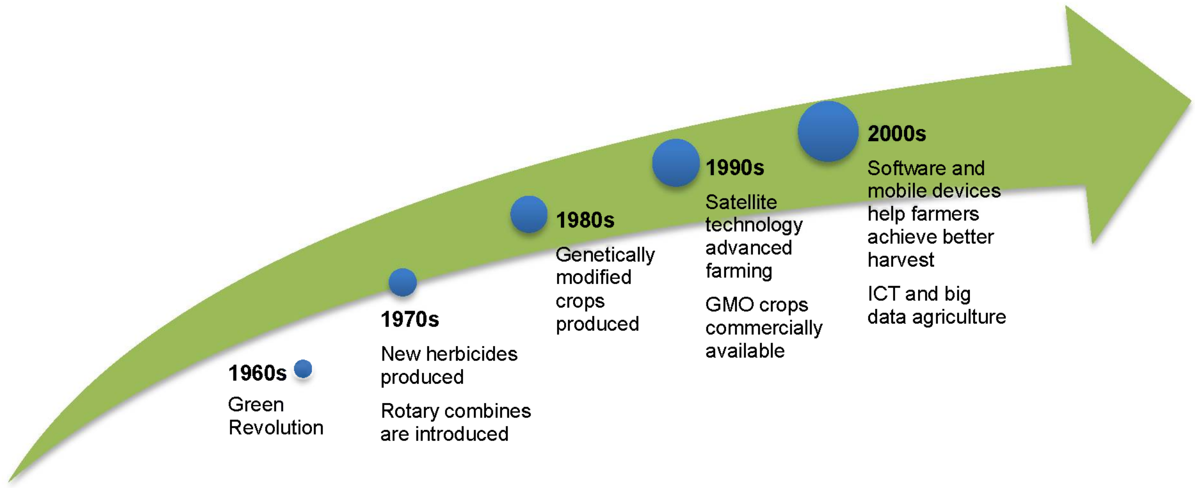
Figure 4.1 Innovation technology intervention on disaster management strategy



5 Areas of Technological Innovation

Agricultural technological innovation plays a significant role in ensuring crop production, food supply, food security and sustainable livelihoods during and after disasters. Technologies have allowed agriculture to be more efficient, resilient and environmentally friendly. Promising effects of implementation of technological innovation in agriculture are increasingly reported. The ongoing efforts of agricultural innovation technology are focusing on physical infrastructure, machinery and equipment, knowledge and skills, and biotechnology. Emerging technological innovation, driven by the biological revolution, the digital revolution, materials science and seasonal climate forecasting, has a role in promoting resilience agriculture through telecommunications, remote monitoring and plant genomics (Figure 5.1).

Figure 5.1 Development of technological innovation in agriculture



Documentation and dissemination of enhanced technological innovations are increasingly available from different sources. This is very positive, considering that each institution has its own advantages and a certain focus to contribute to resilient agriculture. The challenge is how to transfer the discoveries to the end-user and the smallholder farmer. This chapter presents an overview of the key innovations in three stages of DRM: information and early warning, prevention and mitigation, and response and recovery. A summary of the key innovations in these three stages is presented in Appendix 1.

5.1 Information and early warning

People engaged in agriculture need to be informed about impending disasters to ward off, counteract, prepare and cope with the threats that will affect their livelihoods. The potential use of an early warning system in agriculture varies depending on the type of natural hazard (rapid or slow onset disaster) and range of responses for all potential users. Access to early warning systems and information on multi-hazards is essential in DRR. Recent studies on impacts of early warning systems and related technologies show that systems could be rendered cost-effective and make agricultural investment more attractive (ESCAP, 2015). In addition, increasing the number of users of early warning systems could enhance the contribution of early warning to sustainable agriculture in Asia and the Pacific. Improved early warning systems provide a crucial opportunity to speed up rural development, even if a disaster does not occur.

a. Monitoring and observation

Monitoring and observation for early warning involves a risk assessment and hazards monitoring. The data is then presented as early warning information, which is a highly valuable resource and provides evidence to support country and development partners in formulating disaster risk reduction policies and action plans. Regarding food security, information collected covers availability of food supply, volume of demand, prices, distribution chain and other key indicators which can give early identification of disasters; for example, reduced crop growth caused by disease or slow crops growth in volcanic areas caused by hot clouds obscuring the sunlight. At country level, regular reporting on prevailing conditions and early warning of impending food crises can strengthen national capacities in managing food security. However, enabling decision makers at local to subnational levels, to benefit from early warning information may require investment in training, communication, tools and support staff, and might impact regional planning design.

Climatic condition are monitored by the relevant authorities using measurement tools and devices (Figure 5.2) to collect the daily base weather information, including air temperature, air humidity, air pressure, wind direction, wind speed, rainfall and solar irradiance. The weather information is further processed to predict climate anomalies and pest infestations that can threaten agriculture production.

Figure 5.2 Towering Climatology, a tower to put microclimate measurement devices at various above ground altitude (left). A hut to protect the outdoor climatology measurement devices (right)

Climate and weather are very difficult to modify, and even if this is possible, it is costly and requires advanced technology, thus predicting climate is a better option to maintain agricultural production stability. In addition, farmers should intensively monitor their crops from pests (Figure 5.3) and provide an early warning for neighbourhood farmers and the local authorities.

Figure 5.3 A farmer monitors rice crops from invasive apple snails in Bogor, Indonesia

Geographic information systems and remote sensing

Geographic information systems (GIS) can play a strategic role throughout the disaster management cycle, including prevention, preparedness, response and recovery. Information and early warning involves developing early warning systems, conducting vulnerability and risk assessments, stockpiling essential food, water and medicine supplies, and establishing evacuation routes. GIS may be used in this period to evaluate and categorize potential risks, developing evacuation plans and determining optimal routes for evacuation. In the near future, satellite technology could further enable farmers to see their farms from overhead, allowing for better tracking and planning.

A spatio-temporal analysis of agricultural drought risk can help determine the spatial distribution and temporal variation of drought risk within the region. It can therefore provide a theoretical basis for identification, prevention and mitigation of drought. Early warning systems through a combination of remote sensing, agrometeorological monitoring and seasonal climate predictions can provide a good indication of increased risk to calculate the best harvest time. The detailed function of technological innovation in early warning systems for agriculture can be seen in Table 5.1

Table 5.1 Innovation technology in early warning systems for agriculture

Type of technology	Function in early warning system
Climate forecasting and modelling	Expected to provide seasonal, decadal, regional climate predictions and also identify climate anomalies one or two seasons ahead, so that farmers can take preventative measures in selecting type of crop to be planted, completing repairs or adding irrigation
Flood warning system For example, a radar flood staff gauge with an electronic display board that sounds an alarm when the water reaches a critical level, and transmits the alarm to the emergency response agency	▪ Assesses water levels in a river or creek to allow the emergency response team to keep working with the systems they are familiar with ▪ To ensure an efficient response to flooding that offers maximum safety, and also allows some control through the opening or closing of irrigation water gates
Early warning system for earthquakes, volcanic eruptions and tsunamis ▪ Improved seismic surveillance networks ▪ Improved tsunami early warning and monitoring	▪ Helps scientists to alert emergency services to the risk of earthquakes, eruptions and tsunami ▪ GPS stations, which use satellite technology combined with the seismic sensors and other instruments can track exact measurements of any ground movement and weather conditions
Geographic information systems (GIS), satellite-based remote sensing and Crisis map (developed by Google)	▪ Provide basic maps, disaster maps and other geospatial information that can be accessed by public without any charge ▪ Predicts harvests halfway through the growing season to give early warning on food security before the end of the season; remote sensing and GIS applications have advanced hunger early warning system significantly ▪ Flood monitoring can be informed by remote sensing and mapping of information on soil types, water resources, settlements, cropped areas and forests ▪ Provides an early warning map from a collection of national- and regional-scale layers related to weather, hazards and emergency preparedness and response
Aerial and infrared photography using drones	▪ Seeing the crops from the air can reveal patterns that cannot be viewed at eye level; for example, irrigation problems, soil variation and even pest and fungal infestations ▪ The aerial camera can take multispectral images, capture data from the infrared and visual spectra that can be combined to create a cropped display that highlights the differences between healthy and depressed plants in a way that cannot be seen by the naked eye

Type of technology	Function in early warning system
ICT big data ▪ Open access food security database and analysis ▪ Online mapping tool Open Street Map. A real-time traffic map generated and made available to the public (including via Google) using data gathered from moving vehicle	Provides a simple and straightforward way to combine data from scientists, local governments and communities to provide insight into the likely impacts of future disaster events. The data may include: ▪ Main crops balance sheet for annual supply and utilization in all countries ▪ Database of food price monitoring and analysis ▪ The assessment of food supply and demand, market situation ▪ Tools at country level to enhance access to price data and strengthen national capacities to monitor price trends and contribute to improved policy decisions for food security ▪ Guidelines for making an evacuation path
Monitoring kits	To monitoring and tracking environmental conditions frop crop production i.e soil fertility, soil moisture, plant diseases, crop growth rate
Improved Risk Communication Tools ▪ Telephone ▪ Social media ▪ Television ▪ Radio ▪ Cellular phone	▪ Communicates warnings and coordinates preparation activities, particularly SMS alerts for disseminating mass warnings ▪ A social media application allows users to inform their network that they are in disaster area ▪ Traffic information can help in determining the evacuation routes ▪ GPS data from cellular phone to reproduce and analyze people flow during disasters

Drones

Figure 5.4 Drone helicopter used in Agri-ICT Project Republic of Korea for pest and diseases control and fertilizer spraying

Picture by EPIS Republic of Korea (2017)

The use of drones can help make farm management more precise. Drones are used to measure, observe and respond to variability found in crops (Figure 5.4). Agricultural drones have changed the frame of farming and cultivation systems over the past 3-5 years. A drone can equip farmers with detailed visual information and time series data to monitor weekly, daily or even hourly, according to requirements. Agriculture drones can provide detailed visual information of crop and farm damage due to disasters, and monitor crop progress and health condition. This information can be used as early information to avoid productivity failure.

Greenwood (2016) explains the benefit of visual information produced by drone: (1) Seeing the crops from the air can reveal patterns that expose irrigation problems, soil variations and even pests and fungal infestations that cannot be seen at eye level. (2) The aerial camera can take multispectral images, capture data from the infrared and visual spectra that can be combined to create a cropped display that highlights the differences between healthy and stressed plants in a way that cannot be seen by the naked eye. (3) The latest type of drone with physical modifications spray large areas of farmland with pesticides or fertilizers. The inventor claims that drone can cover an extraordinary distance quickly, 4,000-6,000 m^2 in just 10 minutes, which is 40-60 times more efficient than manual spraying (Chuchra, 2016).

Box 5.1 Link to insurance schemes

Agricultural insurance systems in Asia-Pacific countries are at differing levels of programme development and institutional mechanisms. In Indonesia and the Philippines, agriculture insurance is mostly managed by the government through public sector programmes and insurance premium subsidies. In Bangladesh, India and Nepal insurance is provided by non-formal private mutual and community-based organizations. In China and the Republic of Korea, insurance is managed by public-private partnerships, while in Australia and New Zealand, agriculture insurance is purely driven by private markets.

Another form of insurance financing schemes in Indonesia is through incentive provision. To maintain the stability of supply and prices in the market, the government provides incentives to onion farmers who grow crops in the rainy season, a season normally avoided.

In relation to disaster risk, crop insurance allows farmers to remain creditworthy, even in years of significant crop loss, and to avoid falling into the poverty trap. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific region (2011) explains the potential benefits from managing risk through agricultural risk transfer and insurance for individual farmers (micro-level insurance) and at government level (macro-level). These may include:

- protecting rural livelihoods and smoothing incomes during significant disasters, thereby reducing the potential for farmers to fall into the poverty trap
- protecting the productive capacity of rural enterprises and farm households
- protecting financial institutions against weather-related loan defaults
- financing disaster relief and encouraging structured social safety net policies

b. Risk assessment tools

An agricultural risk assessment is a necessary first step in designing effective risk reduction plan, as this is the basic information required to predict the occurrence of disasters, level of vulnerability and likelihood of exposure. Hence, we can prevent disasters, mitigate the impact, respond and efficiently cope with the consequences of the disaster. Hazard mapping, vulnerability and risk assessments are practical tools that have been developed and applied in many countries as the basis for planning appropriate DRR policies and practices.

Risk is determined by combining potential hazards with the conditions of vulnerability. Risk assessment is expected to provide information and recommendation or at least answer the following questions (World Bank, 2016):

- What are the major agricultural risks?
- What are the optimal solutions to manage the key risks?
- What are the gaps in current risk management strategies and plans?
- What is the action plan to strengthen resilience to shocks in agriculture?

Agriculture vulnerability risk assessments may also include social or economic dimensions; including livelihoods (Table 5.2). Hazard and risk maps can be developed at different spatial scales to display the risk distribution across geographical areas. They can be site specific based on administrative area or landscape based.

Table 5.2 Type of data collected for agriculture vulnerability and risk assessment

Vulnerability and risk assessment	Type of data
Exposure (the biophysical impacts of climate change on agroecological systems)	Biophysical indicators (soil characteristic, land topography, landscape)
	Air and climate (temperature, precipitation, wind, humidity)
	Agriculture productivity (type of crops, area and production)
	Water availability and storage, irrigation system
	Crop calendar, i.e. crop diversification or rotation
	Number of farmer with agriculture as the primary livelihood and non-primary livelihood
	Land use type surrounding agriculture area
	Demography of community surrounding agriculture area (including level of education)
Sensitivity (the degree to which a system is either adversely or beneficially affected by climate variability or change)	Agricultural system characteristics (agriculture input, technology, type of crops, irrigation system)
	Number of undernourished people in the agriculture area (for example at village level)
	Effect of climate change (drought and rainfall) on famine in the agriculture area (for example at village level)
	Natural resources and ecosystem services support the agriculture
	Post-harvest management and agriculture product distribution
Adaptive capacity (ability of institutions and individuals to avoid potential damage, to take advantage of opportunities, or to cope with the consequences of change)	Farmer alternative source of income (alternative livelihoods)
	Alternative seed supply and availability of resistant varieties
	Alternative food supply mechanism
	Crop insurance
	Access to information, agriculture input and fund
	Government Policy on climate change mitigation and adaptation
	Climate change mitigation and adaptation measures have been applied
	Transportation to access the agriculture area and
	Policy on protection to farmer and agriculture sector

c. Risk communication tools

Risk communication tools can be defined as a process of informing people about potential hazards that might affect them, affect property or the community. Risk communication is presented as a science-based approach to communicate in high-stress situations, high concern or controversy. From the risk practitioner manager's perspective, the purpose of risk communication is to help the community to understand hazard and its potential impact. From this, it will be easier for the community to understand and actively participate in the processes of vulnerability risk assessment and disaster risk management. Risk communication tools are written, verbal or visual statements containing information about risk in context, comparisons and advice about risk reduction measures. They encourage a dialogue between the information providers and the target audience.

Innovative technologies rely on real-time data from smartphones, drones and remote sensing to enhance their effectiveness and coverage. Some communication tools that can be used in early warning systems are mobile applications, television, social media, cellular phones and smartphones.

- **Website:** DRR website
- **Mobile applications:** group SMS and SMS broadcast

- **Television:** hotlines, news and television can send an early warning by running text for a geological disaster or by stopping the broadcast and replacing it with an early warning
- **Social media:** broadcast information using social media targeting users in the disaster-affected area

Cellular phones are changing the landscape for people all around the world. Through cellular phones, smallholder farmers can access information about the weather, commodity prices, production practices and digital soil maps. Nowadays, researchers use social media to publish data related to disasters. The policymakers can gain inputs from news that becomes viral in social media.

5.2 Prevention and mitigation

Disaster prevention and mitigation are defined as the measures designed and implemented to reduce the impact of disasters events. Agriculture-specific prevention and mitigation measures cover various activities including improvement of land use and management, water management and pest management, and the use of plants and crops which are resistant to extreme biotic and abiotic conditions during disaster events. Experiences of various types of disasters across the Asia-Pacific region have shown the need to invest in technological innovation for disaster prevention and mitigation in agriculture, particularly in the following mitigation practices.

a. Varieties with enhanced resilience

Biotic and abiotic stresses triggered by a natural disasters will affect crop productivity. Biotic stresses include plant diseases, harmful insects and weeds. Abiotic stresses include increasing temperature, decreasing water availability, increasing salinity and inundation, and low light intensity. The ability to respond to unpredictable environmental conditions requires advanced research and adoption of appropriate technologies. The principle of sustainable production and resource conservation will lead to the development of varieties with enhanced resilience to abiotic and biotic stress (Pandey *et al.*, 2017).

A simple example of enhanced resilience is how highland horticultural plants such as potatoes, carrots, broccoli and cabbage can now be grown on low land. Adaptation or shifting the landscape for highland crops also aims to mitigate landslide risk, as farmers are encouraged to plant woody crops on highland areas. However, the practices of growing vegetables on mountain slopes is still very common (Figure 5.5).

Figure 5.5 Planting vegetable crops in the highlands will increase vulnerability of landslides

Salinity-tolerant crops

Salt-affected soils or saline soils occur naturally in low-lying areas due to the accumulation of free salts in the soil profile. It is a typical problem of semi-arid and arid zones of the world. Almost 6 per cent of all land in the Asia-Pacific region is affected to some extent by salinity (Corbishley and Pearce, 2007). Munns (2013) argues that salts in the soil water may inhibit a plant's growth rate because: (1) salt in the soil solution will decrease the plant's ability to take up water; (2) if excessive amounts of salt enter the plant's transpiration stream, it will injure cells in the transpiring leaves. This is the salt-specific or ion-excess effect of salinity.

Biotechnological engineering is expected to increase crops ability to sustain growth and productivity in saline soils. Various biotechnologies can facilitate this by accelerating the discovery of genes and speeding up the delivery of crops with improved salt tolerance by using marker selection and genetic modification. Furthermore, Roy *et al.* (2014) revealed that various traits could be incorporated to improve crop salinity tolerance, including: (1) osmotic tolerance, with long-distance signals that reduce shoot growth, triggered by accumulation Na^+ in the shoot; (2) ion exclusion, where Na^+ and Cl^- transport processes in the roots reduce the accumulation of toxic concentrations of Na^+ and Cl^- within leaves; and (3) tissue tolerance, where high salt concentrations are found in the leaves but compartmentalized at the cellular and intracellular level (especially in the vacuole).

The saltbush *Atriplex amnicola* and a grass *Diplachne* (syn*. Leptochloa*) *fusca* or Kallar are well known in Australia and Asia. They provide graze on saline land, as they show outstanding salt tolerance with high growth rates (Ashraf *et al*., 2009). The three most important crops in the world, namely wheat, rice and maize, have different levels of salt tolerance. Rice is more salt-sensitive, while wheat is a more salt-tolerant crop species; maize falls in between these two species.

Drought-resistant crops

Bioengineering works to produce drought-resistant crops based on the principle of enhancing the leaf's natural ability to preserve water. Water loss from the plant by transpiration mostly occurs through leaf stomata; therefore, the plants need to protect themselves with a thicker layer of leaf wax. A recent study by Pornsiriwong *et al.* (2017) identified a new method which has helped some plants survive for 50 per cent longer in drought conditions, including essential crops such as barley, rice and wheat.

Pornsiriwong *et al.* (2017) mapped a new molecular signalling pathway that controls the plant's ability to close the stomata to conserve water during drought stress. The team also revelaed chloroplasts are the key players that work together with plant hormones during drought stress, chloroplasts in cells surrounding the stomata are able to detect drought stress and activate a chemical signal to close stomata to conserve the water. Boosting the chloroplast signal, by breeding, genetic or agronomic strategies could be key to helping plants preserve water and boosting drought tolerance. Boosting the levels of the chloroplast signal also restores tolerance in drought-sensitive plants and extends their drought survival by about 50 per cent.

Cold-tolerant crops

Cold temperatures are a primary abiotic pressure that negatively affects crop's morphological development and seed production. In rice's case, as it is originally from tropical regions, so it is more sensitive to cold stress than other grain crops, such as rye, wheat and barley that originated in temperate regions. At the rice nursery stage, cold temperatures cause poor germination, seed injury and poor seed establishment. While at the field stage, cold can disrupt reproductive stages and decrease the seed yield.

Rice plant damage due to cold stress at the reproductive stage is significantly higher compared to damage at the vegetative stage because cold temperatures affect microspore development of pollen grains in the anther, which is resulted in higher spikelet sterility. Ultimately, this reduces seed yield (Shakiba *et al.*, 2017).

Shakiba *et al*. (2017) found that reproductive stage-cold treatment at 15°C during the day and 10°C at night increases spikelet sterility up to 90 per cent and reduced grain quality. As a tropical species, the optimum temperature for rice germination and seedling growth ranges from 25°C to 30°C. Cold stress occurs when the temperature falls below 17°C (Andaya and Mackill, 2003). Shakiba *et al.* (2017) found that indica varieties are more sensitive to cold stress than japonica varieties.

Heat-tolerant crops

High temperatures, as result of global warming, are predicted to have an adverse effect on crop growth due to a harmful effect on the plant development cycle. The increasing threat of climatological extremes,including very high temperatures, might lead to catastrophic loss of crop productivity and result in widespread famine. There are differential effects of climate change both regarding the geographic location and the crops. The most extreme reductions in yield will likely be a result of normal and extreme fluctuations in temperature and global warming in general (Zandalinas *et al.*, 2018).

Scientists develop heat-tolerant crops by modifying physiological and biochemical processes of gene expression. These changes are expected to develop gradually and then lead to the development of heat tolerance by acclimation, or in the ideal case, by adaptation. Development of new crop cultivars tolerant of high temperatures is a significant challenge for the plant as it depends on the extremity and duration, as well as the plant type and other environmental factors. High-temperature stress has a wide range of effects on plants, affecting, for example, their physiology, biochemistry and gene regulation pathways. Therefore, strategies for improving heat-stress tolerance are still elusive (Hasanuzzaman *et al.*, 2013).

Plant resistance to pathogens

The incidence of many plant diseases has increased in the past 20 years, and continues to pose serious threats, categorized as emerging infectious diseases (EIDs). EIDs on crops caused by plant pathogens can develop into sudden and severe epidemics, owing to the influence of various characteristics of the pathogen, host and environment (Vurro *et al.*, 2010). For example, red stripe disease in rice was first found in Indonesia in 1987 and has spread all over South-East Asia. Since its first reported appearance, the disease has spread to Malaysia, Viet Nam, the Philippines and Thailand (FFTC, 2012). Red stripe attacks the rice leaves and flowering phase, disrupting the maturation process of the grain (IRRI, 2001). At an expert meeting, FFCC identified the diseases categorized as EIDs in the Asia region. These include:

- EIDs of rice crops: southern rice black-streaked dwarf virus, rice red stripe diseases
- EIDs of fruit and cash crops: citrus greening, banana moko, cassava bacterial blight, plum pox virus
- EIDs of vegetable crops: tomato yellow leaf virus, bacterial fruit blotch pathogen

The aim of developing plant resistance to pathogens is to reduce the use of pesticides, taking into account ecological, economic and human health priorities, and to prevent the emergence of new diseases. It also contributes to modifying cultural practices to adopt to a changing global climate and to save phytogenetic resources from the degradation of natural ecosystems (Das *et al.*, 2014).

Crops have a natural capacity to resist abiotic stress. Magnifying such capacity is essential to achieving sustainable agriculture. The development of plants that are resistant to pathogens has been practiced in agriculture through increased variant selection, occurring either spontaneously or among crossbreeds, selective breeding or through genetic mutations.

Genetically engineered varieties that are resistant to specific pathogens, include varieties that are: (1) resistant to pathogen vector carriers, i.e. varieties resistant to green leafhoppers as transmitters (vector) pathogens; and (2) resistant to the pathogen itself including viruses, bacteria, fungi, nematodes and phytoplasma. The genetic improvement of plant crops by selective breeding is cost-effective and easy to adopt, since the grower only need to use appropriate seeds or other planting material (Evenson and Gollin, 2003).

Figure 5.6 Green leafhopper, the tungro vector, and rice infected by tungro virus

Photos by IRRI (2017)

Tungro-resistant rice is a widely used pathogen-resistant varieties, as tungro is one of the most damaging and destructive diseases of rice in South and South-East Asia. (Figure 5.6). Currently, through genetic engineering, tungro-resistant varieties are available in the Philippines, Malaysia, Indonesia, India and Bangladesh (IRRI, 2017). The development of such varieties was initiated through an IRRI programme in the 1960s and subsequently elaborated by each country. In 1998, IRRI developed varieties resistant to the tungro vector (leafhopper) and the tungro virus. These varieties were tested in several locations in India, Indonesia and the Philippines. In addition, in 2008, India developed tungro-resistant rice by using RNA interference (Tyagi *et al.*, 2008); and, since 2002, Indonesia routinely selects tungro-resistant strains and has successfully developed new site-specific varieties by using the basic population of the IRRI's introduction line. It has also managed to produce varieties resistant both to tungro and rice blast diseases (Indonesian Ministry of Agriculture, 2016).

Early maturity short-cycle varieties

Early maturity, short-cycle varieties fill space and production gaps in the agriculture system. During the dry season, the quick-maturing crops can be planted later and still mature before the end of the season. Short-cycle varieties allow the farmer to harvest the crops and avoid water stressing the plants. For example, vegetables, can be planted early in the season and be replaced later by drought-tolerant crops (Zandalinas, 2018).

b. Farming practices for enhanced resilience

Globally, natural disasters, especially climate-related disasters, are increasing. The climatic conditions are increasingly varied, and the magnitude of their effects is stronger. The climate change brings new uncertainties, risks and changes to existing risks. One of the most efficient ways for agriculture to adapt to natural disasters and climate change is to increase its resilience.

Enhanced resilience agriculture can be achieved by implementing prevention and mitigation efforts in agricultural practices, addressing potential hazards to promote agriculture production systems that meet the demand for food required by growing world population. Enhanced resilience agriculture also contributes to maintaining the stability of the farming economy by sustaining their livelihood sources while maintaining their ability to operate and produce goods.

Integrated farming system

An integrated farming system (IFS) combines crops and livestock, where the by-product of one component can be used for another component. Jayanthi *et al.* (2000) simply describes "the IFS as a mixed animal crop system where the animal component is often raised on agricultural waste products while the animal is used to cultivate the soil and provide manure to be used as fertilizer and fuel".

IFS contributes to adaptation to climatic change because culturing crops and livestock at the same time gives farmers a range of income options when facing uncertain weather conditions associated with increased climate variability. For smallholder farmers, livestock is a walking bank of assets that can be sold during periods of need if crops fail (Clements *et al.*, 2011). IFS also contributes to food security and income generation for the rural poor. Furthermore, it contributes to environmental and agricultural sustainability, and ecosystem services, because the farm can recycle all wastes: one's trash is needed as another's food.

Applying IFS will allow farmers to grow fodder for livestock and poultry. For rice farming, the IFS usually implemented is the rice-fish culture between rice and tilapia or goldfish. Farmers can harvest these two commodities, and fish may help reduce populations of existing and emerging diseases vectors, such as mosquitoes (Clements *et al.,* 2011).

Crop diversification and rotation

Studies have revealed that diversification has a significant role in the resilience of agricultural systems (Lin, 2011). Typically, diversification has meant growing new types of crops or raising new types of livestock. Crop diversification (Figure 5.7) aims to increase the crop portfolio so that farmers are not dependent on a single crop to meet daily life needs and generate income. When farmers only cultivate one crop type, they are exposed to high risks in the event of unforeseen climate events that could severely impact agricultural production, such as the emergence of pests and the sudden onset disaster and drought.

Figure 5.7 A small-scale farmer growing four type of crops at the same time, cucumber, long bean and corn, while rice is the main crop

In theory, the more options available within agricultural value chains, the more this will contribute to agricultural resilience; although, in practice, there are likely optimal levels and combinations of agricultural and livelihood diversification that allow value chains to maintain their function throughout disasters. With diversification, the farmer will increase the chances of dealing with the uncertainty and changes created by climate change. The crops will respond to climate scenarios in different ways, the cold may affect one crop negatively, but production of an alternative crop may increase.

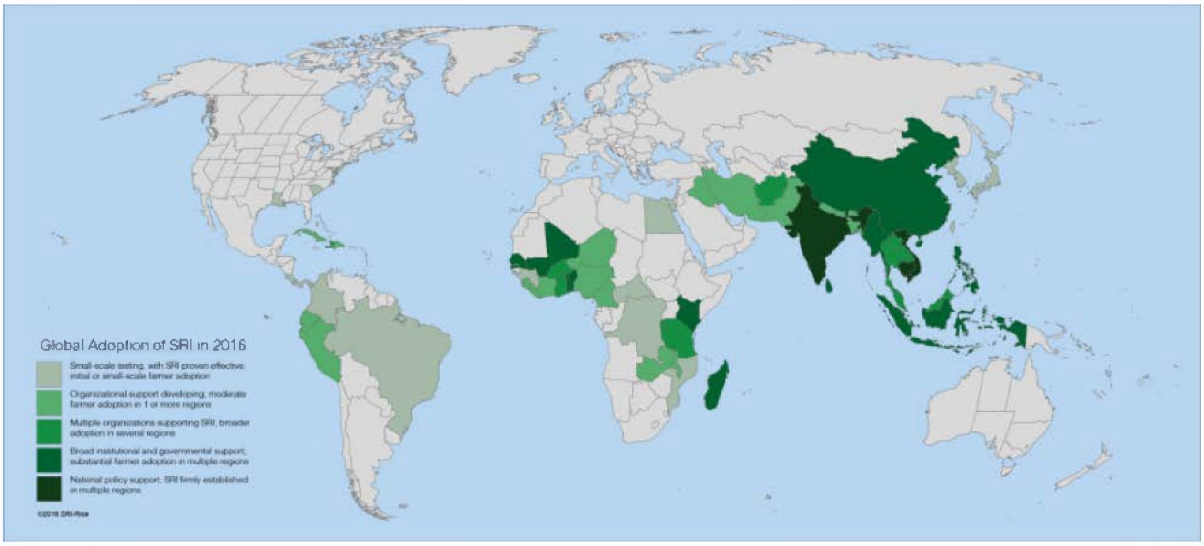
In the rotation, farmers change crops and cultivars, and also modify crop management, for example, by changing the sowing date according to the expected seasonal weather. The seasonal precipitation pattern (onset of rain, duration of the rainy season and distribution during the crop-growing period) is one of the most critical pieces of information for farmers in semi-arid regions using rain-fed cropping, especially for low-input systems in developing countries. This enables them to adapt their sowing dates and crop selection. Matthews *et al.* (1997) reported that for rice production in Asia, the modification of sowing dates at high latitudes, when the temperatures are higher allowed an extended crop-growing season. Permitted a transition from single cropping to double cropping in some locations, could have a significant effect on regional production. Two shorter ripening varieties might be a better strategy than a longer maturing variety because the grain formation and ripening periods are pushed to less favourable conditions later in the season with the longer maturing variety.

Box 5.2 Practices of system of rice intensification (SRI)

The system of rice intensification (SRI) is a technique of rice cultivation that can increase the productivity of irrigated rice by changing the management of plants, soil, water and nutrients (SRI International Network and Resources Center, 2015). The basic concepts of SRI are: (1) planting one very young (8-12 days) plant per hill with loose spacing (25 cm × 25 cm); and (2) disjointed water supply without inundation of the rice field, intermittent irrigation.

The benefits of SRI have been realized in over 50 countries (Figure 5.8) showing an increase in yield of 20-100 per cent, an up to 90 per cent reduction in required seed, and up to 50 per cent water savings. Furthermore, the SRI method has been applied to rain-fed rice and other crops, such as wheat, sugar cane, teff, finger millet and pulses. The results show that the productivity was increased compared to current conventional planting practices. When SRI principles are applied to non-rice crops, it is referred to as a system of crop intensification or SCI (SRI International Network and Resources Center, 2015).

Figure 5.8 Global adoption of SRI in 2016



Source: http://sri.cals.cornell.edu/images/global/SRI_World_Map_2016.png
Accessed 20 September 2017.

A report in October 2017 stated that SRI implementation in Nepal showed that an SRI duplication programme has been generating yields that often doubled, faster harvest, clean water and reduced harvest losses. In addition, once farmers gained experience and skills, SRI was more efficient and less labour intensive. Storing labour and seeds, water and production costs makes SRI even more attractive to farmers. SRI farmers get a 30 per cent higher average yield than farmers using standard practices, with some as high as 62 per cent higher (System of Rice Intensification (SRI) in Nepal, 2017).

c. Practices for improved water efficiency

The Intergovernmental Panel on Climate Change (IPCC) Working Group II predicts that changes in rainfall patterns will contribute to severe freshwater shortages, intensifying flood and drought in some areas (IPCC, 2007). Technology that supports water-efficient practices is important to address potential conditions of natural disasters triggered by climate change.

Water-efficient practices offer a potential gain in net revenue, while also reducing environmental burdens by saving water. Furthermore, enhancing water availability through improved water-efficient technologies for sustainable water use and management is one of key strategies for increasing agricultural productivity and securing food security.

Improving restricted rainfall infiltration

This aims to develop sufficient porosity in the surface soil to allow rainfall to infiltrate and be absorbed. If the surface soil porosity is too low to absorb rainfall or the subsoil porosity is too low to allow rainwater percolation, infiltration will be inadequate, and rainwater will be lost as run-off.

The surface soil porosity may be reduced by pores clogging with particles detached from the soil by the impact of raindrops, or by the deposition of detached particles on the soil surface as impermeable crusts or seals (Shaxson *et al.*, 2003). Naturally, the subsurface porosity is low or may have been reduced by compaction and tillage practices. The degree to which tillage reduces soil porosity is frequently sufficient to restrict root penetration.

Increasing infiltration and reduce run-off by surface residue covers

The benefit of a residue cover is most apparent in soil condition. However, run-off can sometimes occur despite good soil cover (Shaxson *et al.*, 2003). For example, run-off will occur when rainfall intensity is higher than soil infiltration rate, or when the soil pore spaces are already filled with water because the soil is shallow. Thus, water-holding capacity is low, and the subsoil is only slowly permeable.

The cover material depends on what is locally available; the residue covers may include crop residues left in the field after harvesting, leaves and branches lopped from trees growing around the cropping area, or mulches of grasses, shrubs, weeds, litter, husks and other organic waste materials. The following materials may be used as mulches: grasses, sedges, banana leaves and shrubs, forest litter and tree loppings, weeds, rotten thatch and coffee husks. Mulching is most often practised on horticultural crops that produce negligible residues (foliage), are entirely harvested for their foliage or that are completely harvested (e.g. tubers and foliage) (Shaxson *et al.*, 2003).

Improved irrigation

Drought results from the natural reduction in amount of precipitation over an extended period, usually for a season or more. It is often associated with other climatic factors (such as high temperatures, high winds and low relative humidity) that can exacerbate the severity of the event. Drought is not a purely physical phenomenon, but instead is an interplay between natural water availability and human demands for water supply. There are three types of drought (Wilhite and Glantz, 1985):

- Meteorological drought is a prolonged period of below average precipitation.
- Agricultural drought is insufficient moisture for average crop or range production. This condition can arise even with average precipitation, due to soil conditions or agricultural techniques.
- Hydrologic drought is when the water reserves available in sources such as aquifers, lakes and reservoirs fall below the statistical average. This condition can emerge, even at average or above average precipitation, when increased usage of water diminishes the reserves.

When prolonged natural disasters such as droughts occur, the high temperatures and low precipitation in arid area leads to poor organic matter production and rapid oxidation. Low organic matter leads to reduced soil aggregation and low aggregate stability leads to a high potential for wind and water erosion.

Increasing water demand versus water supply results in unsustainable water use and competition for water resources in agriculture. This trend has serious implications for sustainable agricultural development, especially in developing countries. Proper management of water resources by applying appropriate farm technologies plays a significant role in developed and developing countries in regions with limited resources for agricultural production, including improved irrigation as follows:

- **Solar irrigation pumps:** In rural areas where access to an electricity grid is not always guaranteed, farmers may not be able to rely on the traditional irrigation system of using tools powered by fossil fuels. The fiscal burden on public budgets of energy inputs is high, since in many developing countries, electricity or fuels, such as diesel or petrol, are subsidized. Solar irrigation pumps offer a solution. Pumps used for the transport of water are equipped with solar cells, and solar energy is absorbed by the cells and converted into electrical power via a generator, which then operates an electric motor that drives the pump (Kishore *et al.*, 2014).

- **Variable-speed pumps:** The water flow rate and pressure of variable-speed pumps can be adjusted depending on the needs of the crop. Farmers can customize the way the pump operates, allowing it to run at a lower speed depending on demand by changing the pump's rate of rotation. This can provide substantial energy savings as the speed of the motor is reduced (United States Department of Agriculture, 2010).

- **Drip irrigation:** Water is dripped slowly directly onto the roots of plants through a network of valves, pipes and tubes, also known as drip line or drip tape. Small holes called emitters are usually spaced every 20-60 cm along the length of the drip line, pressure forces the water out from the emitters drop by drop. The water is dripped onto the soil surface or directly onto the root zone. The drip line is usually installed in the soil between alternate crop rows. Therefore, the system only wets a fraction of the soil volume and leaves space in the land to store water from rainfall (Stryker, 1997). Enhanced drip irrigation systems are more water-efficient than surface irrigation because they can minimize evaporation:

  ***Subsurface drip irrigation (SDI)*:** Another name for this is buried irrigation. Water is applied directly to the crop's root zone through buried polyethylene tubing. Through this method, the soil surface will stay dry, thereby avoiding surface run-off and soil erosion. This prevents the plant from becoming waterlogged and consequentially becoming more susceptible to infections. An SDI system can deliver water with an efficiency of 95 per cent or higher. This method is especially appropriate for dry and windy locations.

  Deficit drip irrigation: Water supplies are managed based on the growth stages of the crops. Irrigation is applied during the drought-sensitive growth stages of the crops. Beyond that period, the provision of the water supply is very limited or even stopped if rainfall is sufficient to irrigate crops and during the vegetative stages and the late ripening period. This process increases water-use efficiency (ratio of water used in plant metabolism to water lost by plant via transpiration) and water productivity (crop yield per cubic metre of water consumption). However, this may lower the yield and also reduce the quality of some types of crops.

  Sprinkler irrigation: This applies irrigation water in a manner similar to rainfall. Water is distributed through a system of pipes, usually by pumping. It is then sprayed into the air and irrigates the entire soil surface through spray heads, which break it up into small water drops that fall to the ground. Sprinkler irrigation efficiently covers small to large areas and is suitable for use on all types of farm. It is also adaptable to nearly all irrigable soils since sprinklers are available in a wide range of discharge capacities (Brouwer *et al.*, 1990).

d. Improved soil management

Soil management in the context of DRR can be interpreted as an effort to maintain or improve the resilience and quality of agricultural land. Thus, it can support crop productivity, protect and conserve soil resources and reduce the release of greenhouse gases. This chapter will discuss how improvements in soil management contribute to reducing the risk of land damage due to landslides, floods and or run-off.

Slow-forming terraces

A terrace is a levelled surface that is used in farming to cultivate sloping, hilly or mountainous terrain. Terracing can be used on relatively flat land where soil and climate conditions are conducive to erosion. A wide range of crops, such as rice, potatoes, maize, olive trees and vineyards, can be grown on terraced fields. Clements et al. (2011) outlined the functions of slow-forming terraces:

- improve the natural conditions for agricultural production
- decrease the rate of erosion
- increase soil moisture
- generate positive environmental benefits

Conservation tillage

Conservation tillage refers to growing a crop in a previous crop's residues, purposely left on the soil surface. Conservation tillage practices leave about one-third of crop residue on the soil surface in order to slow water movement, which reduces the amount of soil erosion. Conservation tillage is suitable for a range of crops, including grains, vegetables, root crops, sugar cane, cassava, fruit and vines (Clements *et al.*, 2011). Figure 5.9 shows example of conservation tillage where taro is grown on previous crop residue.

Figure 5.9 Taro grown on previous crop residue

Strip cropping

Strip cropping is used to avoid erosion and is effective in certain soils and topography (Arya *et al.*, 2015). The strip crops check the surface run-off and force them to infiltrate into the ground, thereby facilitating the conservation of rainwater. Studies have found that strip cropping is about twice as effective for conserving the rainwater than contouring (Carman, 2016). The hydrological principles of strip cropping are to control soil erosion caused by run-off. Two factors contribute to its effectiveness:

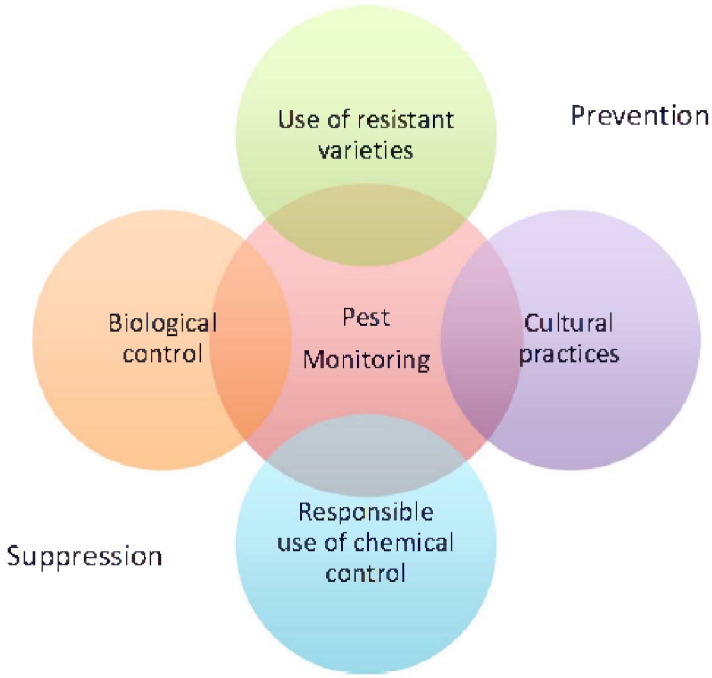
- reducing the run-off flowing through the close-growing sod strips
- increasing soil infiltration rate undercover conditions

e. Integrated pest management

According to FAO (2015b), integrated pest management (IPM) is an ecosystem approach to crop protection and production that combines different management strategies and practices. The approach combines biological control, crop management practices and limited chemical control. The aim of IPM is not necessarily to eliminate all pests but to reduce pest populations to levels where they cannot cause significant loss.

The use of resistant varieties can add value to the IPM system (Figure 5.10); for example, using resistant varieties along with cultural practices, such as field sanitary and crop rotation measures to prevent pest infestation. Resistant varieties may also eliminate pest development in combination with biological control. The use of resistant varieties will contribute to the effectiveness of pest management efforts along with the combination of biological control, farm management practices and chemical control. Effective pest monitoring is essential to minimize the use of chemical control (Maharijaya and Vosman, 2015).

Figure 5.10 The position of resistant varieties in IPM



Source: Maharijaya and Vosman (2015).

IPM makes a key contribution to addressing the challenge of food insecurity and meeting the growing consumer demand for safe food in the Asia-Pacific region. Enhanced biological control through IPM uses beneficial organisms, such as parasitoids and predators. The practices include:

- releasing beneficial insects and providing them with a suitable habitat
- managing plant density and structure to deter diseases
- cultivating weed control based on knowledge of critical competition periods
- managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests

Constraints in implementation of IPM

Koul *et al.* (2004) have grouped the obstacles to implementation of IPM in developing countries as follows:

- **Institutional constraints:** IPM requires an interdisciplinary, multifunction approach. Top down research does not match farmers' needs in the field and farmers feel uninvolved, so in many cases, farmers refuse to apply the methods recommended by researchers.

- **Information constraints:** Lack of IPM information, training, IPM modules, support from experienced IPM teachers, and field-level extension workers not trained on IPM to embed confidence in farmers.

- **Sociological constraints:** The desire of the farmer to solve the pest problem with immediate and high confidence about the effectiveness of chemical pest repellent, as well as promotions of chemical pest products accompanied by the provision of extension agents to promote it.

- **Economic constraints:** Funding for research, extension and training on IPM for extension and farmers is often inadequate.

5.3 Response and recovery

Initial disaster relief, such as search and rescue, urgent medical help and others, is conducted to save lives in imminent danger and to mitigate damage to agricultural production. Emergency relief needs to be relatively quick, but it may be required for an extended period, depending on the level of exposure, disaster magnitude and socioeconomic, as well as environmental, and adaptive capacity. An impact assessment on agriculture is usually begun during the emergency relief period as part of the disaster impact assessment.

a. Impact assessment

A rapid disaster impact assessment in agriculture sector is intended to investigate what is damaged and the extent of the damage, therefore the nominal loss can be predicted and the rehabilitation measures selected. The type of data collected includes anything that is affected, such as number of farm households affected, infrastructure, buildings, agricultural machinery, crops and the extent of the damage.

Aerial photography generated through drone technology and satellite images provides opportunities for the rapid impact assessment to be done easily, quickly and accurately. Drones can map in detail and produce a photo of current damage. A combination of aerial photos and satellite imagery provides information on the damaged area more detail and accurate. Nominal losses can be calculated by stocktaking damage to farming equipment and warehouses, irrigation systems and other agricultural infrastructure, while, the number of affected farming households should be recorded directly from the location. The village head or agricultural extension officer should directly record the number of farming households affected by a disaster.

b. Response options and recovery

The response to a natural disaster should be in line with the appropriate risk reduction strategies in place. Rebuilding agriculture and rural livelihoods as quickly as possible supports early recovery when the post-disaster coping capacity of communities is exceeded. Rapid impact assessment as an early response action followed by a livelihood assessment approach will significantly support effective recovery after a severe natural disaster.

Providing essential production input for farmers to revitalize their farms is a critical part of post-disaster intervention strategy. From experience in Asia and the Pacific, post-disaster should also rebuild social and market support for agriculture products, including policy support. Increasing the ability of government or third parties to conduct a rapid assessment to evaluate access to agricultural inputs and market functionality will ensure an efficient intervention to recover local agricultural production support, input supply and marketing structures.

Based on impact assessment results, recovery of infrastructure and human resource preparedness will follow, as an initial step to restarting farming activity. Agricultural land restoration efforts may include restoring damaged land, managing weeds, controlling pests and managing invasive species. However, natural succession is the most promoted method for land restoration (Conant and Fadem, 2008).

Natural succession

In some cases, the best way to restore farmland is to leave it for a certain time to let natural succession take its course, but this process can take many years. Some support might be needed during natural succession to help land recover; for example, building fences or putting up a sign asking people to stay away from the area and reducing number of livestock grazing the land.

Natural succession is an indicator that the land is not so degraded or heavily contaminated that nothing can grow. During this period, several types of pioneer plants will grow, such as spiny shrub vegetation, hydric herbaceous and shrub vegetation. Abiotic ecological variables, such as slope, surface stoniness, canopy opening, soil pH, land-use history and age of abandoned farmlands are major factors that influence the succession process.

Ecological restoration

Ecological restoration of farmland includes the process of cleaning up and rehabilitating the site. Restoration involves setting up reliable water provisioning (e.g. by digging wells or laying long-distance water pipes) and stabilizing and fixing the soil, which can be done in several stages.

The first stage of ecological restoration of farmland is fixing the soil to prevent dune movement. This first step involves planting grasses and plants to provide wind protection, such as shelterbelts, windbreaks and woodlots, around the farm or planting area. The next step involves improving/enriching the soil by growing nitrogen-fixing plants, such as clover and beans. Possible management alternatives, such as reforestation, are considered in order to integrate those new environments to the modern agricultural landscape.

Managing weeds, pest animals and invasive species

Pests, such as insects, mites, weeds and plant diseases, can be controlled by using other organisms, through predation, parasitism, herbivory or other natural mechanisms. This typically also involves an active human management role.

The basic types of biological pest control strategies are:

- classical biological control, such as introduction of the pest's natural enemy
- augmentation, locally occurring natural enemies are bred and released to improve control
- conservation, natural enemies are increased, such as by planting nectar-producing crop plants in the borders of rice fields

Classical biological control can impact biodiversity by attacking non-target species, especially when a species is introduced without a thorough understanding of the possible consequences. A detailed explanation of IPM is given in 5.2e.

Decontamination (salinity, chemicals, radioactivity)

Soil salinity control is defined as controlling the problem of soil salinity and reclaiming salinized agricultural land to prevent soil degradation by salinization and reclaim already salty (saline) soils. Salinization might be caused by inundation of farmland by seawater due to high waves and storm surges, or intrusion of seawater into freshwater irrigation channels. Salinization also might happen in nearshore farming areas that use groundwater for farming practices. The vacuum of the groundwater source (aquifer) allows seawater to seep in to fill in the void of the water mass, then the saline water enters the farmland through the irrigation system.

Amelioration

Amelioration is process of conditioning the physical and chemical components of farmland to improve soil fertility. Ameliorant materials such as organic fertilizer, mineral soil, zeolite, dolomite, natural phosphate, manure, agricultural lime, ash husks and water chestnut (*Eleocharis dulcis*) can increase soil pH, and soil bases can also reduce the adverse effects of toxic organic acids.

Agricultural efficiency depends on the quality of soils as the primary source of agricultural productivity. Land improvement (amelioration) becomes the most critical component of farming. Amelioration is different from the usual annual agricultural practices, such as ploughing and harrowing. Amelioration effects are long lasting. Thus, amelioration can be defined as a system of measures for radical improvement of unfavourable hydrologic, soil and agroclimatic conditions, for the most efficient use of land resources (Maslov, 2009).

In terms of land productivity, amelioration can bring poor and unused land (swamps, wastelands, anthropogenically degraded lands) into agricultural production. Amelioration can improve the sanitary state of soil and the environment and, hence, it can raise the living standards and quality of life for people (Maslov, 2009).

Drainage

Drainage is the primary method of controlling soil salinity. The drainage system should pass a small fraction of irrigation water or about 10 to 20 per cent of the drainage or leaching fraction to be drained and discharged out of the irrigation (Moqsud and Omine, 2011).

Furthermore, in stable salinity irrigated areas, the salt concentration of drainage water is usually 5-10 times higher than the irrigation water (Moqsud and Omine, 2011). Salt export matches salt import, and salt will not accumulate. The drainage system is designed to remove saline water and to lower the water table. The highest acceptable level of the water table or the shallowest permissible depth depends on irrigation, agricultural practices and type of crops.

Soil washing

Contaminated soil is left after a natural disaster, such as after a tsunami where agricultural land that is close to the sea is inundated with salt water or when flash floods carry sewage, mine waste and debris from nearby industries. Most of the contaminants tend to bind to clay, silt and organic soil particles, and silt and clay stick to larger particles, such as sand and gravel.

Soil washing is one technique to remove contaminant in the soil, especially heavy metals through concentrating the contaminant by chemical or physical separation or a combination of the two. Soil is washed by dissolving or suspending contaminants in the wash solution combined with a physical separation technique. Washing separates the small particles from the large particles by breaking adhesive bonds (CPEO, 1995).

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6 Emerging Highlights

Studies have demonstrated investments in mainstreaming DRR in agriculture systems can result in significant savings in aid and rehabilitation costs. Technological innovations that can be applied in disaster management include physical infrastructure, machinery and equipment (hardware), knowledge and skills (software) and biotechnology. In addressing disaster risk concerns by using the available technology, farmers learn to work better with nature.

6.1 Increasing emphasis on response to climate change

Climate change is intensifying challenges for the agriculture sector

The challenges faced by the agriculture sector are increasing. Climate change leads to increases in temperatures, rainfall variation, and changes the frequency and intensity of extreme weather events. This adds to the pressure on the global agriculture system that already has to respond to increasing demands for food and renewable energy. Furthermore, climate change also contributes to resource problems beyond food security, such as water scarcity, pollution and soil degradation. There is increased urgency to address these challenges.

Climate change is expected to negatively affect both crop and livestock production systems

Although some countries may benefit from changing climate conditions, overall agricultural productivity levels are expected to fall. Impacts on agricultural production will vary among regions and will depend on the intensity of the changes in temperatures and water availability, as well as how these factors interact. By 2050, the three main crops (maize, wheat and rice) are projected to have falling yields. Without CO_2 fertilization, effective adaptation and genetic improvement, each degree-Celsius increase in global mean temperature will, on average, reduce global yields of wheat by 6.0 per cent, rice by 3.2 per cent and maize by 7.4 per cent (Zhao *et al.*, 2017).

Agriculture is also contributing a significant share of greenhouse gases

In 2011, agriculture was contributing to 13 per cent of greenhouse gas (GHG) emissions, making it the second largest global emitter (Russel, 2014). The proportion of GHG emission is 17 per cent from farming activities and an additional 7-14 per cent from changes in land use. The main farm related GHG emissions are methane (CH_4) and nitrous oxide (N_2O). Nitrous oxide emissions come from soils, fertilizer use, and grazing activity, while methane comes from ruminant animals (enteric fermentation) and paddy rice cultivation. The sector generates emissions indirectly due to changes in land use, including land clearing and deforestation. The source of emission and amount will vary widely depending on the type of crops grown, farming practices employed and natural factors, such as weather, topography and hydrology.

Box 6.1 Climate smart agriculture programmes

Innovative technology in agriculture through big data usage, satellite imagery, information and communications contribute to 'smart agriculture'. The most common definition is provided by FAO that defines climate smart agriculture (CSA) as "agriculture which sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals". This definition clearly presents the principal goal of CSA for food security and development (FAO, 2013), where productivity, adaptation and mitigation are recognized as three interlinked pillars for achieving the goal as described below.

The three pillars of CSA:

- **Productivity:** CSA aims to increase agricultural productivity sustainably and incomes from crops, livestock and fish, without having a negative impact on the environment. In return, it will raise food and nutritional security. The fundamental concept related to increasing production is sustainable intensification.
- **Adaptation:** CSA aims to reduce farmer exposure to short-term risks, and at the same time strengthen resilience by building farmer capacity to adapt and prosper in the face of shocks and longer-term stresses. The primary focus is to protect the ecosystem services which maintain productivity and ability to adapt to climate change.
- **Mitigation:** CSA should help to reduce and remove GHG emissions. This applies to each calorie or kilo of food, fibre and fuel produced. Deforestation should be avoided and soils and trees managed in ways that optimize their potential to act as carbon sinks and absorb CO2 from the atmosphere.

6.2 Use of ICT/big data

Internet technology is expected to improve agriculture systems. Innovation technology in agriculture through big data usage, satellite imagery, information and communications contribute to a more developed and modern agriculture sector. Information on research results in agriculture is easily shared and accessed. Precision agriculture has been growing, and it can now reach a level where it is possible to collect large quantities of data and to control and monitor individual plants. Based on a review by Wolfert *et al.* (2017) on Big Data in Smart Farming, the role of big data in all stages of the disaster management cycle can be explained as follows:

- **Monitoring hazards:** Seismographs, satellites and drones offer ever-improving remote-sensing capabilities. Adding range of data from community smartphones or information from their social media feeds offers tremendous potential information for hazard monitoring such as earthquakes and floods.

- **Assessing exposure and vulnerability toward the hazards:** Satellite images enable experts to identify geographical and infrastructure risks. Open-sourcing initiatives like the Open Street Map can empower volunteers to add ground-level data and updated photographs that are useful for verification purposes. Call detail records - phone metadata tracking numbers and times of calls - allow the estimation of population distribution and socioeconomic status in a disaster-affected area.

- **Guiding disaster responses**. Social media can be monitored to provide early warning of threats ranging from disease outbreaks to food insecurity. Remote sensing has been used to provide an early assessment of damage caused by hurricanes and earthquakes. Cellular phone data provide vital information on population movements and behavioural responses after a disaster happens.

- **Assessing the resilience of natural systems**. Satellite images are able to reveal the changes of ecosystem quality, for example, soil quality and water availability. Information from satellite image analysis has been used as a base to determine the intervention measures that can support agriculture and food production. Community science reporting via social media and other platforms can radically expand scientists' observations of ecological systems.

- **Engagement of communities.** Building a long-term resilience takes more than enhancing the ability of both external and local actors to react to single events. Resilient communities manage their natural systems, strengthen their infrastructure and maintain the social ties and networks that make communities strong. The longer-term potential of big data lies in its capacity to raise citizens' awareness and empower them to act.

Status and future challenges for big data in the agricultural sector

A classic example of big data sources in agriculture includes stock of crops, livestock and fisheries. In more detail, it could cover data of crop health variability. In the future, government agencies, farmers' organizations, agrobusinesses, traders and markets, and the scientific community will generate, uses and maintain the massive amount of data related to agricultural production, weather and climate, agriculture insurance, marketing, supply chains, packaging and distribution.

Furthermore, research data specific to agriculture, such as genotype data, phenotype data, spectrophotometer data, sensor data and images, which need to be translated and integrated into tables, diagrams and other forms use big data to present information in a simple and meaningful way. The process of using big data involves discovery, processing, combining and visualizing data from distributed and heterogeneous data repositories that can support information distribution and ultimately will support agricultural development. The challenge of using big data is how to provide new efficient decision-making tools to help acquire and share data, extract knowledge and share information among different actors in the agriculture sector.

6.3 Use of indigenous technology

Indigenous knowledge and technology is culture specific and represents a community lifestyle that has helped local people survive for generations. This knowledge comes from the interaction between community members and the environment in which they live (Iloka, 2016). The local cultivation of crops and livestock raising in Asia and the Pacific relies heavily on local knowledge. Furthermore, indigenous technology has the following characteristics (Jha, 2008):

- low capital intensity, whatever capital is built up (like bunds, terraces and wells) is laboresque or cooperative
- usually environment- and ecology-friendly
- generally site specific with limited adaptability
- generates only small increments in output

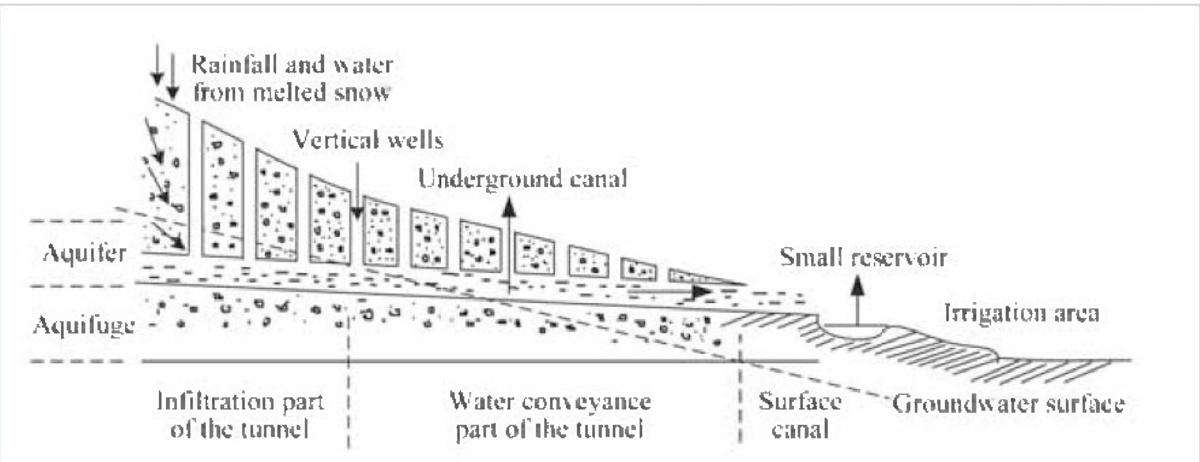
Indigenous technology is still considered unreliable and tends to be abandoned. Whereas, in some cases, it is evident that indigenous technology in agriculture can overcome existing natural hazards, so it is very important in maintaining the stability of agricultural production in an area (Sethi *et al.*, 2011). Some examples of indigenous agricultural innovation technology applied in the Asia-Pacific region include Karez technology for drought disaster reduction in China and weather forecasting through indigenous knowledge for crop cultivation in the drought-prone area of Viet Nam.

Box 6.2 Karez, an underground irrigation system

Karez is a traditional underground irrigation system developed in Turpan Xinjiang of China. Karez was mainly constructed between the 17th and 20th centuries. The evaporation in Turpan is very high, therefore the water from upstream will evaporate or seep underneath the sand or stone before it emerges as a stream and reaches the agriculture areas. Moreover, the geological condition in Turpan is suitable to develop underground canals to amass the underground water.

Karez is very important in supporting agriculture and even the domestic water uses of the Turpan community as they live in an arid area. The Karez system made Turpan, an arid area of northwestern China, famous for its wide variety of agricultural products. Modern technology has been integrated into the traditional Karez system to reinforce the successful traditional practice.

As a comprehensive system, Karez is composed of four primary components: vertical wells, underground canals, a surface canal and small reservoirs. The vertical well is primarily used to assist in digging the 3 km to 30 km underground canals. The vertical well also can be used to extract water from the underground canals when the whole Karez system is completed. When the underground canal reaches the farmland, it is converted to a surface canal and it is linked to a small reservoir or directly connected to a system of water channels for farm irrigation (Fang *et al*., 2008).



Source: Fang *et al.* (2008).

6.4 Resilience of post-harvest value chain

The impact of shocks and natural disasters can be mitigated effectively if appropriate agricultural practices are put in place, including good storage of food to ensure household and community food security during disaster response and recovery. Good storage involves controlling the following factors: temperature, moisture, light, pests and hygiene (Table 6.1).

Table 6.1 Storage condition requirements of some food commodities

Commodities	Moisture/humidity	Temperature/light	Other
Cereals and pulses	Can be stored below their safe moisture level for periods of a year or more.	Under a wide range of temperatures.	N/A
Seed for growing	Moisture levels need to be low; a 1 per cent decrease in moisture content below 14 per cent doubles storage time. Maximum drying temperatures of 35°C. Full sun drying is not recommended.	Cool storage is necessary. A decrease of 5°C in temperature doubles storage time.	Seed harvested when not fully ripe will lose its viability sooner than mature seed.
Root and tuber crops	Keep humidity low to avoid rotting.	Ventilation is needed to avoid rotting. Yams can be stored for 4 months at normal temperatures (25-35°C). Potatoes for only 5 weeks as they are sensitive to sunlight. Chill rooms for storage on a large scale. Store should be ventilated during the coolest part of the day and isolated during hottest time.	To increase storage life, use special treatment called 'curing.' which consists of letting tubers grow layers of cork cells around the surface.
Fruit and vegetables	N/A	Keep better when cooled but damaged by freezing. Simple evaporative air-cooled cabinets allow small farmers to store them. Underground storage in pits and cellars are used.	Surface waxing or wrapping prevents the the spread of rot from one fruit to another. Keep in CO_2 rich atmosphere.

Table modified from http://www.climatetechwiki.org/content/seed-and-grain-storage

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7 Policy Support for Enabling Innovation

The emergence of technological innovation requires the right conditions, including infrastructure and skills, availability of financial resources for research and development, and effective implementation of regulations. Infrastructure includes facilities, tools and instruments necessary for research. Skills refer to human resources, knowledge services and networks that support the process of developing new technologies.

In general, restrictive regulation may hamper innovative activity by reducing the attractiveness of engaging in R&D, whereas more flexible regulations, can better stimulate innovation (although this is not always the case). The factors that affect innovation are the availability of funding, the ease of appropriation, cost of securing protection for the idea, the market size, risk involved in innovation and other government-related regulations.

7.1 Accelerating innovation

a. Legislation for patents and intellectual property rights

Intellectual property rights (IPR) is a general term covering patents, copyright, trademarks, industrial designs, geographical indications and other undisclosed information (WTO, 1995), such as new plant varieties. IPR confers economic benefit as the result of intellectual creativity. Proper protection of IPR through legislation creates a motivating environment for technological innovation, so that people will invest their resources in developing new technology or improving existing technology without having to worry about intellectual property theft. In aggregate, IPR promotion and protection of intellectual property encourages economic growth, creates new jobs and industries, and enhances quality of life (WIPO, n.d.).

b. Investment in research and development

R&D plays a critical role in the global innovation process. It is essential to invest in technological R&D that contributes to agricultural growth and total factor productivity by increasing crop and livestock yields through the development of new technologies (that is, new varieties and techniques) and also by technological diffusion and adoption.

Investment in research and development is the most productive way to support agriculture, and some experts argue that "massive public and private investments in research and development are required if agriculture is aimed to benefit from the use of new technologies and techniques" (FAO, 2009). The need for substantial investment in agricultural R&D will increase due to climate change and intensifying water scarcity.

Funding for R&D can be distributed to different groups through different incentives and rules. For example, capital subsidies/long-term credit can give farmers financial support systems. Easier access to funding can be provided to access credit guarantee schemes. Rules can make it easier for young entrepreneurs to secure funding from institutions in the form of equity or debt. Regarding regulations, more prescriptive regulation tends to hamper innovative activity, whereas the more flexible regulation is, the better innovation can be stimulated.

Box 7.1 Research and development incentive scheme in Malaysia*

Malaysia offers a wide range of incentives and financial assistance to attract investments in research and development (R&D) activities. This incentive scheme started in 1982 through a tax deduction scheme. It was supported by the issuance of regulations The Promotion of Investments Act 1986 which defines the type of R&D to be funded as "any systematic or intensive study carried out in the field of science or technology with the objective of using the results of the study for the production or improvement of materials, devices, products, produce or processes but does not include:

- quality control of products or routine testing of materials, devices, products or produce;
- research in the social sciences or humanities;
- routine data collection;
- efficiency surveys or management studies; and
- market research or sales promotion."

Over the last three decades, the Malaysian Government has developed and diversified various incentive mechanisms and schemes, tailoring these to industry sectors who locate their R&D activities in the country. The R&D incentives in Malaysia include:

- double deduction (applies to in-house R&D and contract R&D)
- pioneer status (which provides full income tax exemption for 10 years)
- investment tax allowance
- tax exemptions (includes exemptions from income tax, import duty, sales tax and excise duty)

*Source MIDA (2012).

c. Capacity-building and institutional arrangements

Partnerships between academia, the agriculture industry and government are essential in accelerating innovation. Since the higher education system is highly diversified, it can contribute to research to enhance productivity and natural disaster resilience. Collaborative activities can be carried out, including service and training, patenting, collaborative R&D, networking events and industrial collaboration for education. An appropriate and comprehensive strategy will significantly contribute to creating a productive environment to develop knowledge, consensus and innovative technology.

Strengthening institutional and technical capacities in agricultural resilience to natural disasters and climate change aims to ensure efficient institutional arrangements and processes to effectively address agriculture DRR. The gaps in knowledge transfer from researcher to small-scale farmer can be resolved through extension provisioning to conduct training or provide field assistance during the implementation of new technological innovation.

d. Support mechanisms

Seed and gene banks

Plant genetic resources for food and agriculture are a strategic asset for crop improvement through farmer selection, conventional plant breeding and modern biotechnological techniques. Crop improvement enables agriculture to adapt to change and develop new food varieties and new uses. Supportive policies and laws should create an enabling environment for the applications of plant genetic resources in crop improvement, and adoption of improved plant varieties by farmers. Policy support needs to be put in place, including legal frameworks that facilitate the conservation, exchange and sustainable use of such plant genetic resources.

Access to information and knowledge sharing

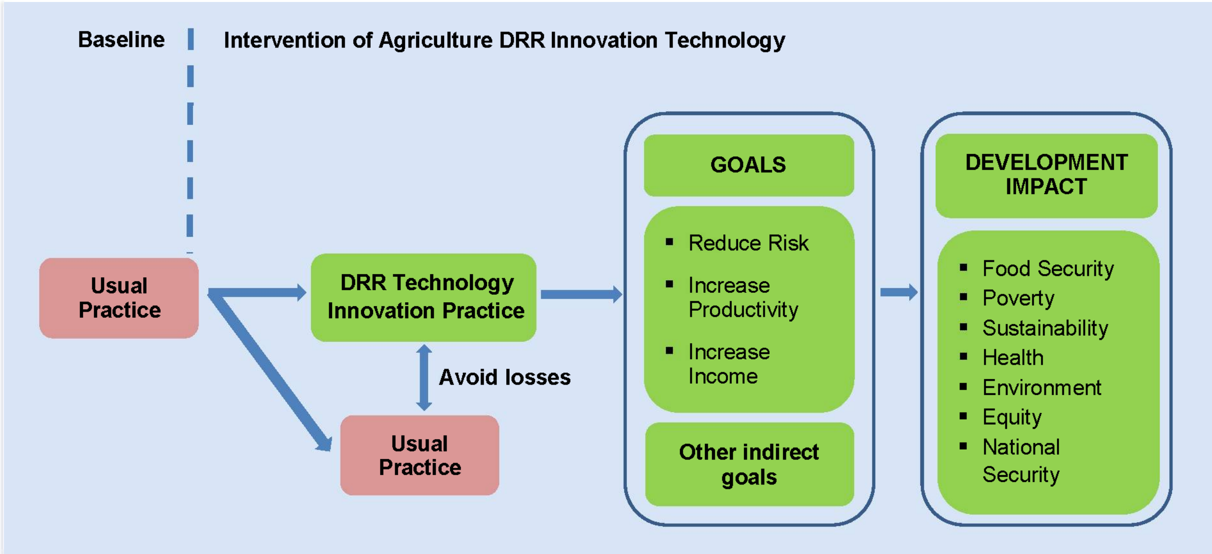
The diffusion of a new information or knowledge is mostly spread through a social system or social networking (Raju, 2016). As the result of the diffusion, people as part of a social system, adopt a new idea, behaviour or product. Knowledge-sharing and creation in a social context are where creative individuals share their knowledge within a group (Leonard and Sensiper, 1998). Innovation and technology in agriculture are more complex and systemic, thus requiring access to information and the transfer of knowledge from diverse perspectives through networking. The challenge of these networks is to manage and develop interpretations of various experiences to capture future-oriented expertise and knowledge. Furthermore, knowledge-sharing will shape future business development even among individual farmers, community-based organizations, government and international markets.

e. Technology assessment tools

Framework for evaluation agriculture intervention

The Framework Impact Evaluation developed by the Independent Evaluation Group (IEG) of the World Bank (IEG, 2011) follows the disaster management cycle to evaluate interventions. It is a simplified and generalized impact pathway of the primary outcomes sought from agricultural interventions, such as level of risk, productivity, income and profits (Figure 7.1). Furthermore, the outcomes can lead to macro-level development improvements.

Figure 7.1 Evaluation logical framework of intervention of agriculture DRR innovation technology



Source: Modified from FAO (2017b) and (IEG, 2011).

Methodology of impact evaluation

Defining impact indicators is not a straightforward exercise. There are many channels to improve agriculture resilience, especially productivity, farm income and profit. There are also various ways of defining and measuring outcome indicators, such as yields, depending on how the intervention has been designed and the type of intervention being evaluated. Long-term changes in developmental goals and macro developmental impacts (such as poverty reduction) cannot be attributed to a single intervention.

Some basic definitions used in indicators include:

- Yields: production or labour per total area of cultivated land
- Agricultural income: earnings from agriculture
- Income: earnings from all activities
- Consumption: expenditure at the household level
- Production: the amount of crop or other agriculture product harvested from a certain agriculture area
- Profits: marginal gains or net benefits (sales minus costs)

Table 7.1 Indicator in evaluate DRR agriculture intervention

Direct impact indicator	Indirect impact indicator
▪ Total loss ▪ Total damage ▪ Disaster affected area ▪ Yield ▪ Productivity ▪ Production ▪ Value of output per hectare ▪ Household income ▪ Total gross margin for all agricultural production ▪ Biophysics of agriculture land (i.e contour of land, soil characteristics)	▪ Price gain ▪ Fertilizer use ▪ Planting multi-year crop ▪ Reduction in pesticide application ▪ Intensive use of lands ▪ Access to credit ▪ Change in household liquid assets ▪ Knowledge of farming practices ▪ Reduction in risk

Modified from IEG (2011) and Mollet and Barelli (2016)

Box 7.2 Evaluation of irrigation interventions

Increasing cropping intensity by growing several crops per year on the same plot under irrigated conditions and increased quality of water is enabling farmers to replace low-yielding crops with more profitable high-yield crops. Water-related interventions seek to affect productivity and farm income by stabilizing and intensifying cropping through water supply improvements. Interventions on irrigation aim to improve access to irrigation through infrastructure (dams), plot-level technologies (drip irrigation) and changes in irrigation management structures to give farmers greater leverage in the use of water. The main impacts to be identified are stabilization of cropping patterns, crop yields and agricultural outputs.

Table 7.2 Indicator in evaluation irrigation intervention

Variable	Impact Indicator
Availability of irrigation	▪ Type of irrigation ▪ Source of water supply ▪ Water supply improvement ▪ Crops growth ▪ Productivity ▪ Household income ▪ Other side effect of irrigation availability
Access to irrigation	▪ Number of farm irrigated ▪ Area of agriculture irrigated ▪ Distance to irrigation service ▪ Cost to access irrigation service ▪ Operating management of irrigation system
Participation in irrigation management training	▪ Number of training participant ▪ Number of training ▪ Evaluation before and after training

Facilities for field testing

Innovation technology needs field testing to evaluate performance in uncontrolled environmental conditions. This enables comparison with other devices/tools and tests for durability and longevity in the circumstances in which it will be used. It also assesses whether the new technology is applicable locally, visible and profitable. Research institutions sometimes require a location to test the innovation technology applications developed in a laboratory setting at field level.

At small farmer level, the application of new technology is still oriented to meet the family's food needs by applying very simple technology. Farmers with larger land resources can optimize their resources to increase their income and family welfare. However, the applied technology is still very simple, so the productivity results are very low.

To test technology innovation effects on a larger scale, the government or a third party can use large farmlands as demonstration plots through a guarantee scheme. If the results from the demonstration plots are less than their average income under the usual practice, then the government or the third party makes up the shortfall. The availability of extension services with knowledge of the new technology application is also important to provide assistance to small-scale farmers in implementing the innovation.

7.2 Accelerating dissemination

Dissemination of innovation should engage a wide range of actors and networks. The role of policymakers is critical in creating an enabling environment and introducing relevant technologies at the country level. Regional cooperation can facilitate policymakers' learning and capacity-building. Many countries in the region share similar climatic conditions, natural disasters, agricultural produce and level of technology. Knowledge exchange on technological innovation among these countries can help policymakers to introduce necessary changes, including institutional and system changes to their countries. Simultaneously, regional cooperation provides opportunities for technological leapfrogging through networking with countries with advanced technologies. Such regional cooperation contributes towards the region's achievement of the 2030 Agenda. Sustainable and resilient agriculture supports many of the SDGs.

Agriculture extension

Agricultural extension aims to promote learning for farmers. In this context, agricultural extension has a significant role in introducing new types of location-specific natural disaster technologies and the opportunity to increase people's incomes. Extension workers act as information resources, facilitators, motivators, and local and farmer institutional facilitators in access to information and testing processes of new technologies, and linkages with relevant stakeholders.

The dissemination of IT-based agriculture innovation by local extension and institutionalizing the innovation into farming daily activities is an ideal model of information distribution. Along with it, several improvements in the role of each party are needed; for example, in addition to having knowledge of IT-based agriculture innovation, extension workers must be ready to answer questions related to the technical operation of an agriculture-based cellular phone applications. Optimizing the synergy between formal institutions and the local agencies will facilitate IT-based agriculture innovation dissemination.

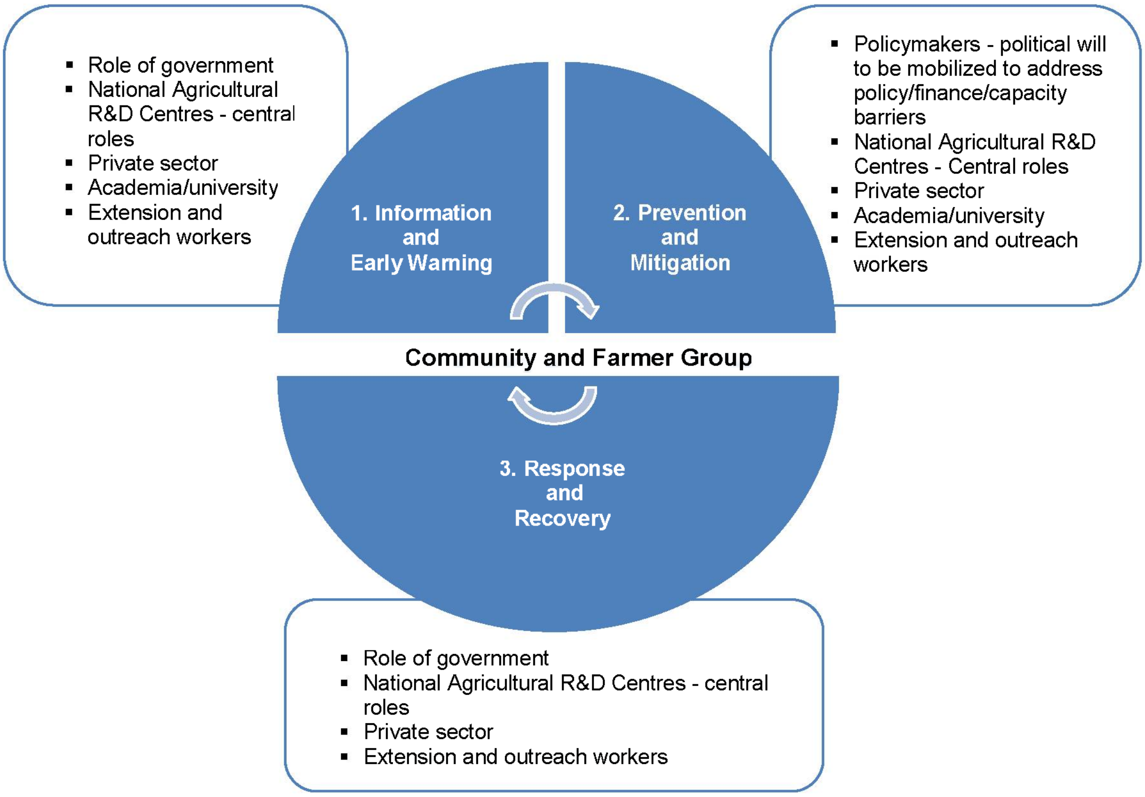
7.3 Stakeholder participation

Policy on agricultural innovation technology related to DRR addresses complex aspects that require involvement from a variety of stakeholders and advocates. Ultimately, community involvement is the key factor for success in creating resilient agriculture. Building resilient agriculture with appropriate coping mechanisms is the fundamental principle behind any DRR. Stakeholders may include local government and other competent authorities, such as national disaster management authorities, agriculture bodies, NGO networks (both DRR humanitarian NGOs and community development NGOs), financing institutions, private/business, the media and academic community (Figure 7.2).

Timeliness is the essence in DRR and how quickly these stakeholders act and work together is ultimately crucial. Each stakeholder has their own responsibility in different phases of disaster management, including in information and early warning, prevention and mitigation, response and recovery.

A lack of agricultural technology will prevent smallholder farmers from optimizing their land use, forcing them to struggle with poor soil, diseases, pests, drought, unreliable seeds and inadequate information about best practices and pricing. Sharing and developing agricultural innovations with smallholder farmers is the most efficient way to reduce poverty and hunger around the world, reduce the food gap and strengthen communities' resilience to natural disaster and climate change. It is imperative to recognize the advantage of investing in and educating smallholder farming communities, NGOs, corporations and governments, who all work toward new agricultural innovations aim to reduce poverty.

Figure 7.2 Stakeholder's role in agriculture disaster risk management



Communications in a common language are needed to avoid ineffective coordination and collaboration between individuals or organizations. In the disaster management case, especially early warning, good communication among stakeholders can encourage early action as the organizations that produce warnings are not those that disseminate the information. These warnings are dispatched to local newspapers, radio and television stations, emergency services and other users.

8 Regional Cooperation to Accelerate Innovation

Regional cooperation to mitigate natural disaster and climate change risks and build resilient agriculture is needed as the effects of climate change intensify and transboundary occurrences of natural disasters increase. Thus, there is a demand for transboundary solutions. Actions taken on a regional level can be particularly effective as the benefits generated are greater than individual country responses.

8.1 Initiative by CAPSA-SATNET Asia 2012-2015

SATNET Asia was a network of institutions and people who shared knowledge on sustainable agricultural practices and agricultural technologies in Asia and the Pacific region. There were more than 45 associate member institutions in target countries, including government entities, research and academic organizations, NGOs, donors and private sector organizations. In total, over 1,400 people were part of the broader network.

SATNET Asia facilitated knowledge transfer through the development of a portfolio of best practices on sustainable agriculture and trade facilitation. Furthermore, the SATNET Asia portal provided a platform for researchers and practitioners to share and exchange information on sustainable agriculture technologies and market linkages in the region. In particular, the portal aimed to:

- share news and information on events and key activities of network participants as well as job, training and funding opportunities
- facilitate access to research publications, policy briefs, fact sheets and training materials
- provide a database of information on sustainable agriculture technologies being promoted by network participants
- allow network participants to engage with one another through an online discussion platform called the SATNET Social Hub and comment on information contained in the portal

The project objective was to increase and accelerate the rate of adoption of agricultural technologies that were sustainable, productivity enhancing and suitable for the poorest and most vulnerable people of South and South-East Asia, through:

- developing an analytical framework to assess sustainable technologies
- collecting and disseminating of technology information, through a dedicated web portal, series of technology fact sheets, thematic training band publications, farmer-to-farmer learning and policy dialogue events

8.2 Lessons learned from SATNET Asia

SATNET Asia was designed to address the lack of alternative agricultural technologies and their dissemination to poor farmers. The network also addressed trade constraints on the import and export of food and agricultural products of target countries by assisting in the identification of measures that facilitate regional trade and their transfer to different agents along domestic and regional value chains. The output of the programme included a web portal connected to 1,000 experts across the region, over l70 publications, including technology fact sheets, policy briefs, training manuals and other reports, and 55 training and dialogue events in which over 1,400 policymakers and experts participated. The network grew from 26 to 45 associates and is currently sending information to around 1,200 interested individuals. The project was relevant to regional and national priorities and efficiently dealt with implementation issues, working effectively to reach its aims.

We can see the potential of networking between policymakers and experts in Asia. This relationship is important as agriculture is still the leading sector driving the national and regional economy. SATNET Asia fully developed partnerships and engaged and consulted with stakeholders. Based on the evaluation of the project, it is known that there is high demand for:

- training that introduces new technologies and improves the process to support technology innovation/transfer
- knowledge exchange mechanisms and platforms for networking with stakeholders at regional, subregional and national levels

In the future, disaster resilient agriculture should consider:

- Potential of technological innovation to be showcased to mobilize policy support
- Analytical work: continue to develop analytical works with broader relevant issue with inputs from member state experts
- Knowledge-sharing and networking: revitalizing SATNET, including thematic focus groups/communities; publish technology monographs/fact sheets
- South-south dialogue and capacity-building in cooperation with member states and partners

9 Conclusion

Natural disaster events are increasing in number and scale across Asia-Pacific region and causing a devastating impact on agriculture sectors and community livelihoods. On average, the agriculture sector suffers an average of 22 per cent of the total damage and losses caused by disasters. The fact that 40 per cent of community livelihoods in the region are directly and indirectly dependent on agriculture; the need to feed the increase in world population which is predicted to reach 9.73 billion by 2050; and the economic growth that will change the diet of societies across Asia and the Pacific make greater investment to manage the risks of disasters in the region more important than ever.

One of the main challenges for agriculture in dealing with natural disasters is lack of technology support, particularly for smallholder farmers, the majority of producers in Asia and the Pacific. The situation prevents them from accessing early warning information, limiting their options for mitigation and the recovery of their land. Without sufficient technological innovation support, the smallholder farmers are vulnerable to the disasters and fail to appropriately utilize their land, as they have to cope with increasing pest and disease, unreliable seed and deteriorating soil quality. Various studies have shown that support for multisector and interdisciplinary collaboration across the region to develop and share agricultural technological innovations could be the most efficient way to strengthen smallholders, speed up efforts to reduce poverty and hunger and become resilient in the face of disaster. Therefore, investing in technological innovation; education for smallholder farming communities and other concerned stakeholders, including government and corporations, and strengthening information-sharing mechanisms should be a policy imperative for the region.

The governments of Asia-Pacific countries should work together in developing and adopting agricultural technologies to provide early warning and mitigate the underlying disaster risks to the region. With multisector and interdisciplinary collaboration across Asia-Pacific countries, knowledge about technological innovation for disaster risk management in the agriculture sector will proliferate. The capacity of farming communities, especially smallholders, will increase to cope with more complex challenges in agriculture. In the end, investment in technological innovation will mean that any disaster event in the region will not compromise food security and nutrition, and the sector's growth and contribution to the national economies will be maintained.

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Appendices

Appendix 1 Summary of innovation and technology for each type of natural disaster

Natural disaster	Description*	Innovation technology for agriculture disaster management		
		Information and early warning	Prevention and mitigation	Response and recovery
Drought	Agricultural drought is the impact of meteorological dryness (lack of rainfall) and hydrology (lack of water supply from water sources such as rivers and reservoirs) as a consequence of a natural reduction in precipitation over an extended period of time, usually a season or more, often associated with other climatic factors (high temperatures, high winds and low relative humidity) that can aggravate the severity of the event. Drought occurs when soil moisture is insufficient to sustain yield and average growth of the plant. Water requirements for plants, however, depend on plant species, growth rates and soil facilities.	▪ Satellite image and or drone (aerial images) to monitor aquifers and crops ▪ Climate forecasting and modelling ▪ Monitoring kits for drought index (soil moisture) ▪ Early warning dissemination through communication infrastructure	▪ Drought-resistant varieties ▪ Integrated farming system ▪ Insurance ▪ Water-efficient farming ▪ Crop diversification and rotation ▪ Improved irrigation system	▪ Damage assessment ▪ Planting drought-resistant varieties
Earthquake	Shaking and displacement of ground due to seismic waves. An earthquake is the result of a sudden release of stored energy in the Earth's crust that creates seismic waves. They can be tectonic or volcanic in origin. At the Earth's surface, they are felt as a shaking or displacement of the ground. The energy released in the hypocentre can be measured in different frequency ranges.	▪ Hazard mapping/crisis map ▪ Improved seismic surveillance ▪ Early warning dissemination through communication infrastructure ▪ Real-time traffic map and GPS data from cellular phone for evacuation plan	▪ Food storage warehouse ▪ Early maturity/ short-cycle varieties ▪ Insurance ▪ Agroforestry ▪ Integrated farming system	▪ Damage assessment ▪ Spatial planning ▪ Land amelioration
Epidemic	Unusual increase in the number of cases of an infectious diseases that already exist in the region or population concerned, or the appearance of an infectious disease previously absent from a region.	▪ Crop monitoring by drone or satellite ▪ Weather forecasting ▪ Spatial epidemic information ▪ ICT big data for food stock and supply information ▪ Dissemination early warning through communication tools	▪ Plant resistance to pathogen ▪ Early maturity/short-cycle varieties ▪ Crop rotation ▪ Harvest management ▪ Integrated pest management ▪ Integrated farming system ▪ Insurance	▪ Damage assessment ▪ Integrated pest management ▪ Crop diversification, planting fast-growing crops
Flood	**Flash flood:** Rapid inland floods due to intense rainfall. A flash flood describes sudden flooding with short duration. In slope terrains, the water flows rapidly with a high destruction potential. In flat terrains, the rainwater cannot infiltrate into the ground or run	▪ Flood warning system ▪ Climate forecasting and modelling ▪ Crisis map ▪ GIS and satellite image to monitor aquifers	▪ Crop rotation ▪ Early maturity/ short-cycle varieties ▪ Agroforestry	▪ Damage assessment and mapping affected area ▪ Spatial planning ▪ Integrated farming system

Natural disaster	Description*	Innovation technology for agriculture disaster management		
		Information and early warning	Prevention and mitigation	Response and recovery
	off (due to small slope) as quickly as it falls. Flash floods are typically associated with thunderstorms. A flash flood can occur at virtually any place. **Flood:** A condition that occurs when water overflows the natural or artificial confines of a stream or other body of water, or accumulates by drainage over low-lying areas	▪ Drone to monitor water movement from upstream ▪ Open street map for evacuation ▪ Dissemination early warning through risk communication tools		▪ Land amelioration
Forest fire	An uncontrolled fire that causes extensive damage. They may start by natural causes such as volcanic eruption or lightning, or may be caused by arsonists or careless smokers, by those burning wood or by clearing a forest area.	▪ Crisis map layered by hot spot map ▪ Climate forecast and Modelling ▪ Satellite based remote sensing and aerial photography ▪ Open street map for evacuation ▪ Dissemination early warning through risk communication tools	▪ Risk modelling ▪ Insurance	▪ Damage assessment and mapping affected area ▪ Spatial planning ▪ Integrated farming system
Heat wave	A heat wave is a prolonged period of excessively hot weather, which may be accompanied by excessive humidity.	▪ Climate forecasting and modeling ▪ Satellite image and drone (aerial images) to monitor aquifers and crops ▪ Climate forecasting and modelling ▪ Monitoring kits for drought index (soil moisture) ▪ Early warning dissemination through risk communication tools	▪ Vulnerability and risk modelling ▪ Heat-tolerant crops ▪ Insurance	▪ Planting heat-tolerant crops
Insect infestation	Pervasive influx and development of insect or parasites affecting humans, animals, crops and materials.	▪ Dissemination early warning through risk communication tools ▪ Crop monitoring by drone or satellite image ▪ Weather forecasting ▪ Spatial epidemic information	▪ Risk modelling ▪ Vulnerability assessment ▪ Harvesting management ▪ Integrated pest management ▪ Insurance	▪ Integrated pest management ▪ Crop diversification
Landslide	Any kind of moderate to rapid soil movement, including mudslide and debris flow. A landslide is the movement of soil or rock controlled by gravity and the speed of the movement usually ranges between slow and rapid.	▪ Climate forecasting and modelling to monitor rainfall ▪ Landslide detection through satellite based remote sensing and aerial photography to monitoring slope stability ▪ Improved seismic surveillance ▪ Open street map for evacuation ▪ Dissemination early warning through risk communication tools	▪ Risk modelling ▪ Digital elevation models ▪ Integrated farming system ▪ Agroforestry ▪ Insurance	▪ Mapping affected area ▪ Soil management ▪ Spatial planning ▪ Agroforestry

Natural disaster	Description*	Innovation technology for agriculture disaster management		
		Information and early warning	Prevention and mitigation	Response and recovery
Storm surge	Coastal flood induced by wind. A storm surge is the rise of the water level in the sea, an estuary or lake as a result of strong winds driving the seawater towards the coast. The areas threatened by storm surges are coastal lowlands.	▪ Weather forecasting and climate modelling ▪ GIS, crisis map layered with storm hazards ▪ Open street map for evacuation plan ▪ Dissemination early warning through risk communication tools	▪ Vulnerability risk analysis ▪ Insurance	▪ Mapping affected area ▪ Integrated farming system ▪ Agroforestry
Tropical Cyclones, Typhoons	These are regional names for the same phenomenon. **Tropical Cyclones:** Depressions in the tropics which develop into storms in the southwest Indian Ocean, the Bay of Bengal and the Arabian Sea, parts of the south Pacific and along the northern coasts of Australia. Typhoons: Northwest Pacific	▪ Weather forecasting and climate modelling ▪ GIS, crisis map layered with storm hazards ▪ Open street map for evacuation plan ▪ Dissemination early warning through risk communication tools	▪ Vulnerability risk analysis ▪ Insurance	▪ Mapping affected area ▪ Integrated farming system ▪ Agroforestry combined with fast growing crops
Tsunami	Series of large waves of extremely long wavelength and period usually generated by a violent, impulsive undersea disturbance or activity near the coast or in the ocean. When a sudden displacement of a large volume of water occurs, or if the sea floor is suddenly raised or dropped by an earthquake, big tsunami waves can be formed. The waves travel out of the area of origin and can be extremely dangerous and damaging when they reach the shore.	▪ Improved tsunami early warning and monitoring ▪ Crisis map ▪ Open street map for evacuation plan ▪ Dissemination early warning through risk communication tools	▪ Risk modelling ▪ Insurance	▪ Damage assessment and mapping affected area ▪ Spatial planning ▪ Land amelioration
Volcanic	All volcanic activity, such as rock fall, ash fall, lava streams, gases, etc. Volcanic activity describes both the transport of magma and or gases to the Earth's surface, which can be accompanied by tremors and eruptions, and the interaction of magma and water (e.g. groundwater, crater lake) underneath the Earth's surface which can result on phreatic eruptions. Depending on the composition of the magma, eruptions can be explosive and effusive and result in variations of rock fall, ash fall, lava streams, pyroclastic flows, emission of gases, etc.	▪ Improved seismic surveillance networks ▪ Aerial photography ▪ Crisis map ▪ Open street map for evacuation Plan ▪ Dissemination early warning through risk communication tools	▪ Risk modelling ▪ Insurance	▪ Damage assessment and mapping affected area ▪ Spatial planning ▪ Land amelioration

*Descriptions of natural disaster are adopted from Brauch, *et.al* (2011)

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Technological Innovation for Enhancing Agricultural Resilience to Natural Disasters and Climate Change

The impacts of natural disasters on the agriculture sector are particularly high in developing countries, reaching 22 per cent of total damage and losses. Various studies have shown that a lack of integration of disaster risk reduction (DRR) into agricultural development plans and actions (and vice versa) has contributed to more damage and losses. Due to the increasing frequency of natural disasters in Asia and the Pacific in the last two decades, there is an urgent need to reduce vulnerability and develop a more resilient agriculture, which in turn will reduce the risks and costs of damage from future disasters. Investments of 1 dollar in DRR can save as much as 4 dollars in avoidable future losses.

This working paper demonstrates technological innovation as a crucial intervention to improve agricultural resilience towards natural disasters and climate change. Innovation plays significant roles in all five stages of disaster management: (1) institutional and framework development; (2) disaster risk management (DRM) strategy setting and DRR planning; (3) information and early warning; (4) prevention and mitigation; and (5) response and recovery. This working paper will focus on how technological innovation could help in DRR management in stages 3-5 of DRM.

ISBN 978-979-9317-90-2