Forest-based Disaster Risk Reduction

COOKBOOK

How to Adapt to Disasters Caused by Climate Change

(Provisional English Translation)

REDD-plus and F-DRR Research and Development Center Japan

FFPRI

Forward

In recent years, weather disasters thought to be caused by climate change have been increasing in scale and are significantly impacting human social life. The Sixth Assessment Report released in February 2022 by the Intergovernmental Panel on Climate Change (IPCC) clearly states that “Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (high confidence).” In particular, in the Asian monsoon region, including Japan, dense populations, land development extending to mountain foothills, and long coastlines create conditions where large typhoons can easily lead to severe disasters in mountainous area and storm-surge damage. Especially in developing countries located in this region, rapid population growth and increased production capacity have often resulted in unregulated human-driven land-use changes, such as the conversion of forest lands into agricultural fields, as well as the loss of mangroves due to the development of aquaculture ponds, farmland, and rice paddies in coastal areas. As a result, the disaster risk reduction functions originally provided by forests have been compromised, leading to major natural disasters. Because regions prone to such natural disasters are widespread, countermeasures based solely on infrastructure development have inherent limitations. It is therefore essential to enhance the resilience of mountainous and coastal areas through forest conservation and restoration in order to reduce the impacts of natural disasters.

Against this backdrop, the REDD-plus and Forest-DRR Research and Development Center of the Forestry and Forest Products Research Institute (FFPRI) published the Japanese edition of this book, “Forest-based Disaster Risk Reduction COOKBOOK,” in February 2025, under a subsidy project of the Forestry Agency. The cookbook is a technical guide that plainly explains the basic knowledge and technologies required to engage in disaster risk reduction using functions of forests. The cookbook consists of four parts: “Introduction,” “Planning,” “Technical,” and “Reference.” The “Introduction” section is intended for all individuals working on forest-based disaster risk reduction, the “Planning” section for planners of such projects, and the “Technical” section for engineers involved at the project level. The “Reference” section introduces trends in forest-based disaster risk reduction efforts using forests in developing countries. By reading “Introduction” and “Planning” together, or “Planning” and “Technical” together, readers can deepen their understanding.

Following positive feedback from readers of the Japanese edition and many inquiries asking, “When will the English version be available?”, we are pleased to present this provisional English translation. Every effort has been made to ensure the accuracy of this English translation; however, unintended errors may remain. Readers are kindly requested to consult the original Japanese edition available on the center’s website.

We hope that this provisional English translation will help expand understanding among international readers of forest-based disaster risk reduction, as published last year in Japanese by our center, and that it will contribute to reducing disasters in mountainous area and storm-surge damage occurring around the world.

February 2026

REDD-plus and Forest-DRR Research and Development Center
Forestry and Forest Products Research Institute (FFPRI)
Forest Research and Management Organization

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Introduction

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Chapter 1
Forest-based Disaster Risk Reduction

In recent years, there have been reports of increased intensity and frequency of heavy rainfall, extremely low-pressure cyclones, and increased frequency of typhoons on a global scale. This has led to a noticeable increase in the scale and frequency of slope disasters as well as severe storm surge damage in coastal areas. In addition, disorderly land use changes, such as the conversion of forest land to residential areas in mountainous and coastal regions, are exacerbating these damages. As a result, effective adaptation strategies for natural disasters caused by climate change have become a common global challenge.

This chapter explains the functions of forests and the concept of disaster risk reduction that utilizes these functions, then followed by introduction of the current state of natural disasters intensifying worldwide due to climate change and explains the role and risks of forests in disaster risk reduction under such circumstances.

Recipe - I01

What are the functions of forests?

Forests have a variety of functions that are closely related to human life, such as biodiversity conservation, global environment conservation, sediment and soil protection, water source conservation, comfort environment creation, health and recreation, culture, and material production. Among the various functions of forests, those useful for disaster risk reduction include sediment-related disaster prevention/soil conservation and water resources conservation. In order to maintain these multifunctions of forests in the future, proper management of forests is important. In particular, if the next generation of forests do not grow up on the site of logging, the root systems that developed before the logging will decay, and the disaster risk reduction functions of the forest will be reduced.

Functions of forests

Forests have various functions that directly and indirectly benefit human life. The functions of forests, generally referred to as multifunctional, can be broadly categorized into biodiversity conservation, global environment conservation, sediment-related disaster prevention/soil conservation, water resources conservation, comfort environment formation, health and recreation, cultural functions, and material production functions (Figure I01-1) [1), 2)]. In recent years, as a measure to mitigate climate change, attention has been focused on the global environmental conservation function of forests; absorbing carbon dioxide from the atmosphere, fixing carbon as organic substances within the trees, and releasing oxygen. At the same time, there is growing interest in the sediment-related disaster prevention/soil conservation and water resources conservation functions of forests as adaptation to natural disasters caused by the emerging effects of climate change.

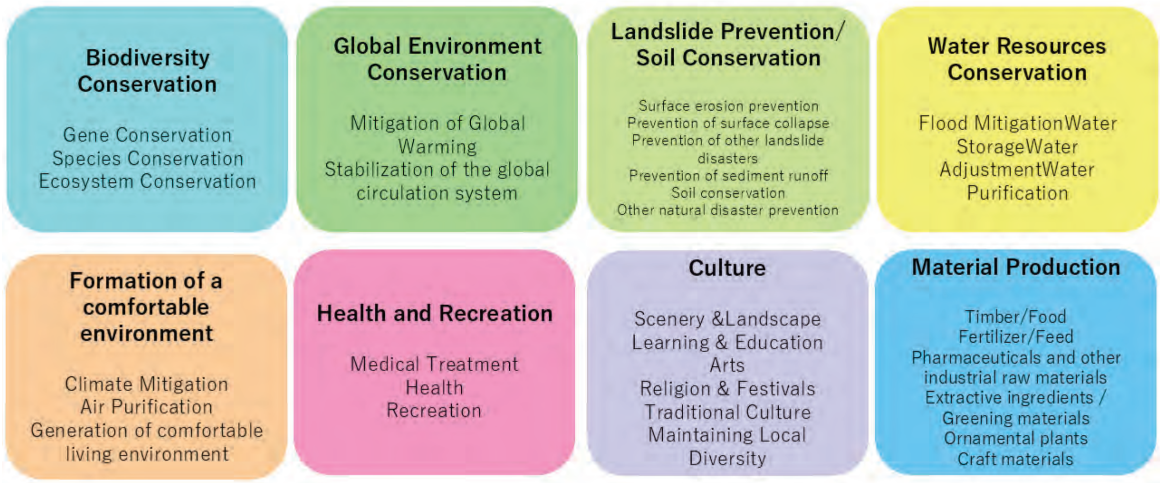
The material production function includes the production of environmentally friendly materials such as wood fuel, building materials, raw materials for wood products, and pulp, as well as the production of food such as mushrooms, fertilizers, feed, medicines, and other industrial materials, greening materials, ornamental plants, and craft materials. For biodiversity, it has fundamental functions such as preservation of genes, plant species, animal species, fungi, and other living species, and preservation of ecosystems. As for global environmental conservation functions, they absorb carbon dioxide through photosynthesis, fix carbon, and use it as an alternative energy source to fossil fuels to mitigate global warming, as well

INFO

1) Science Council of Japan (2001) *[Evaluation of the multifunctional roles of agriculture and forests related to the global environment and human life: Report]*

INFO

2) Forestry Agency (2018) Forest and Forestry White Paper (Fiscal Year 2017)



FigureI01-1 Multifunctional roles of forest [1), 2)]

as regulate the natural environment on a global scale by lowering temperature through transpiration, thereby contributing to stabilizing the global climate system. There is concern that deforestation and forest degradation in developing countries will not only impair these functions but also lead to the progression of global warming by releasing large amounts of carbon dioxide into the atmosphere through logging. Therefore, the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) has established a framework called REDD-plus, which aims to maintain the global environmental conservation function of forests. The REDD-plus framework is intended to maintain the global environmental conservation function of forests.

The value of these multifunctional functions varies greatly depending on the natural and social conditions under which forests grow. For example, forests growing in flat areas with little rainfall cannot prevent landslides, and forests that are difficult to access cannot be expected to provide health, recreation, or cultural functions. In addition, there are other functions that are performed beyond or outside of the area where the forests grow. Water rsources conservation functions benefit not only the area where the forest grows, but also its downstream areas. Global environmental conservation functions that mitigate global warming and stabilize the earth's climate are functions that contribute to issues at the global level.

Functions useful for disaster risk reduction

Among the various functions of forests, those useful for disaster risk reduction against natural disasters include sediment-related disaster prevention/soil conservation functions and water resources conservation functions.

・The functions of sediment-related disaster prevention/soil conservation

The sediment-related disaster prevention/soil conservation function is to prevent landslides through the root systems of forests and suppress the runoff of surface soil due to rainfall by covering the ground with trees and grasses, and is

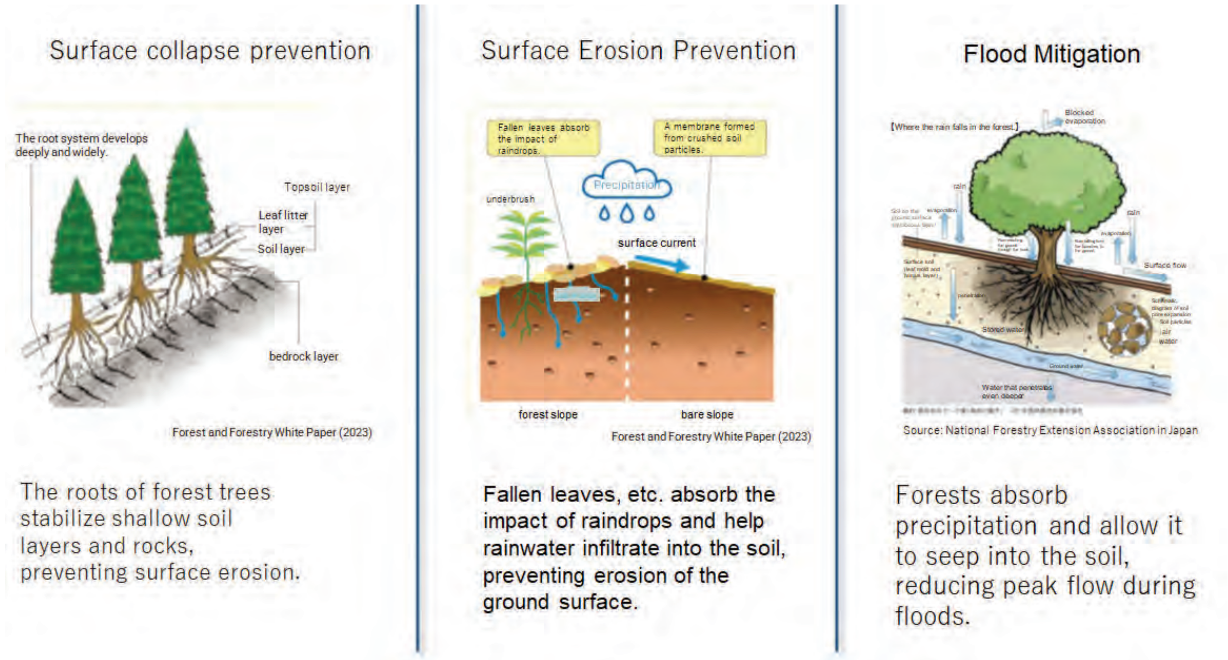


Figure I01-2 Disaster prevention and mitigation functions of forests [3), 5)]

expected to be highly effective through the growth and development of root systems and subsoil vegetation. Specifically, there are two functions: surface collapse prevention and surface erosion prevention (Figure I01-2) [3)].

INFO

3) Forestry Agency (2023) Forest and Forestry White Paper (Fiscal Year 2022)

Slope failure occurs when a mountain slope collapses due to heavy rainfall caused by typhoons or low-pressure systems, earthquakes, snowmelt, volcanic eruptions, topographical changes, etc. It is classified into “surface collapse” and “deep collapse” according to the depth and scale of the collapse. Among these, forests have the function of preventing “surface collapse” through the effect of tree root systems. In the case of deep collapses, the roots of trees do not have the ability to hold together sediment and rocks, and the forest function does not prevent collapses. In addition, heavy rains can cause the surface soil layer, including the root system, to collapse, so it is necessary to recognize the limitations of the forest's function to prevent surface collapse. The surface collapse prevention function of forests can be expected to be effective through a well-developed root system, and this function is reduced when the forest is cleared and the root system decays. It takes several years for the root system to completely decay, and in the process, the net effect of the horizontal root system and the pile effect of the vertical root system are gradually lost [4)].

INFO

4) Conservation Division, Private Forest Department, Forestry Agency (2023) *[The function of forest root systems in preventing shallow landslides]*

Surface erosion is caused by a variety of factors, including weather, topography, geology, and vegetation. In particular, surface erosion occurs when the impact of raindrops destroys the soil structure on the ground surface, making it difficult for water to penetrate into the soil, and surface flows generated along the slope scrape the ground surface. In contrast, forests prevent surface erosion by reducing raindrop energy through the upper vegetation and leaf litter, reducing surface flow velocity through stems and leaf litter, reducing surface flow through improved soil infiltration capacity, and binding soil particles to the sweeping force of surface flow through the root system.

・Water resources conservation function

The forest soil covered with fallen leaves and undergrowth plays an important role in the water resources conservation function of forests. The forest canopy and undergrowth catch precipitation, evaporate some of it, store it in the forest soil with high water retention capacity, and allow it to runoff to rivers over time, thereby reducing peak flows during floods (flood mitigation function) (Figure I01-2) [5]. In addition, water stored deep in forest soils and bedrock helps to maintain a certain volume of water by flowing out into rivers during periods of no rainfall by moving through them by various pathways and speeds (water volume control function). Forest soils also filter infiltrated water and purify the turbidity of runoff (water purification function). These functions are collectively referred to as the water source conservation function [3), 6)]. Among these functions, the flood mitigation function is useful for disaster prevention and mitigation.

INFO

5) Zenkoku Ringyo Kairyo Fukyu Kyokai (2007) *[Forest data book No. 2: Functions of forests]*

INFO

6) Conservation Division, Private Forest Department, Forestry Agency (2023) *[Toward the enhancement of forest water recharge (water retention) functions]*

Appropriate forest management to maintain forest functions

In order to ensure that the multifunctions of forests continue to be fulfilled in the future, appropriate forest management is necessary to actively create and nurture healthy forests through the efforts of humans. In order to quickly restore the functions of forests on former logging sites, planting is generally used. Without planting on logging sites, not only does it take a very long time for the forest to regenerate, but depending on the vegetation conditions, shrubs and pioneer species may still dominate even after a decade or more, and there may not be enough hardy species present. Forests regenerated by planting require appropriate nursery care, thinning, etc. thereafter. If these operations are not carried out properly, the planted trees will be overwhelmed by other plants and will not be able to grow adequately. If the next generation of forests does not grow on the site of logging for a long period of time, the root systems that developed before the logging will decay, and the disaster prevention and mitigation functions of the forest will be reduced.

Recipe - I02

Concept of forest-based disaster risk reduction

Refer to

Recipe-I01
What are the functions of forests? as a parent Recipe

Ecosystem-based Disaster Risk Reduction (Eco-DRR) is an approach that focuses on the role of ecosystems in addressing natural disaster risks and proactively leverages this role. "Green infrastructure" is defined as a strategically planned network of natural and semi-natural areas and other environmental features designed and managed to provide a wide range of ecosystem services, as opposed to "gray infrastructure," which refers to man-made infrastructure. *Chisan* techniques are those that maintain and create forests by stabilizing hillside slopes and rehabilitating degraded streams, thereby maintaining and improving forest functions. *Chisan* can be expected to be more effective by promoting appropriate land use planning, land use restrictions, and raising awareness of disaster prevention among local residents.

EbA, Eco-DRR, and forest-based disaster risk reduction

Ecosystem-based Adaptation (EbA) refers to the use of biodiversity and ecosystem services as part of adaptation strategies to adapt to the adverse effects of climate change [1]. EbA can be used to protect human communities from the impacts of climate change, including storm and flood damage, coastal erosion, salinization of freshwater resources, and reduced agricultural productivity, etc. The term EbA was first introduced at UNFCCC COP14 (2008) by the International Union for Conservation of Nature and Natural Resources (IUCN) and its member organizations [2]. Furthermore, in 2009, an expert group report was issued under the Convention on Biological Diversity (CBD) to formally define EbA [1].

Ecosystem-based Disaster Risk Reduction (Eco-DRR) is closely related to the EbA concept, but is not limited to climate change-related disasters. Eco-DRR is an approach that focuses on the role of ecosystems in natural disaster risk and actively utilizes them. Forests play a particularly important role in Eco-DRR. In recent years, there have been discussions and resolutions related to adaptation, disaster risk reduction, and Eco-DRR in various international frameworks (Table I02-1).

The basic idea of Eco-DRR is to “lower the risk of natural disasters by avoiding exposure through the maintenance of natural land use (choice not to live or use) and reducing vulnerability through physical protection of ecosystems, such as forests and coral reefs (mitigation of the effects of hazard reduction)" (Figure I02-1) [3]. Here, exposure avoidance refers to avoiding exposure of human lives and property to hazardous natural phenomena by avoiding construction of housing and road infrastructure facilities on land vulnerable to natural disasters, such as

INFO

1) Secretariat of CBD (2009) Connecting biodiversity and climate change mitigation and adaptation: Report of the second ad hoc technical expert group on biodiversity and climate change

INFO

2) UNFCCC Secretariat (2008) Ideas and proposals on the elements contained in paragraph 1 of the Bali Action Plan

INFO

3) Ministry of the Environment (Japan) (2016) *[Concepts on ecosystem-based disaster risk reduction and mitigation]*

near steep slopes with high risk of landslides and coastal areas susceptible to tsunami and storm surges. Vulnerability reduction also refers to reducing the vulnerability of a society to disasters and allowing ecosystems to function as physical buffers to mitigate hazardous natural phenomena, such as coastal forests protecting people's homes from wind and blowing sand from the sea and attenuating tsunami energy.

Eco-DRR is classified into four types by the Ministry of the Environment of Japan [3] and Japan International Cooperation Agency (JICA) [4]: ecosystem conservation and management (e.g., establishment of protected areas), rehabilitation of degraded ecosystems (e.g., appropriate management of forests), creation of new ecosystems (e.g., afforestation), and integration of ecosystems and man-made structures (e.g., *Chisan* projects).

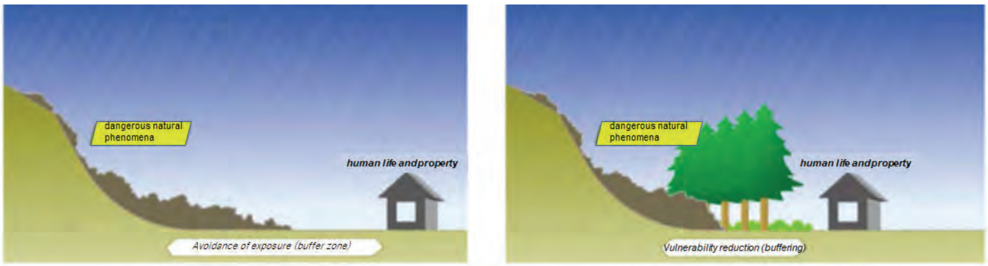
In forest-based disaster risk reduction, the maintenance and management of plantation trees, for example, and other subsequent care are also extremely important to ensure that the forest functions effectively. In order to maintain and properly renew the functions over decades, it is essential to establish a strong

INFO

4) JICA (2017) Ecosystem-based Disaster Risk Reduction (Eco-DRR): Practices, Effects, International Trends and JICA's Initiatives nternational Trends and JICA's Initiatives

Table I02-1 Discussions, resolutions, and initiatives related to adaptation, disaster prevention and mitigation, Eco-DRR, etc. in major international frameworks

International Framework	Discussions, resolutions, and initiatives related to adaptation, disaster risk reduction, Eco-DRR, etc.
United Nations World Conference on Disaster Risk Reduction "Sendai Framework for Disaster Risk Reduction 2015-2030" (2015)	At the Third United Nations World Conference on Disaster Risk Reduction held in Sendai in March 2015, the Sendai Framework for Disaster Risk Reduction 2015-2030, an international guideline for disaster prevention and mitigation after 2015, was agreed upon. Ecosystems were positioned as a means of disaster risk reduction, with emphasis placed on strengthening their sustainable use and management. The following priorities were identified: (1) promoting an ecosystem-based approach internationally, (2) assessing disaster risks in high-risk areas such as mountainous regions and river basins and floodplains, and (3) implementing an environmental and natural resource management approach that integrates the sustainable use and management of ecosystems with disaster risk reduction.
United Nations Framework Convention on Climate Change "Paris Agreement" (2015)	The Paris Agreement was adopted at the 21st Conference of the Parties (COP21) in November 2015. Adaptation was positioned in Article 7. It refers to the need to consider ecosystems in climate change adaptation measures.
Convention on Biological Diversity, "Biodiversity, Climate Change, and Disaster Risk Reduction" (2014)	At the 12th Conference of the Parties in 2014, "biodiversity, climate change, and disaster risk reduction" was one of the topics discussed, and countries were recommended to incorporate ecosystem-based approaches into their domestic disaster risk reduction policies.
Ramsar Convention (2014)	At the 12th Conference of the Parties in 2014, the disaster prevention role of wetland ecosystems was recognized, and parties were encouraged to incorporate wetland-based disaster prevention into national strategies and related policies, as well as to assess the disaster risks of wetlands.
Partnership for Environment and Disaster Risk Reduction (PEDRR)	Established in 2008, it consists of international organizations such as the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN), as well as NGOs and research institutions. It is working to promote and expand the implementation of Eco-DRR and mainstream it into development plans at the international, national, and local levels.



1-Avoiding exposure 2-Avoiding vulnerabilities

Figure I02-1 Principles of disaster mitigation applicable to Eco-DRR [3]

implementation system with local stakeholders, including local residents, and to transfer sufficient technology and know-how. In addition to forest activities such as afforestation, education and awareness-raising activities related to forest-based disaster risk reduction should also be conducted, and the leaders of such activities should be included in the system. Compared to man-made structures, Eco-DRR measures require more time before they are effective, and their effectiveness is more uncertain. Recognizing these weaknesses and limitations of forest-based disaster risk reduction, the secondary effects of forests and ecosystems (contribution to local livelihoods, provision of ecosystem services, etc.) should also be properly evaluated, and a comprehensive decision should be made to choose forest-based disaster risk reduction as a method.

Gray infrastructure and green infrastructure

Green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services, including water purification and regulation, air quality improvement, recreation and well-being, and climate mitigation and adaptation [5]. Green infrastructure can be utilized in a variety of areas such as rainwater management, climate adaptation, heat stress reduction, increased biodiversity, food production, air quality improvement, sustainable energy production, clean water, healthy soils, etc., as well as for human-centered functions such as enhancing quality of life through recreation and providing shade and shelter around towns and cities. They also serve to provide an ecological framework for social, economic, and environmental health. For example, in some cases, networks of green corridors have been planned to facilitate animal migration.

Green infrastructure is defined in contrast to gray infrastructure, which refers to man-made infrastructure such as transportation networks and waterway networks. On the other hand, there are examples of hybrid green and gray infrastructure, such as rooftop greening, wall greening, and transportation infrastructure that takes ecological continuity into consideration. Furthermore, there are also infrastructures positioned in the gradation stage from green to gray. Japan has positioned green infrastructure as a concept that includes disaster prevention [6]. The Ministry of Land, Infrastructure, Transport, and Tourism of Japan (MLIT) formulated the "Strategy for Promoting Green Infrastructure in 2019. The

INFO

5) European Commission (2013) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Green Infrastructure (GI) - Enhancing Europe’s Natural Capital

INFO

6) Ministry of Land, Infrastructure, Transport and Tourism (2016) *[Green infrastructure: Toward a better relationship between people and the natural environment]*

strategy emphasizes various roles of green infrastructure that should be developed, including addressing climate change, including related disaster risk reduction, regional revitalization, and ecosystem functions [7].

INFO

7) Ministry of Land, Infrastructure, Transport and Tourism (2019) Green Infrastructure Promotion Strategy (2019)

Philosophy of '*Chisan*'

Chisan technology is a technology to maintain and improve the functions of forests by maintaining and building forests through stabilization of hillside slopes and restoration and maintenance of devastated streams. This technology is expected to make a significant contribution to comprehensive disaster prevention measures by enhancing the forest's functions of preventing landslides, preserving soil, and conserving water resources, thereby protecting residents' lives and property from slope failure and other sediment-related disasters, and reducing the risk of flood damage through flood mitigation functions. In addition, the technology is also expected to contribute to global warming countermeasures through forest carbon capture.

The effectiveness of *Chisan* can be enhanced by promoting appropriate land use planning, land use restrictions, and raising awareness of disaster prevention among local residents. In the targeted developing countries, sustainable *Chisan* can be achieved with the cooperation of local residents and by utilizing traditional wisdom and technology. In this way, the concept of *Chisan* contributes not only to disaster risk reduction, but also to environmental conservation and the revitalization of local communities.

Recipe - I03

Intensifying natural disasters

Globally, the risk of natural disasters associated with climate change is increasing, and disasters are becoming more intense. Over the past 30 years, the most frequently reported disasters have been floods and flash floods, with Asia being the region with the highest number of reported disasters. Sixty percent of slope disasters and landslides that have occurred worldwide have been reported in Asia. During periods of economic growth, there is a strong tendency to disregard traditional land use rules, and the use of land with high disaster risks can lead to the occurrence of mountain disasters. In such regions, appropriate land use planning, land use restrictions, and disaster prevention and environmental awareness among residents are necessary. Extreme phenomena associated with climate change affect not only developed countries but also developing countries, and in particular, developing countries in low-latitude regions of Asia are concerned about the increasing intensity and frequency of heavy rainfall.

Types and trends of natural disasters

Globally, the risk of natural disasters associated with climate change is increasing, and disasters are becoming more intense. In addition, in developing countries, disorderly land changes, such as the conversion of forests to farmland, are exacerbating disasters. Over the past 30 years, the most frequently reported disasters have been floods and flash floods, accounting for more than 40% of all disasters. In contrast, landslides and mudslides account for only 5.6% of all disasters. However, landslides and mudslides can occur as secondary effects when

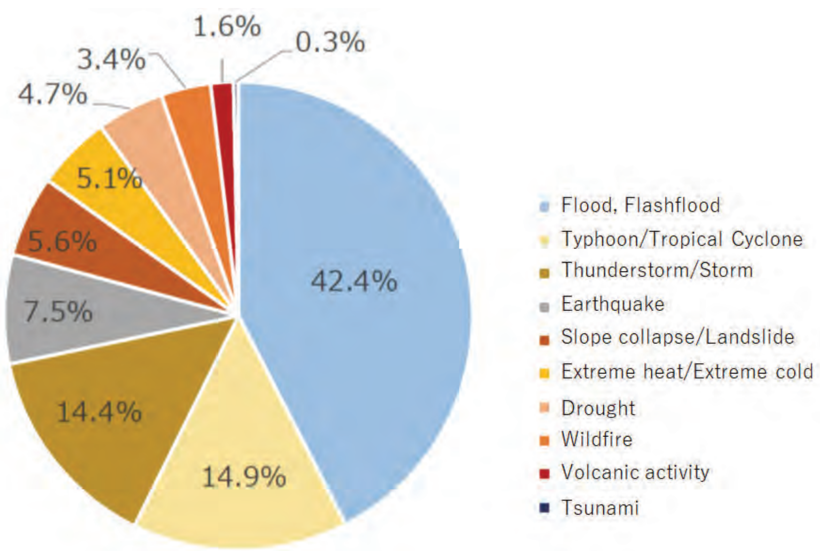


Figure I03-1 Number of disasters worldwide (1991–2020, 10,045 incidents)
Created from 1)

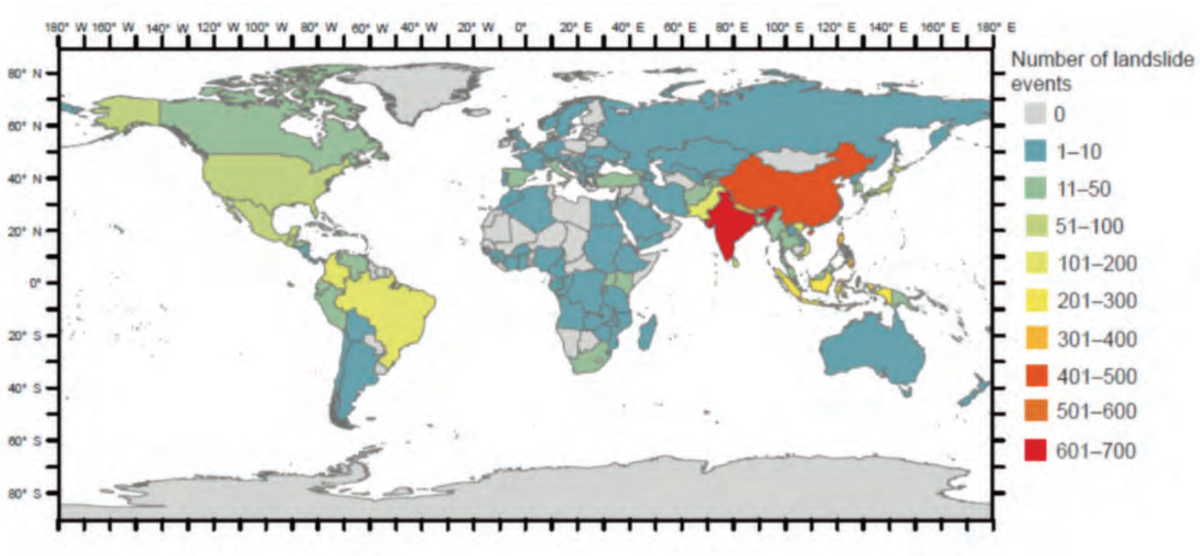


Figure I03-2 Number of non-seismically triggered fatal landslide events from 2004 to 2016 by country [2)]

floods, flash floods, earthquakes, typhoons, or tropical cyclones occur. In such cases, the damage from landslides and mudslides is often lumped together with the damage from floods, flash floods, earthquakes, typhoons, or tropical cyclones, and it is estimated that the actual damage from landslides and mudslides is greater than the data values indicate (Figure I03-1) [1)].

60% of the slope failures and landslides that have occurred worldwide have been reported in Asia, including China, India, Indonesia, and Nepal (Figure I03-2) [2)]. Although Asia accounts for less than 30% of the world's land, it has a high population density, with about 60% of the world's population living in Asia. In addition, there are multiple plate boundaries in Asia, forming various trenches and mountain ranges. Furthermore, during the summer, large amounts of water vapor from the Indian Ocean and Pacific Ocean bring heavy rainfall. Due to these factors, Asia experiences more disasters caused by volcanoes, earthquakes, floods, typhoons, and tropical cyclones than other regions.

Asia is the region with the highest number of reported disasters over the past 30 years (Figure I03-3) [1)]. Among disasters that occurred between 2010 and 2020, the number of victims was highest in Asia, followed by Africa and North America, while the economic damage was greatest in Asia, followed by North America and Europe. Regarding the economic damage figures, in developed countries, natural disasters are often covered by disaster insurance systems, which collect extensive information, and the average value of damaged houses and other structures tends to be higher than in developing countries, leading to larger damage figures. On the other hand, in developing countries, disaster insurance systems are underdeveloped, making it difficult to accurately assess damage. Additionally, infrastructure investments during recovery and the average value of a single house are lower compared to developed countries, leading to smaller reported damage amounts.

INFO

1) EM-DAT
https://www.emdat.be/

INFO

2) Melanie J. Froude and David N. Petley (2018) Global fatal landslide occurrence from 2004 to 2016. Nat. Hazards Earth Syst. Sci., 18, 2161–2181

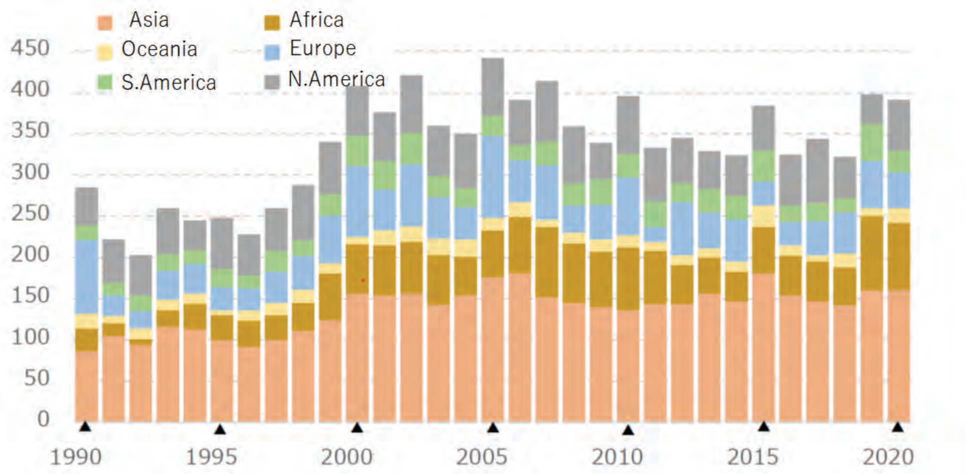


Figure I03-3 Number of disaster reports by region Created from 1)

Increased risks due to development

When a country's economy grows rapidly, inappropriate land use can lead to frequent sediment-related disasters, as has been seen in Japan and other parts of the world. During periods of economic growth, when industrial activity becomes more active and the population increases rapidly, traditional land use rules tend to be neglected, and the use of land with high disaster risk can lead to sediment-related disasters. Unregulated deforestation and road construction without consideration for drainage functions in mountainous regions increase slope vulnerability, causing sediment-related disasters such as slope collapses and surface erosion during heavy rains. These disasters not only damage farmland and homes that serve as livelihood means for people living in mountainous areas but can also result in severe disasters that claim human lives. Additionally, mangroves in coastal areas not only have a high wave-breaking effect but also reduce coastal erosion by acting as a seawall through their root systems. However, cutting down mangroves to develop aquaculture ponds, farmland, or rice fields results in the loss of seawall functions, leading to flood damage spreading inland during high tides. Such unregulated land alterations increase the vulnerability and exposure of natural systems, exacerbating hazard risks and further escalating disaster risks associated with extreme events.

In such areas, appropriate land use planning, land use restrictions, and residents' awareness of disaster prevention and the environment are necessary. In particular, in the monsoon Asia region, which is prone to disasters, appropriate land use restrictions may limit economic activity in the short term, but from a long-term national perspective, there is no doubt that they contribute to the safety of residents. In Japan, there are numerous cases where residential development in areas with high disaster risk has been linked to disasters. However, in developing countries where disaster risk reduction measures are just beginning to be implemented, it is essential to introduce planned land use and promote disaster risk awareness. In coastal areas, it is important to evaluate and preserve the disaster risk reduction functions of coastal areas against storm surge damage caused by mangroves, etc., at an early stage. Raising awareness of the disaster risks associated with land will lead to a reduction in disaster prevention budgets and stability in people's lives in the future, and is considered to be extremely cost-effective in terms of investment in the future.

Risks associated with climate change

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) points out that anthropogenic climate change is causing a wide range of adverse effects and associated losses and damages to nature and humans that exceed those caused by natural climate change [3)]. Abnormal development of low-pressure systems, including typhoons, hurricanes, and cyclones, has led to an increase in the intensity and frequency of heavy rainfall, which can cause sediment-related disasters in mountainous areas and storm surge disasters in coastal areas, as well as abnormal rises in sea levels and other extreme phenomena observed on a global scale. According to the IPCC's socio-economic scenarios (Shared Socioeconomic Pathways: SSPs), these extreme phenomena are expected to become stronger and more frequent in the future, raising concerns about the intensification of disasters worldwide. Such extreme phenomena associated with climate change affect not only developed countries but also developing countries, and there are particular concerns about the increasing intensity and frequency of heavy rainfall in developing countries in low-latitude Asian regions where heavy rainfall occurs during the rainy season.

INFO

3) IPCC (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability - Summary for Policymakers

Recipe - I04

Role and risks of forests in disaster risk reduction

Refer to

Recipe-I02
Concept of forest-based disaster risk reduction as a parent Recipe

Sediment-related disasters are caused by a combination of predisposing factors such as geology, topography, slope, soil, and vegetation, and triggering factors such as rainfall and earthquakes. The two main functions of forests in preventing landslides are to cover the ground with tree branches and fallen leaves to prevent soil erosion and runoff caused by rainwater, and to prevent landslides by anchoring soil and rocks with tree roots. The function of the tree root system in preventing surface collapse is to suppress the movement of sediment by roots extending horizontally and spreading out like a net, and the function of roots extending vertically beneath the tree to anchor the tree like a stake and act as a resistant force to suppress sediment movement when a collapse is about to occur. Coastal forests also play a role in protecting the lives and property of people living in coastal areas and enriching their lives by fulfilling their function of disaster prevention.

Forest functions against mountain disasters

Sediment-related disasters in mountainous areas are influenced by predisposing factors such as geology, topography, slope, soil, and vegetation. In mountainous areas in particular, the predisposing factors to landslides can be reduced by maintaining healthy forests. However, the presence of predisposing factors alone is not enough to cause disasters in mountainous areas; they must be combined with triggering factors such as rainfall and earthquakes that trigger the occurrence of the disasters [1]. In particular, in recent years, climate change has caused typhoons, tropical cyclones, and linear precipitation zones to grow in size, which in turn cause disasters in mountainous areas when strong rains continue for a long period of time.

Slope collapse is the collapse of mountain slopes caused by heavy rainfall from

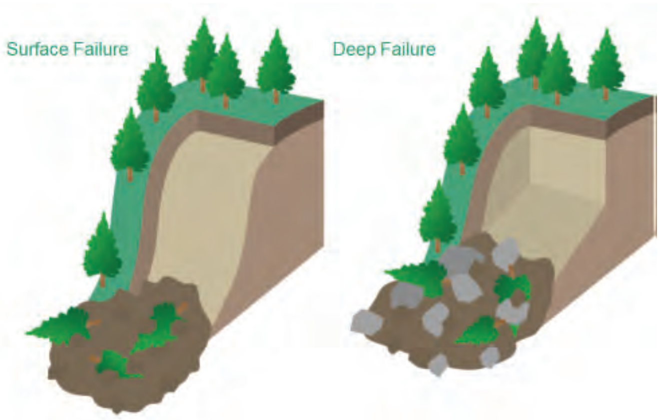


Figure I04-1 Types of Slope Collapse [2]

INFO

1) Conservation Division, Private Forest Department, Forestry Agency (2023) *[Draft guidelines for planning forest management to enhance the shallow landslide prevention function of forests]*

typhoons and cyclones, earthquakes, snowmelt, volcanic eruptions, and landform alteration. Slope collapses are classified into several types according to the mechanism of occurrence and the way sediments move, and among them, the depth of collapse is relevant to forests. Slope collapses are classified into two categories according to the depth and scale of the collapse: surface collapses and deep collapses (Figure I04-1). Forests have the function of preventing "surface collapses" among these types of collapses. It cannot prevent deep collapse, which occurs at depths that roots cannot reach [1), 2)].

Regarding the relationship between surface collapses occurring in mountainous areas and forests, researchers have statistically shown that the presence of forests reduces the number and frequency of collapse sites. On the other hand, there are few studies on how forests reduce the occurrence of surface collapses and how the reduction is affected by the quality of forest maintenance, and forest maintenance methods to enhance forests' anti-collapse function have not been established.

It is recognized that the surface collapse prevention function of forests is mainly provided by their root systems. Regarding the effects of forest improvement such as controlled logging on the root systems of trees, certain research results have been accumulated, such as root decay of harvested trees and an increase in the amount of growth of the root systems of remaining trees as a result of increased openness due to controlled logging, and quantitative evaluation methods have been established, but research is still in its developing stage and many things remain unknown.

The effect of tree root systems in preventing surface collapse is mainly due to the net effect of roots extending horizontally along the ground surface and

INFO

2) Conservation Division, Private Forest Department, Forestry Agency (2023) *[The function of forest root systems in preventing shallow landslides]*

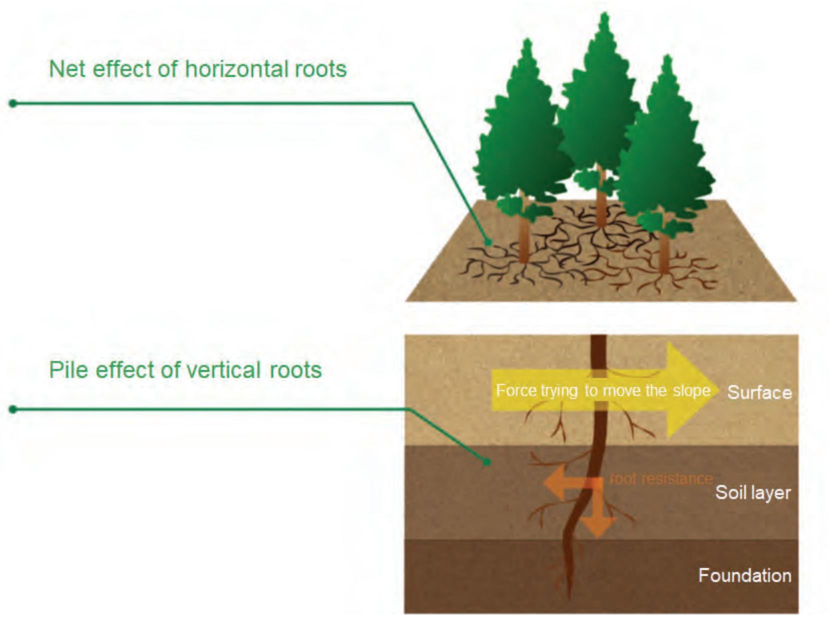


Figure I04-2 Effectiveness of tree root systems in preventing landslide [2)] intertwining with each other to suppress sediment movement (the net effect of horizontal roots) and the root system of vertical roots extending vertically beneath the tree, which connect to hard rock crevices in deeper areas to anchor the tree like a pile, thereby preventing the collapse. The vertical roots under the tree connect to the hard bedrock in the deeper part of the tree and act like a pile to hold the tree in place and prevent sediment movement when a collapse is about to occur (the pile effect of vertical root) (Fig. I04-2) [2].

Limitations of the landslide prevention function of forests

While it is clear that forests have a collapse prevention function, there are also limitations to this function. It is not possible to prevent all surface collapses, as collapses have occurred even on forested mountains. It is known that in the case of heavy rainfalls above a certain size, even forests may not be able to control collapses.

One important point to keep in mind when considering the collapse prevention function of forests is that the collapse prevention function is temporarily reduced when forests are cut down. In addition, the degree of decline in root mass changes when comparing clearcutting to thinning due to the different intensity of harvesting, and the degree and duration of decline in the collapse prevention function also changes. Since the root systems of harvested trees decay within a few years, the netting and piling effects are gradually lost and the collapse prevention function declines, so that even if new trees are planted after harvesting, the collapse prevention function will remain low for about 10 to 20 years until the trees become large (Figure I04-3) [2].

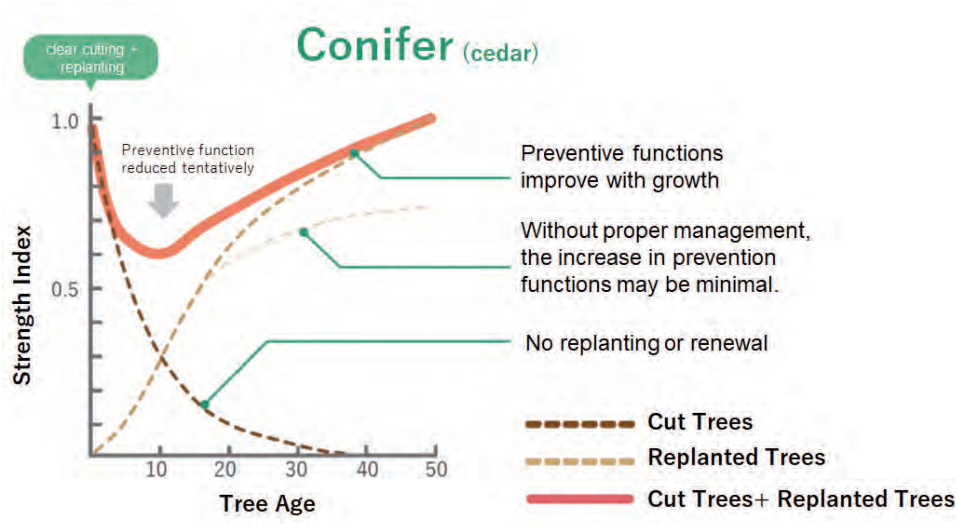


Figure I04-3 Relationship between forest age and collapse prevention function [2]

Role and limitations of coastal forests

In recent years, with the progression of climate change, an increase in the frequency of very low pressure cyclones and typhoons has been reported, causing serious damage from storm surges and high waves in coastal areas. Coastal forests, including mangroves, in coastal areas not only mitigate the force of waves from the ocean, but their root systems also serve as shore protection. However, the development of aquaculture ponds and agricultural lands due to economic growth has led to deforestation and coastal erosion. This has resulted in the loss of the function of coastal protection against storm surges and tidal waves, and when storm surges and tidal waves occur, the damage is spread further inland. Coastal forests play a role in protecting the lives and property of people living in coastal areas and enriching their lives by fulfilling disaster prevention functions [3)].

Tidal damage, a typical disaster in coastal areas, refers to damage caused by sea breezes, storm surges, and tsunamis. When dense salty sea breezes blow deep inland from the coast, they cause extensive damage to crops and other plants, buildings, automobiles, and infrastructure. In addition, storm surges, which are caused by an abnormal rise in sea level due to typhoons and developing low-pressure systems, and tsunamis, which are generated when sea level changes due to a large earthquake that occurs under the sea floor, can cause damage such as flooding to houses and arable land and people being carried away by waves as sea water enters the inland area.

In order to drastically improve the disaster prevention function of coastal forests, it is necessary to expand the width of the forest zone. The wider the forest, the more effective the vortex viscosity will be in reducing the force of waves against larger storm surges, tidal waves, and tsunamis. This will also reduce the wave force on trees on the inland side, resulting in more surviving trees, which will increase the resilience of the forest zone and increase its effectiveness in trapping drifting debris.

INFO

3) Conservation Division, Private Forest Department, Forestry Agency (2023) *[Aiming for disaster-resilient overseas protection forest]*

2

Chapter 2 International Trends towards Disaster Risk Reduction

From the perspective of climate change adaptation, discussions and initiatives aimed at disaster risk reduction are becoming increasingly active on the international stage. The IPCC refers to the risks posed by climate change and adaptation measures in its assessment reports, and discussions on avoiding climate change risks have begun at the UNFCCC COP, where mitigation measures have been the main topic of discussion.

This chapter introduces discussions on climate change adaptation at IPCC and UN-related meetings. It also organizes the current status and challenges of Japan's bilateral aid for climate change adaptation through ODA, international aid frameworks funded by contributions from Japan and other countries, and disaster risk reduction projects by international organizations such as the World Bank and the Asian Development Bank.

Recipe - I05

Discussion at IPCC

The IPCC's Sixth Assessment Report concludes that "it is unequivocal" that human influence has warmed the atmosphere, ocean and land, and that the frequency and intensity of heavy precipitation events have increased since the 1950s, the global proportion of major (Category 3-5) tropical cyclone occurrence has increased over the last four decades. The report also indicates that the ice loss on land and thermal expansion from ocean warming have caused global mean sea level to rise. The report also predicts an increase in annual mean precipitation and global mean sea level will continue to rise over the 21st century. Such sea level rise will cause damage to coastal settlements and infrastructure, and storm surges and heavy rainfall will combine to increase the risk of combined flooding.

What is IPCC

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental organization established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), and as of March 2022, 195 countries and regions join the IPCC. The IPCC has three Working Groups (WGs) and one Inventory Task Force (TFI). The roles of each are as follows

WG1: Assessment of the physical science basis of the climate system and climate change

WG2: Assessment of the vulnerability of socio-economic and natural systems to climate change, the negative and positive consequences of climate change and options for adapting to it

WG3: Climate change mitigation, assessing methods for reducing greenhouse gas emissions, and removing greenhouse gases from the atmosphere

TFI: Responsible for the internationally-agreed methodologies used for the calculation of national anthropogenic greenhouse gas emissions and removals by signatories to UNFCC and its Paris Agreement

The purpose of the IPCC is to provide regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. With the help of scientists from around the world, the IPCC regularly prepares assessment reports based on the published literature and provides an evaluation of the latest scientific knowledge on climate change. Special reports are prepared on key topics related to climate change. Special reports related to natural hazards and adaptation include the "Special Report on Managing the Risks of Extreme Events and Disasters to Promote Adaptation to Climate Change (SREX)" and the "Special Report on the Ocean and Cryosphere in the Climate Change (SROCC)." These reports are presented here in the order in order of publication.

Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

Following a proposal by Norway and the International Strategy for Disaster Reduction (ISDR), the IPCC prepared the SREX [1)] in 2012. This report assessed the scientific literature on the relationship between climate change and extreme weather and climate events (extreme weather and climate events) and the impact of these events on sustainable development, and was prepared for use by policy makers and others in climate change-related disaster risk management and climate change adaptation measures.

The report notes that economic losses from weather- and climate-related disasters have increased, but with large spatial and interannual variability (high confidence, based on high agreement, medium evidence). With regard to extreme events and their impacts, the report predicts that it is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe, and it is very likely that mean sea level rise will contribute to upward trends in extreme coastal high water levels in the future. In addressing managing changing risks of climate extremes and disasters, the report suggests that multi-hazard risk management approaches provide opportunities to reduce complex and compound hazards (high agreement, robust evidence), that integration of local knowledge with additional scientific and technical knowledge can improve disaster risk reduction and climate change adaptation (high agreement, robust evidence), and that An iterative process of monitoring, research, evaluation, learning, and innovation can reduce disaster risk and promote adaptive management in the context of climate extremes (high agreement, robust evidence).

The report also defines the core concepts central to the SREX.

Climate Extreme (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as `climate extremes.

Exposure: The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected.

Disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions,

INFO

1) IPCC (2012) Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., et al. (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 3-21.

leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Disaster Risk: The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Disaster Risk Management: Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, resilience, and sustainable development.

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Transformation: The altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems)

Special Report on Ocean and Cryosphere in a Changing Climate

The IPCC decided to prepare SROCC (commonly known as the "Ocean and Cryosphere Special Report") [2] at its 43rd General Assembly, held in Nairobi, Kenya in April 2016, and the report was approved at the September 2019 meeting in Monaco. The report was approved and accepted by the 51st General Assembly. This report is an important document that provides the scientific basis for international efforts to address global warming in the ocean and cryosphere.

It is noted that coastal communities are exposed to multiple climate-related hazards, including tropical cyclones, extreme sea levels and flooding, marine heatwaves, sea ice loss, and permafrost thaw (high confidence). In addition, extreme sea levels and coastal hazards will be exacerbated by projected increases in tropical cyclone intensity and precipitation (high confidence), requiring responses to address sea level rise (Figure I05-1).

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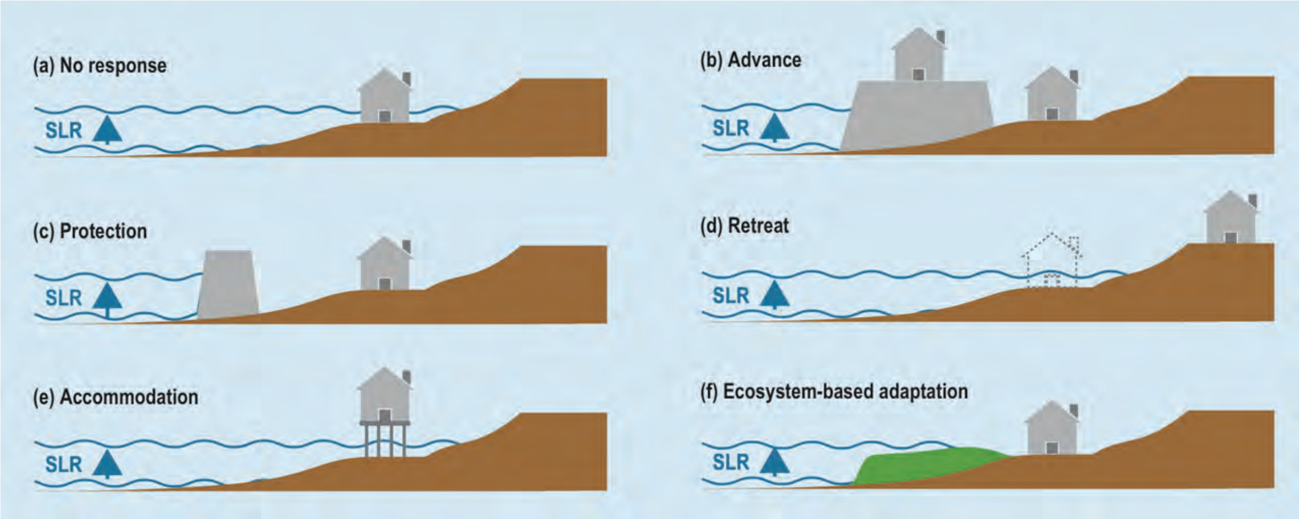
2) IPCC (2019) : IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [Pörtner H. -O., et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 755 pp.



FigureI05-1 Different types of responses to coastal risk and sea level rise (SLR) [2)]

IPCC Sixth Assessment Report

Each of the IPCC's Sixth Assessment Reports was written by WGs, with WG I reporting on "Natural Science Basis," [3)] WG II on "Impacts, Adaptation and Vulnerability" [4)] and WG III on "Climate Change Mitigation." [5)]

The report concludes that "it is unequivocal" that human influence has warmed the atmosphere, ocean, and land, which is a higher level of likelihood than the "extremely high (>95%)" noted in the Fifth Assessment Report. The report further states that the frequency and intensity of heavy precipitation over land have increased since the 1950s, and that the incidence of strong tropical cyclones has increased over the past 40 years as an observed fact. The report then points out that heat storage in the climate system has caused a rise in the global mean sea level due to the icesheet melt and thermal expansion caused by ocean warming.

As for the future, they project that annual mean precipitation at the end of the century (2081-2100) will be up to 13% higher than it was between 1995 and 2014. In particular, monsoon-related precipitation is projected to increase globally over the medium to long term, particularly in South Asia, Southeast Asia, East Asia, and West Africa. It is also projected that global mean sea level by 2100 will be 0.28 to 1.01 meters higher than it was between 1995 and 2014. The report then points out that such continuous and accelerated sea-level rise will cause damage to coastal settlements and infrastructure, and that storm surges and heavy rainfall will combine to increase the combined flood risk.

INFO

3) IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press 2391 pp.

INFO

4) IPCC (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Pörtner H.-O., et al. (eds.)]. Cambridge University Press. 3056 pp.

INFO

5) IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Shukla P. R., et al. (eds.)]. Cambridge University Press.

Recipe - I06

Discussions at the United Nations

In 2015, the United Nations hosted the 3rd UN World Conference on Disaster Risk Reduction, UN Summit on Sustainable Development, and COP21 of the UNFCCC as conferences related to climate change adaptation. These conferences adopted the "Sendai Framework for Disaster Reduction 2015-2030, the "Sustainable Development Goals (SDGs)," and the "Paris Agreement," which have a significant impact on current climate change measures. The Sendai Framework for Disaster Risk Reduction advocates the concept of "prevent new and reduce existing disaster risk." The SDGs set a target of "strengthening resilience and adaptive capacity of all countries to withstand climate-related and natural disasters. Article 7 of the Paris Agreement sets a global goal for adaptation, namely, strengthening resilience and reducing vulnerability to climate change.

Three international frameworks related to climate change adaptation

With climate change becoming more apparent, 2015 was a major starting point for climate change action in international frameworks by the United Nations.

First, the 3rd United Nations World Conference on Disaster Risk Reduction was held in Sendai in March 2015. Both the 1st (Yokohama, 1994) and the 2nd (Kobe, 2005) conferences of this UN-organized conference, which discusses international disaster risk reduction strategies, were held in Japan. The decision to hold this conference in Sendai was made in 2013, two years after the Great East Japan Earthquake. “The Sendai Framework for Disaster Risk Reduction 2015-2030," [1] a guideline for international disaster risk reduction efforts through 2030 adopted at this conference, aims to significantly reduce disaster losses to human life and other national economic and social assets over the 15-year period from 2015 to 2030. To this end, the concept of “prevent new and reduce existing disaster risk," in which potential risk factors of disasters are addressed in advance, is advocated. For disaster risk reduction, decision-making based on the latest scientific data from various angles will be required. Predicting the risk of disaster occurrence will also be important for proactive disaster prevention, and a variety of spatial information for prediction will be necessary. The risk of disasters due to climate change is increasing year by year, and there is an urgent need to build a system to maintain a sustainable society against climate change.

Six months later, in September 2015, the Sustainable Development Summit was held at UN Headquarters in New York. At this meeting, the “2030 Agenda for

INFO

1) Sendai Framework for Disaster Risk Reduction 2015–2030
https://www.mofa.go.jp/mofaj/files/000081166.pdf

Sustainable Development" [2] was adopted. The world now faces various problems such as poverty, gender and education disparities, resource issues, and environmental problems. In order to realize a sustainable society where no one is left behind, the “Sustainable Development Goals (SDGs)," which have now become a part of our daily lives, have been established. The SDGs set 17 goals to solve social, economic, and environmental problems and 169 targets to achieve them. For climate change, Goal 13 is to "take urgent measures to mitigate climate change and its impacts. Within this target, a target was set to "strengthen resilience and adaptive capacity of all countries to climate-related hazards and natural disasters.

Then, in December 2015, UNFCCC COP21 was held in Paris; the COP adopted the Paris Agreement [3], a new implementation agreement on post-2020 climate change issues. To enter into force, the Paris Agreement needed to be ratified by at least 55 countries and the total greenhouse gas emissions of those countries had to be at least 55% of global emissions. The Paris Agreement sets a Global Goal on Adaptation (GGA), which consists of building capacity for adaptation and strengthening resilience and reducing vulnerability to climate change, and is supposed to contribute to sustainable development.

INFO

2) Transforming our world: the 2030 Agenda for Sustainable Development https://www.mofa.go.jp/mofaj/gaiko/oda/sdgs/pdf/000101502.pdf

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3) Paris Agreement https://www.mofa.go.jp/mofaj/files/000197312.pdf

The UN World Conference on Disaster Risk Reduction

Specific disaster risk reduction efforts based on “Nature-based Solutions (NbS)" have been driven by discussions at the three “UN World Conferences on Disaster Risk Reduction" held in Yokohama (1994), Kobe (2005), and Sendai (2015). The Sendai Framework for Disaster Reduction (2015-2030) was adopted at the Sendai Conference as a successor to the “Yokohama Strategy and Action Plan (1994-2005)" and the “Hyogo Framework for Action (2005-2015)." The priority action guidelines were 1) understanding disaster risk, 2) disaster risk governance for disaster risk management, 3) investment in disaster risk reduction for resilience, and 4) strengthening preparedness for effective emergency response and “Build Back Better". After the Yokohama Conference, the “United Nations International Strategy for Disaster Reduction (UNISDR)," established in 1999, was renamed the “United Nations Office for Disaster Risk Reduction (UNDRR)" in 2019, and the UNDRR is currently taking the lead in international discussions on disaster risk reduction in line with the Sendai Framework for Disaster Risk Reduction. A noteworthy international trend in disaster risk reduction in recent years is the growing recognition of the interconnectedness of climate change, biodiversity, sustainable development, and disaster risk reduction (Figure I06-1) [4]. Especially since the mid-2000s, this trend appears to have intensified, and more integrated concepts and approaches are increasingly being adopted.

The Sendai Framework for Disaster Ris Reduction recognizes that disaster risk reduction is a cost-effective investment in preventing future losses, and that it is essential to anticipate, plan for, and reduce disaster risks in order to more effectively protect people, communities, nations, their livelihoods, health, cultural

INFO

4) Prime Minister's Office (2018) Overseas Deployment Strategy (Disaster Risk Reduction) https://www.kantei.go.jp/jp/singi/keikyou/dai40/bousai_honbun.pdf

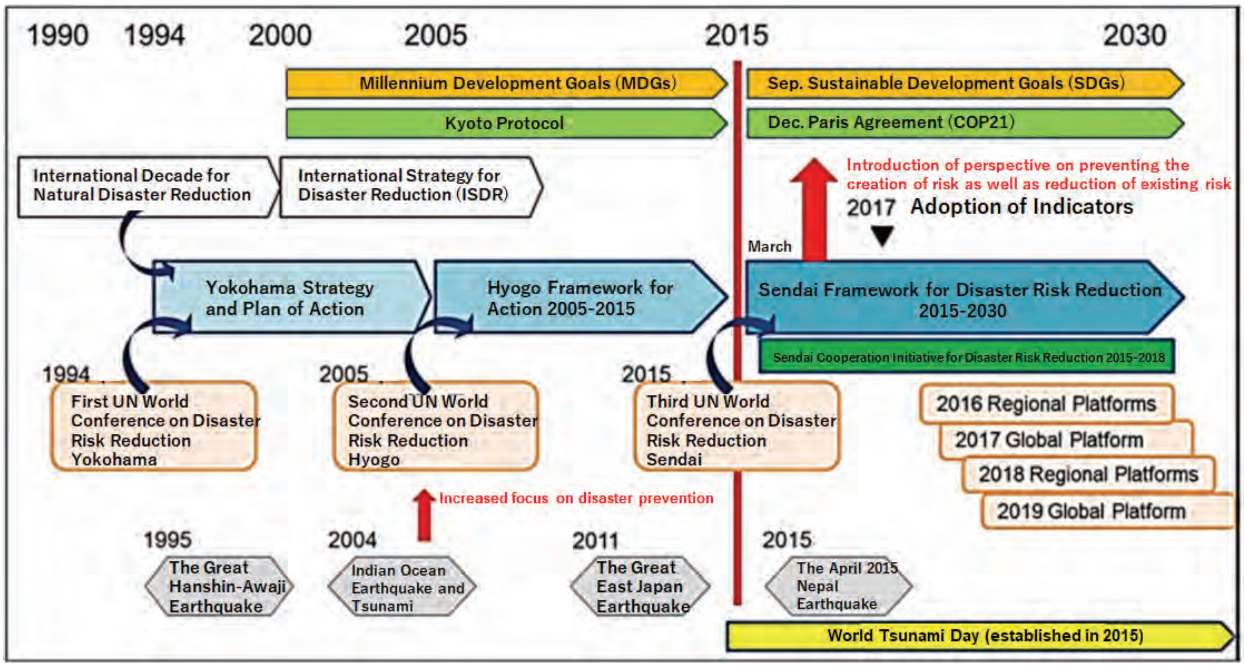

Figure I06-1 Discussions at the UN World Conference on Disaster Risk Reduction [4)]

heritage, socio-economic assets, and ecosystems, and thereby The framework points out the urgency and importance of increasing the resilience of each of these by It also identifies poverty and inequality, climate change, unplanned and rapid urbanization, inadequate land management, population change, weak organizational structures, and policies lacking risk information as potential risks, and suggests that in order to reduce such disaster risks, the monitoring, assessment, and understanding of disaster risks, their information and In order to reduce such risks, it is necessary to monitor, assess, and understand disaster risks, share information on these risks and how they arise, strengthen disaster risk governance and coordination across relevant institutions and sectors, and involve relevant stakeholders at appropriate levels. The framework also states that the development, regular updating, and dissemination of location-specific disaster risk information, including risk maps, to policy makers, the general public, and local communities facing disaster risk, where available and in appropriate formats using geospatial information technology, will help to improve understanding of disaster risk. The framework states that the use of geospatial information technology, where available and appropriate, and its dissemination in appropriate formats to local communities facing disaster risk can help to improve understanding of disaster risk. In doing so, the use of spatial and current information, such as geographic information systems (GIS), and innovations in information and communication technology can improve data assessment and measurement tools, collection, analysis, and delivery.

Discussions under the UNFCCC

The UNFCCC is an international treaty adopted in 1992 primarily to prevent dangerous interference by humans with the climate system through stabilizing atmospheric greenhouse gas concentrations. The UNFCCC COP21, held in Paris, France in 2015, adopted a new implementing agreement (Paris Agreement) with the goal of limiting the increase in global average temperature to 2°C below pre-industrial levels and pursuing efforts to limit the increase to 1.5°C or less, if possible. Countries are currently pursuing climate change measures under this agreement.

Under Article 7 of the Paris Agreement, the parties will set a GGA to enhance the capacity to adapt to climate change and to strengthen resilience and reduce vulnerability to climate change. In response to this, the UNFCCC COP26, held in Glasgow, UK in 2021, established the Glasgow-Sharm El Sheikh Work Programme on GGA (Figure I06-2) to achieve the GGA. At this meeting, Japan pledged to double its assistance in the field of adaptation over the five years to 2025, including a total of about US$14.8 billion in public and private sector assistance for adaptation. The Glasgow-Sharm el-Sheikh Work Programme has been working for two years and its outcome is the adoption of the “UAE Framework for Global Climate Resilience" for the achievement of the GGA and assessment of its progress. The framework sets seven thematic goals. Among them, there is potential for disaster risk reduction through the use of forest functions in the goals of strengthening climate resilience against water-related disasters and resilience of infrastructure and human settlements against the impacts of climate change.

Figure I06-2 COP26 in Glasgow, UK, which was postponed for one year due to COVID-19

Recipe - I07

Japan's international aid framework

Japan's Official Development Assistance includes bilateral aid, which directly supports developing regions, and multilateral aid, which contributes to and finances international organizations. In the framework of bilateral assistance, one of the most accessible funds that can be used by the private sector for projects related to forest-based disaster risk reduction is "SME and SDGs Business Support Program" by Japan International Cooperation Agency. The multilateral assistance framework has a multilayered structure, and when private companies seek multilateral assistance for institutional and financial resources that can be used for projects related to forest-based disaster risk reduction, they do not directly access Japanese-funded funds, but rather access the projects and financial schemes of implementing agencies with which each fund has a partnership.

Japan's official development assistance

Official Development Assistance (ODA) is official funds and activities for the development of developing regions, financed by them for international cooperation activities by governments and government agencies. ODA can be divided into grants, government loans, etc. There are two types of ODA: bilateral aid, which provides direct assistance to developing regions, and multilateral aid, which contributes to or finances international organizations.

Grants in bilateral aid refer to cooperation provided free of charge to developing regions. The schemes implemented by Japan include Grant Aid, which provides funds necessary for social and economic development to developing regions without imposing repayment obligations, and Technical Cooperation, which utilizes Japan's knowledge, technology, and experience to develop human resources who will become the driving force for social and economic development in developing regions.

Additionally, Japan's bilateral aid includes government loans: yen loans, which provide necessary funds to developing regions under lenient lending terms featuring low interest rates and long repayment periods; and overseas investment and financing, which provides equity participation and investment to private sector entities responsible for implementing projects in developing regions.

Multilateral assistance includes contributions to international development institutions such as the World Bank (WB), as well as to United Nations agencies such as the United Nations Development Programme(UNDP)and the United Nations Children's Fund (UNICEF).

Trends in Japan's bilateral aid framework

In the framework of Japan's direct aid to developing countries (bilateral aid), one of the most accessible programs and funds that can be used for projects related to disaster risk reduction is “SME and SDG Business Support Program " [1] by Japan International Cooperation Agency (JICA) (Figure I07-1). The purpose of this program is to support the creation of businesses by Japanese private companies that contribute to solving problems in developing countries, and to work on the co-creation of value by utilizing the networks, relationships of trust, and know-how with governments of developing countries that JICA has built through its ODA to meet the needs of companies. The support menu includes support for companies of different sizes and according to their business stage. The support menu includes a “Needs Assessment Survey (up to 15 million yen (US$100,000))" and a “Business Demonstration Project (up to 40 million yen (US$270,000))," depending on the size of the company and the stage of the business. There is also a track record of projects in the field of disaster risk reduction.

JICA's “Grassroots Technical Cooperation Program" [2] is another potential funding scheme. This is an international cooperation program for Japanese NGOs/CSOs, other private organizations, local governments, or universities that are willing to cooperate with the residents of developing countries for the purpose of assisting in the economic and social development and reconstruction of the region, without regard to their own profit. These are joint projects in which JICA consigns to the proposing organization the activities proposed by the organization based on the technology, knowledge, and experience possessed by the organization, and

INFO

1) Small and Medium-sized Enterprise / SDGs Business Support Program (JICA Biz) https://www.jica.go.jp/activities/schemes/priv_partner/activities/sme/index.html

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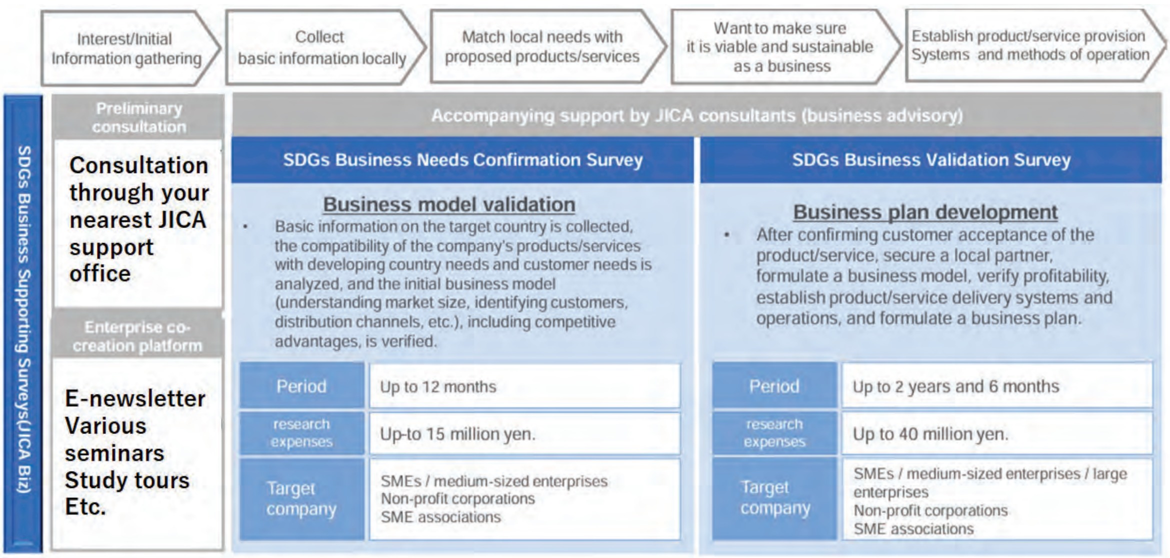
2) JICA Grassroots Technical Cooperation Projects https://www.jica.go.jp/activities/schemes/partner/kusanone/index.html



FigureI07-1 Overview of SDGs Business Supporting Program [1]

JICA implements the activities under a cooperative relationship between JICA and the organization. There are three types of Grassroots Technical Cooperation Projects: “Grassroots Cooperation Support Type" (up to 3 years, 10 million yen (US$67,000)), “Grassroots Partner Type" (up to 3 years, 100 million yen (US$670,000)), and “Community Revitalization Type" (up to 3 years, 60 million yen (US$400,000)). The Grassroots Cooperation Support Type is intended for NGOs and other organizations that have little experience in providing assistance to developing countries, and is expected to help these organizations gain experience in international cooperation with developing countries through project implementation and become active players in international cooperation in the future. The Grassroots Cooperation Partner Type is intended for NGOs and other organizations that have a good track record in international cooperation in developing countries. The Community Revitalization Type is targeted at Japan's local governments, and is expected to encourage overseas development utilizing the knowledge, experience, and technology of local governments and related organizations, thereby contributing to the resolution of development issues in developing countries as well as to the revitalization of the Japanese region and economy.

Trends in Japan's multilateral aid frameworks

The framework of Japan's indirect assistance to developing countries (multilateral aid) presents a multiple structure. When private companies seek multilateral assistance funds to finance projects related to forest-based disaster risk reduction, they do not directly access Japanese-funded funds, but rather access the projects and funding schemes of implementing agencies with which the respective funds (in most cases, trust funds managed by the WB) have partnerships. Access will be provided by the implementing agencies with which each Fund (often the Trust Fund administered by the WB) has a partnership. The funds that each country contributes to include the Global Facility for Disaster Reduction and Recovery (GFDRR), which is pro-disaster risk reduction, and the Global Environment Facility (GEF), which is pro-environment and larger in scale, The Green Climate Fund (GCF) and the Adaptation Fund (AF) are climate change supporters. Implementing agencies include traditional international development agencies such as the Asian Development Bank (ADB), Food and Agriculture Organization of the United Nations (FAO), and UNDP, as well as relatively new funding scheme organizations such as the Climate Technology Centre & Network (CTCN) and the Private Sector Facility (PSF).

CTCN supports technology transfer of environmentally friendly technologies (including “adaptation") to developing countries to address climate change. CTCN provides technical assistance, capacity building support, and advice on policies and legal systems, with the aim of strengthening local capacity for technological innovation and creating an enabling environment for increased investment in climate change mitigation and adaptation projects (Figure I07-2). The CTCN projects (Technical Assistance (TA) projects) are submitted to the CTCN Secretariat by the National Designated Entity (NDE) of a developing country as a TA request, and a technical assistance plan is developed by a CTCN request experts team (Figure I07-2) [3]. There are two types of assistance schemes: Fast TA and Regular TA.

INFO

3) Climate Technology Centre & Network : CTCN https://www/env.go.jp/earth/ondanka/ctcn.html

Fast TA projects: Technical assistance of US$15,000 or less. Basically implemented by consortium organizations. Implementation period is less than 2 months.

Regular TA projects: Technical assistance of US$250,000 or less. The project will be publicly solicited through the UN procurement process (international bidding), and network organizations registered with the CTCN will participate in the bidding process to determine the recipient of the assistance. The period of implementation will be about one year.

PSF is a framework under which the private sector can access GCF funds through Accredited Entities (AEs).

The increasing number of implementing agencies that can utilize these multilateral assistance funds increases the opportunities and possibilities for the private sector to access multilateral funds, but it is necessary to understand that there are certain transaction costs (e.g., additional overhead costs) for the private sector to access multilateral assistance funds, such as the need to be familiar with international accounting systems (e.g., methods and timelines).

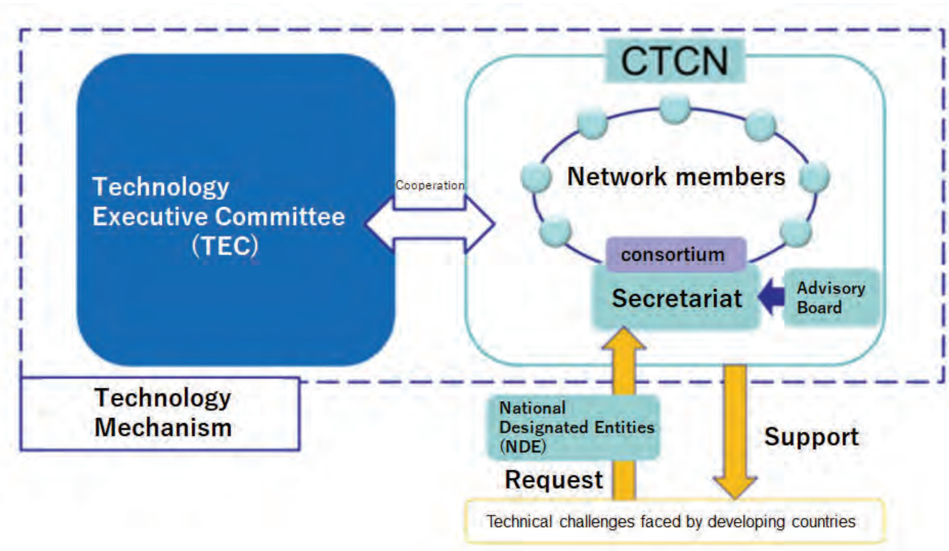


Figure I07-2 Framework of Climate Technology Centre and Network (CTCN) [3]

Recipe - I08

Current status and challenges of international organization projects

For detail, refer to

International Trends in Strengthening the Disaster Mitigation and Prevention Functions of Forests: Basic Survey Report on Corporate Participation (2023) N.B. in Japanese language

Japan's contributions to eight agencies with climate change funds (World Bank, Asian Development Bank, Green Climate Fund, Global Environment Facility, Food and Agriculture Organization of the UN, UN Environment Programme, UN Development Programme, and UN Office for Disaster Risk Reduction) has been in the top five among OCED DAC members from 2016 to 2020, in terms of contributions. In the case of World Bank projects, there is no process involving the private sector in the project formation stage, but communication with the private sector exists on various occasions. Asian Development Bank, like World Bank, provides a forum for regular information sharing and consultation. The scale of budgets spent by World Bank, Green Climate Fund, Global Environment Facility, and others on climate change measures has been increasing year by year, matching international trends.

Funding trends of international organizations

Between 2016 and 2020, Japan's contributions to the eight organizations with climate change funds (World Bank (WB), Asian Development Bank (ADB), Green Climate Fund (GCF), Global Environment Facility (GEF), Food and Agriculture Organization of the UN (FAO), UN Environment Programme (UNEP), UN Development Programme (UNDP), and UN Office for Disaster Risk Reduction (UNDRR)) has been in the top five among DAC members. Specifically them, Japan

TableI08-01 Top 10 Countries (and Japan) of Contractors, Suppliers, and Consultants of Asian Development Bank (2021) [1)]

	Goods, Works and Other Related Services			Consulting Services			Total	
	Country	Contract (million USD)		Country	Contract (million USD)		Country	Contract (million USD)
1	China, People's Republic of	3,294.9	1	India	93.1	1	China, People's Republic of	3,329.5
2	India	2,719.8	2	Indonesia	53.8	2	India	2,812.9
3	Bangladesh	1,108.4	3	Japan	50.4	3	Bangladesh	1,117.0
4	Philippines	467.2	4	France	48.1	4	Philippines	490.2
5	Viet Nam	343.1	5	Australia	35.1	5	Viet Nam	355.1
6	Pakistan	297.7	6	China, People's Republic of	34.6	6	Indonesia	334.8
7	Indonesia	281.0	7	Spain	34.2	7	Pakistan	311.4
8	Sri Lanka	231.7	8	Korea, Republic of	28.5	8	Sri Lanka	241.1
9	Mongolia	159.9	9	Singapore	18.3	9	Mongolia	169.8
10	Nepal	134.4	10	Turkey	16.6	10	Nepal	142.4
31	Japan	7.7				21	Japan	58.1
	Total	9,961.4		Total	697		Total	10,658.4

is the largest contributor to ADB, GCF, and the GEF.

In contrast, contracts to Japanese companies ranked 21st in WB and 21st in ADB (both in 2021), which is small compared to the size of the Japanese government's contribution (Table I08-1) [1]. Emerging economies, such as China and India dominate the amount of contracts made, and the amount of orders received within recipient countries is also growing.

The number of projects related to forest-based disaster risk reduction under multilateral funds is small, and the planning and implementation of such projects are lagging behind.

INFO

1) Asian Development Bank (2022) 2021 Annual Procurement Report.

Trends in international organizations' projects and participation of Japanese companies

In the case of WB projects, the partner country government and WB are responsible for project implementation policies and project identification, so there is no process involving private companies and others in the project formation stage. However, there are various opportunities for communication with the private sector, and it is believed that technical and project-related information is exchanged. Many consultants, contractors, and others gather information even before the official announcement of the project, conduct surveys, and prepare proposals for participation in the project.

In terms of contracts awarded by country for WB operations, Chinese and Indian firms have received by far the largest orders, and they have been active as emerging countries. In particular, China and India are the top borrowing countries in the number of projects ordered and the contract amount, and as a result, the number of projects ordered in their countries is accumulated as a track record. Based on their experience, these countries and regions are further increasing their orders for projects from international organizations in neighboring countries and regions.

Japan and the WB have been working together in partnership for a long time to provide assistance to developing countries to increase their resilience against disasters, and established the Japan-WB Joint Program on Disaster Risk Reduction in 2014. The goals of the program are twofold: to support mainstreaming disaster risk reduction in the planning and implementation of development investments in developing countries; and to link Japanese and global disaster risk reduction experience, technology, and knowledge to mainstreaming efforts in developing countries and within WB. The program aims to achieve this through technical cooperation, capacity building, and sharing of Japanese and global knowledge and best practices in the field of disaster risk management with developing countries and WB teams.

The Global Facility for Disaster Reduction and Recovery (GFDRR) is a global partnership within WB to improve understanding of vulnerability to natural disasters and climate change in developing countries and to provide technical support for risk reduction measures, GFDRR is funded by 11 countries and managed by the WB in collaboration with various partners including international organizations, research institutions, universities, foundations, and the private sector involved in risk insurance.

GFDRR considers NbS as an important keyword for climate change action, and sees its benefit as adaptation to climate change by reducing the risk of climate-related disasters such as floods, extreme weather events, and cyclones. Disaster risk reduction through natural resources such as forests through mountain development shares this philosophy with disaster prevention by NbS, and contributes simultaneously to climate change adaptation and, in many cases, to biodiversity, water security, and climate change mitigation.

Similar to WB, ADB has a regular forum for information sharing and consultation with the private sector, and the basic policies and regulations are similar, as they share the same awareness of common issues and measures to address them. The top contracting countries of ADB as a whole are all mainly countries that are implementing projects in their own countries, and many orders are contracted to domestic companies in the countries where the projects are implemented. Of particular note are India and China, where the amount of contract awards exceeded the size of the projects awarded in their respective countries. This is similar to the situation with WB projects, indicating that private companies in India and China are using their experience and achievements in their home countries to enter and win projects in neighboring countries and regions.

A characteristic of private firms that receive orders for projects as foreign firms is that they make good use of companies and human resources in the country where the project is to be implemented. In the case of large-scale construction projects, partnerships with local firms that have experience in local public works projects are useful. The use of local human resources reduces labor costs and allows the company to bid at lower prices, giving it an advantage in competitive bidding. For example, only the head of the engineering team may be from a developed country, while the rest of the team may be international or local personnel to reduce costs (Table I08-2).

Table I08-2 Measures to be taken to win future international organization projects

• Building a track record through JICA projects and establishing networks with local companies and experts
• Establishment of an organizational structure to promote orders from international organizations
• Employment of overseas talent, experienced personnel, etc.
• Increase in the quality and quantity of project information through localization and utilization of local bases
• Acquiring projects with local partner companies and building a track record as a joint venture member
• Reducing costs by hiring local and freelance personnel

Directions for promoting the participation of Japanese companies in international organization projects

Disaster risk reduction with natural resources such as forests through forest management is a cross-sectoral issue that simultaneously contributes to climate change adaptation and, in many cases, to biodiversity conservation, soil and water conservation, maintenance and increase of carbon absorption and reduction of emissions by forests, and climate change mitigation. This is a cross-sectoral issue that contributes simultaneously to climate change mitigation. The scale of budgets spent by WB, GCF, GEF, and other organizations to address climate change is increasing year by year, in line with international trends.

Furthermore, WB considers NbS as an important keyword for climate change action and is promoting the development of the NbS approach in collaboration with GFDRR. The NbS approach clearly states that disaster reduction is to be addressed, and disaster risk reduction and *Chisan* projects that utilize forests are in line with this framework. It is desirable for Japan to actively provide effective input on the importance of forest-based disaster risk reduction and *Chisan* projects in international discussions and bilateral dialogues in line with these international trends. To keep up with these international trends, it is also important for research institutes that should be responsible for advanced knowledge and technology to actively promote information and technology exchange with the government and the private sector regarding disaster prevention and mitigation functions through mountain building.

In many cases, both bilateral and multilateral assistance is provided by the government agency in charge of the project area, which is the contact point for the recipient country. In such cases, the project field of the government agency in charge will have a significant impact on the content of the project. It would be effective to expand the approach to the development of forest-based disaster risk reduction and *Chisan* projects from the traditional approach of forming a project with the government agency in charge of forest and forestry as the counterpart agency, to one of providing input as one component of different project fields. For example, slope disaster prevention associated with road construction, slope disaster prevention associated with construction of structures to reduce flood risks, and afforestation. According to ADB Indonesia office, there are in fact examples of similar activities being undertaken even though they are not ostensibly forestry projects. It is hoped that approaches will be promoted to incorporate the disaster risk reduction component into various sectors, without being limited to forestry and forestry projects. It would be useful for the private sector to keep this direction in mind when identifying needs for forest-based disaster risk reduction technologies overseas and building relationships with local and international companies that can serve as local partners.

Planning

3

Chapter 3 Approaches to Utilizing Disaster Risk Reduction Functions of Forests

In order to maximize the disaster risk reduction functions of forests in developing countries, it is necessary to adopt approaches tailored to each region and to work with local redidents to formulate land use plans that enable these functions to be realized.

This chapter summarizes the points to be considered and the knowledge that can be utilized when implementing forest management and *Chisan* projects for forest-based disaster risk reduction. It also provides an overview of methods for working with local residents to formulate land use plans that maximize forest-based disaster risk reduction functions.

Forest-based disaster risk reduction and applicable knowledge

Refer to

Recipe-I02
Concept of Forest-based Disaster Bisk Reduction as a patent Recipe

In order to utilize the functions of forests for disaster risk reduction, it is necessary to conduct studies based on local characteristics such as the type of disaster, risk of occurrence, topography and natural environment, and the available technologies. In addition, it is important to establish a local implementation system and understand the limits of ecosystem functions. While the importance of conserving forests has been clearly recognized from the perspective of preserving the global and local environment, it is also important to establish technologies to prevent sediment-related disasters and preserve the mountain environment while obtaining forest resources, since forest resources are essential for our livelihood. The *Chisan* technology is also related to the use of forest resources and the conservation of the mountain environment, and is characterized by its approach to disaster risk reduction from a medium- to long-term and multifaceted perspective.

Key points of forest-based disaster risk reduction

Forests are the most important key ecosystem (ecological resources) for Eco-DRR in non-urban geomorphic spaces such as mountains, rivers, and coasts, and research has been conducted on the relationship between forests and slope failure, debris flows, and avalanches, especially in the European Alps. However, the use of forests for disaster risk reduction has been attracting more attention in recent years, as coastal forests are now known to be effective in reducing damage caused by tsunamis. Japan's history and technology of forest-based disaster prevention in mountainous areas which began in the 17th century, are internationally recognized [1] and attracting attention worldwide. With the growing recognition that forest-based disaster risk reduction is a core theme of Eco-DRR, Japan's forest-based disaster risk reduction, which explores field-based empirical research and practice in both mountainous and coastal areas in Southeast Asia, will have a significant impact on international disaster response trends, especially in the Southeast Asian region. significant impact.

There are already several forest-based disaster risk reduction efforts in the Asian region, a number of which Japan has provided technical assistance and advice to. Through these projects, a great deal of information that will be helpful in considering the possibilities for future overseas development of *Chisan* technology is obtained. The following is a summary of information obtained through these pioneering overseas cooperation efforts. The following points can be highlighted as the main points for forest-based disaster risk reduction.

(1) Consideration based on the type of disaster, risk of occurrence, and regional

INFO

1) Moos C., et al. (2018) Ecosystem-based disaster risk reduction in mountains. Earth-Science Reviews, 177, 497-513.

characteristics such as topography and natural environment, and available technologies

Since the main objective of the initiatives is to demonstrate the effectiveness of disaster risk reduction, effective methods should be selected from this perspective. It is very important to examine the feasibility of the project based on whether the method utilizing the ecosystem including forests is suitable for the target area and whether each company can provide forest-based disaster risk reduction technologies suitable for the target area. In particular, it has been pointed out that in tropical regions, thick fine-grained materials originating from the weathering zone can easily lead to accelerated erosion and frequent collapses, so it is essential to consider not only the geology but also the soil generating environment when analyzing the natural environment.

(2) Establishment of a local implementation system

For forest-based disaster risk reduction using forests, subsequent care, for example, maintenance and management of plantation trees, will be extremely important to ensure their functionality. In order to maintain and properly renew the functions over several years or decades, it is essential to establish a strong implementation system with local stakeholders, including local residents, and transfer sufficient technology and know-how. In addition to activities in forests such as afforestation, education and awareness-raising activities related to forest-based disaster risk reduction should also be conducted, and the leaders of such activities should be included in the system.

(3) Understanding the limitations of ecosystem functions

Compared to man-made structures, Eco-DRR require longer time to exert its effect, and are characterized by a range of uncertainties in the amount of effect manifested, due to the involvement of multiple factors (Figure P01-1) [2). Recognizing these limitations, the secondary effects of forest ecosystems (contribution to local livelihoods improvements, provision of ecosystem services, etc.) should also be

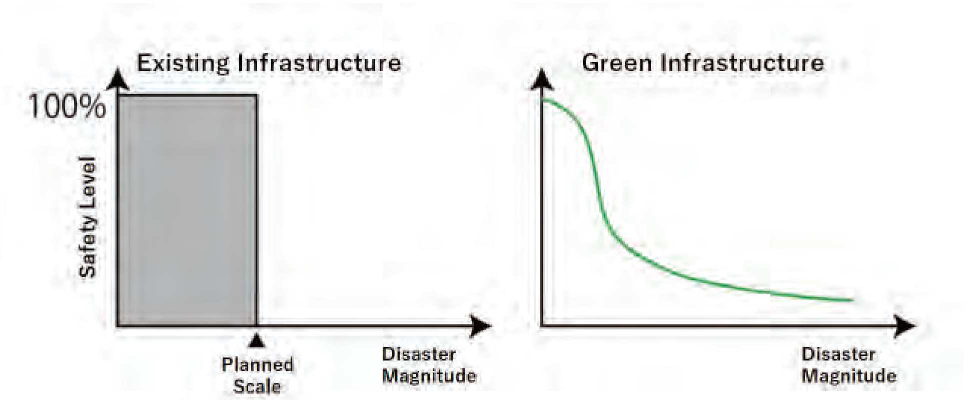


Figure P01-1 Differences between existing infrastructure (gray infrastructure) and green infrastructure [2)]

INFO

2) Nakamura, F. (2020) *[Green infrastructure indispensable for future national land conservation]. In Green Infrastructure Research Group et al. (Eds.), Practical Green Infrastructure (pp. 25–38). Nikkei BP. (Original work published in Japanese)*

appropriately evaluated, and a comprehensive judgment should be made on the selection of forest-based disaster risk reduction technologies as a method. Forest-based disaster risk reduction technology is a comprehensive technology that combines soft measures (land use planning), ecological measures (afforestation and greening), and engineering measures (stream works and hillside works) in various proportions according to local conditions, and should not rely solely on the disaster prevention function of the ecosystem. It is also effective to use small-scale disaster prevention facilities (gray infrastructure) as a supplement, as in Japan's Bare Mountain Restoration *Chisan* Project. For example, if accelerated erosion is feared due to the presence of thick weathered materials such as angular gravel, sand, and clay, the early installation of small check dams in the form of erosion control dams can be expected to prevent erosion and stabilize the upstream watershed.

Organizing knowledge that can be used for disaster risk reduction measures

Natural disasters are phenomena in which nature causes damage to human lives, assets, and public facilities, and unless such socioeconomic values (conservation targets) are located in the area, they are not subject to discussion regarding disaster risk reduction in the narrow sense. However, this is not the case if the issues of sediment transport, water quality conservation, water source recharge, ecosystem conservation, and reduction of greenhouse gases in the earth's atmosphere (environmental conservation) are considered as disasters in the broad sense that relate to the existence of local communities and the survival of humankind. In this sense, disasters and the environment are closely related and inherently inseparable. Since the 1970s, the importance of forest conservation has been clearly recognized from the perspective of global and regional environmental conservation, while the resources obtained from forests, such as timber, are indispensable for our livelihood, so it is also important to establish advanced technologies to prevent sediment-related disasters in mountainous area and preserve the mountain environment while obtaining forest resources. Therefore, it is also important to establish advanced technologies to prevent mountain disasters and preserve the mountain environment while obtaining forest resources. The Chisan technology is also related to the use of forest resources and the conservation of the mountain environment, and is characterized by its approach to disaster risk reduction from a medium- to long-term and multifaceted perspective.

One of the findings of previous studies on the disaster prevention function of forests in Japan is that slope failure is related to the age of the forest. Numerous disaster case studies have shown that the collapse rates of young forests and old forests differ greatly in the same area, even when the forests are around 20 years old [3]. It is thought that the lack of development of tree trunks and root systems in young forests is related to the occurrence of collapses, and empirical studies on

INFO

3) Tsukamoto, Y (1986) [Study on the effects of tree root systems on preventing slope failures]. Bulletin of the University Forests, Faculty of Agriculture, Tokyo University of Agriculture and Technology, 23, 65–124.

this aspect have been conducted while overcoming various difficulties. The other is that roads, such as work and mountain trails, built on mountain slopes increase slope failures and surface erosion. The basic factor is that road surfaces that are hardened by trampling have less infiltration capacity for rainwater, and lateral infiltration flows from the top of the slope run off from the cut surface, causing rapid and large amounts of water runoff during rainfall events [4)].

In Southeast Asia, where mountain slopes have been extensively used mainly for agricultural production, surface erosion caused by gully, rill, and sheet wash occurs during the heavy rains that occur repeatedly during the rainy season, resulting in large amounts of sediment runoff and serious environmental impacts, including economic losses, in many cases in downstream areas [5)].

In addition, as mentioned above, forest-based disaster risk reduction is attracting attention not only in mountainous areas but also at the coast. The effectiveness of forests in disaster risk reduction is clearly demonstrated, for example, by the fact that the tsunami triggered by the 2004 Sumatra earthquake was reduced by coastal forests, especially mangroves, and that this had a significant disaster mitigation effect, as reported from various regions along the Indian Ocean coast [6)]. Numerous model calculations have shown that mangroves can reduce tsunami energy, and the level of this effect depends on the density of trees, the thickness of trunks, branches, and roots, and the slope of the coast [7), 8)]. There are many examples of disaster prevention forests that are expected to reduce fluid flow by forests, such as tsunamis, and in Japan, disaster prevention forests have long been created with the expectation that forests will reduce floods, avalanches, and debris flows.

INFO

4) Sidle R. C., et al(2006) Erosion processes in steep terrain—Truths, myths, and uncertainties related to forest management in Southeast Asia. Forest Ecology and Management 224, 199–225.

INFO

5) Furuichi T and Wasson R. J.(2011)Placing sediment budgets in the socio-economic context for management of sedimentation in Lake Inle, Myanmar (Burma). IAHS Red Book 349, 103-113.

INFO

6) Danielsen F., et al.(2005) The Asian Tsunami: A Protective Role for Coastal Vegetation. Science 310, 643.

INFO

7) Alongi D.M.(2008) Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science 76, 1-13.

INFO

8) Horstman E. M., et al.(2014)Wave attenuation in mangroves: A quantitative approach to field observations. Coastal Engineering 94, 47–62.

Recipe - P02

Land use planning and management for forest-based disaster risk reduction

Refer to

Recipe-I02
Concept of forest-based disaster risk reduction as a parent Recipe

Appropriate land use planning and land management, including forests, are required to fully realize the disaster risk reduction functions of forests. In order to fulfill the public benefit functions of forests, such as avoiding the risk of natural disasters, Japan has established a protection forest system that restricts the rights of forest owners for public good. In order for forests to fulfill their functions for disaster risk reduction, the spatial arrangement of forests, agricultural lands, residential areas, and other infrastructures with disaster-prone areas is important. For areas where disaster risk reduction are particularly needed, a land use plan should be formulated, taking into consideration the introduction of man-made infrastructures, namely, *Chisan* facilities. In order for the forests to fulfill their functions for disaster risk reduction as expected in the formulated land use plan and countermeasure scenarios, land management after the plan is formulated is important.

Necessity of land use planning and management and the protection forest system

Appropriate land use planning and land management, including forests, are required to fully realize the disaster risk reduction functions of forests. Land use planning and land management can be at various levels, from the relatively extensive regional level to the local level in the living area of local residents. As the scope becomes smaller, it may involve restrictions on the use of land and resources by local residents, and consideration should be given to the impact on their rights and socio-economic activities For example, if the hill behind one resident's house is owned by another resident, and the owner wants to clear the forest there and convert it to cultivated land, prohibiting logging would restrict the owner's rights because of the increased disaster risk to the residents at the base.

In order to fulfill the public benefit functions of forests, such as avoiding the risk of natural disasters, Japan has designated protection forests (Figure P02-1) [1), 2)]. In Japan, the topography is steep and there are many rapid streams, and protecting human lives and paddy field, which is operated on slightly open flat land, from natural disasters has been an important issue for a long time. During the Edo period (1603-1868), each fief regulated the treatment of village-owned forests, etc., which were used as commons by village communities to prevent disasters, and also independently protected forests such as Suigen-yama (water resource mountain) and Byobu-yama (wind shield mountain). However, with the start of the Meiji era (1868-1912), privately owned forests became free for logging, and underbrush, fallen leaves and branches, firewood and charcoal, and other materials were harvested unregulated from village-owned and privately owned

INFO

1) Forestry Agency *[Overview of Conservation Forests]* https://www.rinya.maff.go.jp/puresu/h15-7gatu/0710/s4.pdf

INFO

2) Kyushu Regional Forest Office *[Conservaton Forests]* https://rinya.maff.go.jp/kyusyu/tisan/hoan.html

Figure P02-1: An example of a landslide protection forest in Japan that provides public function [2)]

forests as raw materials for agricultural fertilizers, etc., leading to forest devastation and frequent disasters. In response, the Meiji government established a system of forests whereby the Ministry of Agriculture and Commerce would decide whether or not to cut down trees in order to preserve privately owned forests, which were important for national land preservation. Furthermore, in response to the unprecedented flood disaster in 1896, the Forest Law was established in 1897, establishing a system of protection forests that unified the government's authority to supervise forests by unifying the government's logging-banned forests and logging-suspended forests.

The forest law was revised several times, and today, in order to achieve public purposes such as disaster prevention, water source conservation, and preservation of the living environment, forests that need to fulfill these functions in particular are designated as protection forests. This system is designed to ensure the appropriate conservation of forests and forest operations by regulating logging, changes to land form, and other activities.

In addition, when forest owners cut down standing trees in forests, they are required to replant trees in accordance with the methods, duration, and species specified as part of the designated management requirements. Prefectural governors shall issue cease and desist orders, afforestation orders, and restoration orders to those who cut down standing trees or change the land form without permission, and shall order those who violate the planting obligation and do not implement planting to take necessary actions for afforestation.

On the other hand, as compensation for losses associated with protection forests, an amount equivalent to 5% of the assessed value of standing trees will be compensated for protection forests (standard felling age or older) where the method of harvesting is prohibited or selective logging is specified in the designated operation requirements. In addition, real estate acquisition tax, fixed asset tax, and special land holding tax are exempted, and for inheritance tax and gift tax, a certain percentage of the assessed value of forest land and standing trees is deducted, depending on the nature of the restrictions on harvesting in safety forests.

The protection forest system restricts the rights of forest owners for public purposes, and it is not a system that can be introduced overnight in developing countries. Therefore, it is first necessary to foster consensus among various stakeholders on measures to avoid disaster risks. Future issues should also include the creation of a public-purpose system similar to the safety forest system to deal with the increased risk of natural disasters due to climate change.

Land use planning for forest-based disaster risk reduction

INFO

3) JICA (2017) Ecosystem-based Disaster Risk Reduction (Eco-DRR): Practices, Effects, International Trends and JICA's Initiatives

INFO

4) Nehren U., et al. (2014) The ecosystem-based disaster risk reduction case study and exercise source book. UNDRR, 100p

In order to develop a land use plan for forests to fulfill their disaster risk reduction functions, it is necessary to take into account the characteristics of the target area and the types of natural disasters expected to occur [3]. Land use planning includes both non-spatial and spatial elements [4]. Non-spatial elements include the enumeration of resources needed, the time period covered by the plan, strategies and actions, and the people involved. Because disasters strike specific areas, the spatial component is very important in planning to mitigate risks from disasters. And spatial land use planning helps to prescribe, regulate, and determine land use for various purposes, whether at the local, regional, or global level.

The spatial arrangement of forests, agricultural lands, settlements, and other

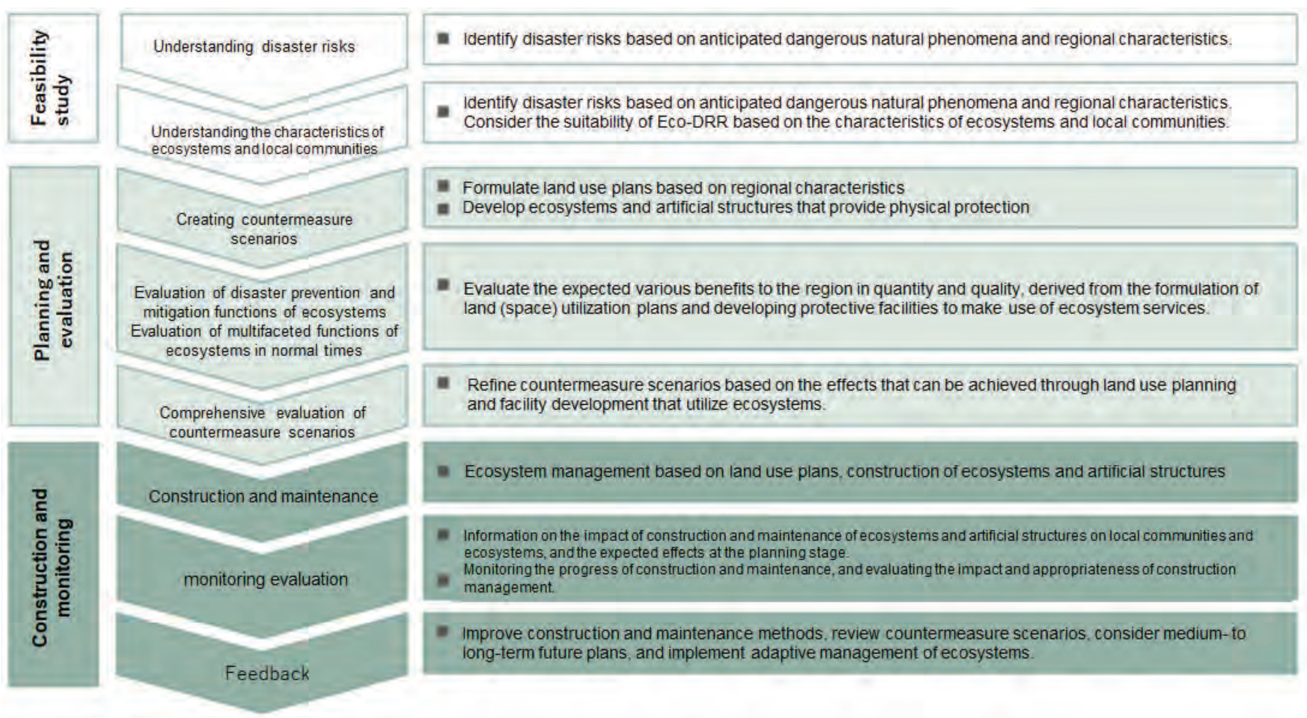


Figure P02-2 How to proceed with Eco-DRR [Modified from 3)] infrastructure, as well as their location in relation to disaster sites, is also important for the disaster risk reduction functions of forests. Therefore, a risk map to predict the risk of disaster occurrence should be prepared prior to the development of land use plans.

Next, based on the spatial arrangement of forests, agricultural lands, residential areas, and other infrastructure in relation to the likely disaster locations, forests and infrastructures that provide physical defense functions are examined. There are limitations to the disaster risk reduction functions of forests. For example, it is necessary to understand that even if a forest is planted on a slope farmland from the viewpoint of disaster risk reduction, it takes a considerable amount of time for the forest to function, and there is a high degree of uncertainty regarding its effectiveness. Therefore, land use plans should be developed for areas where disaster prevention and mitigation are particularly needed, taking into consideration the introduction of infrastructures, namely, *Chisan* facilities [3)].

Furthermore, qualitative and quantitative evaluation of the various effects expected from the use of forests in the region will be conducted for the formulated plans. The effects to be evaluated are not limited to disaster risk reduction functions, but also include effects from forest functions that benefit the area, as well as negative effects. Based on the evaluation, countermeasure scenarios against disaster risks will be refined. In doing so, comparisons of multiple scenarios and the consistency of each scenario with the legal systems, budgets, and existing plans of each country and region should also be considered (Figure P02-2) [3)].

Land management for forest-based disaster risk reduction

In order for forests to fulfill their disaster risk reduction functions expected in the formulated land use plans and countermeasure scenarios, land management after the plans are formulated is important. While forests grow over time and enhance the function of soil suppression by their root systems, there are periods when their disaster prevention/mitigation function declines as they are cut down for timber and chip production. Disaster risk reduction measures using forests are also subject to natural environmental changes and changes in social conditions, which may result in land use planning and the effectiveness of *Chisan* facilities differing from the original goals. Therefore, forests should be managed so as to minimize the functional decline caused by logging. For example, if there are settlements or critical infrastructure on the lower slopes of forests, it is recommended to clearcut small areas instead of large areas to avoid large-scale slope failures. In addition, forest road management should be included in forest management, especially in developing countries, because the risk of slope failure increases as forest roads are established in the mountains.

Even when land management is underway, land use plans should be re-formulated because it will be difficult to maintain the disaster risk reduction functions of forests if a disaster occurs in a place other than where it was predicted or if the assumptions made at the time of planning are changed.

Recipe - P03

Developing a plan through community collaboration

Refer to

Recipe-I02
Concept of forest-based disaster risk reduction as a parent Recipe

In order to develop a feasible land use plan to fulfill the disaster risk reduction functions of forests, the livelihoods of local residents and natural resources should be understood and the feasibility of applying forest-based disaster risk reduction technologies should be examined, and a land use plan based on the characteristics of the region should be developed. It is necessary to formulate a land use plan based on the characteristics of the region. There are two types of plans that must be developed for forest-based disaster risk reduction: land use plans and land management plans that include forest management based on such plans. In order to select the more rational of the multiple options for disaster preparedness, quantitative assessment and scientific findings can help to develop a common understanding to build consensus among stakeholders with different interests. Forest zoning can help implement efficient and effective forest management to fulfill the functions assigned to the zone.

Developing plans through consensus among stakeholders

When natural disasters occur, the most important parties involved are the residents in the area. Therefore, it is necessary for local residents to understand the advantages and disadvantages of the forest-based disaster risk reduction, including *Chisan* facilities, and to take measures in line with the desired future vision of the community (Figure P03-1). In some communities, the knowledge of disaster countermeasures based on past disaster experiences has been passed down from generation to generation, and the participation of local residents will provide an opportunity to utilize such knowledge in disaster prevention [1].

INFO

1) JICA (2017) Ecosystem-based Disaster Risk Reduction (Eco-DRR): Practices, Effects, International Trends and JICA's Initiatives

Figure P03-1 Sharing Information in Local Communities

In order to formulate a feasible land use plan to realize the forest-based disaster risk reduction, it is necessary to understand the natural resources used in the daily lives of local residents and local industries, to examine the applicability of forest-based disaster risk reduction technologies, and to formulate a land use plan based on local characteristics. In order to utilize forest-based disaster risk reduction, project collaboration across administrative organizations and measures involving privately owned land are required. It is also essential to take a viewpoint to enhance the effectiveness of disaster reduction by guiding land use and resource management toward the maintenance of healthy forests through sectoral collaboration.

However, many people living in developing countries, especially in areas with high disaster risk such as steep slopes, are in a difficult economic position. Therefore, a land use plan that involves a trade-off between disaster risk reduction and household income must be carefully developed with various stakeholders, including local government agencies, NGOs, and, in some cases, universities that can provide scientific evidence. For example, the plan must be developed with the agreement of various stakeholders on such details as income for afforestation activities, forest management practices, rights for timber utilization, and the area that can be harvested at one time.

Land use plan and management plan

There are two types of plans that must be developed in cooperation with local residents for forest-based disaster risk reduction: land use plans and land management plans that include forest management based on those plans. Even if a land use plan for forest-based disaster risk reduction is formulated, if the land is not managed in a sustainable manner afterwards, the functions envisioned in the plan will not be realized. Since local residents are the main actors in managing land use, it is essential to have a participatory process. Local communities play an important role in sustainable land management and forest-based disaster risk reduction. Local residents are highly dependent on the local environment and resources for their livelihoods, and often have expert knowledge of their environment. Therefore, it is beneficial to utilize their knowledge in planning, and at the same time, their resilience can be enhanced by clearly positioning their rights in plans and policies [2)].

Normally, risk management is the main focus of land use planning for forest-based disaster risk reduction, but it is necessary to add economic considerations at this stage. In promoting risk management, there is a possibility of placing restrictions on the economic activities of local residents. Therefore, a land use plan should be developed by obtaining consensus of local residents on land use, and consensus should also be formed on countermeasure scenarios against disaster risks with the participation of local residents. In some cases, the introduction of a *Chisan* facility may help to gain consensus among local residents in the land use planning process. In such cases, it is advisable for local government officials to

INFO

2) Nehren U., et al. (2014) The ecosystem-based disaster risk reduction case study and exercise source book. UNDRR, 100pp

Figure P03-2 Land management by local communities

explain about the facility to local residents to deepen their understanding of the facility.

Since land management is greatly related to the livelihoods and lives of local residents, the local community is expected to take the initiative in land management (Figure P03-2). People in the local community are not always homogeneous and sometimes there are conflicts. Therefore, it is important to establish a mechanism for dialogue and cooperation within the community and with external stakeholders in order to develop a land management plan. Community participation in land management for forest-based disaster risk reduction technologies will strengthen the community's capacity for forest-based disaster risk reduction, and will build partnerships at all levels with various stakeholders. Working with local communities on all processes from disaster risk assessment to land use planning and land management planning will promote local people's understanding and ultimately lead to a long-lasting land management process of forest-based disaster risk reduction.

Providing scientific evidence

In order to select the more rational of multiple options for disaster management, quantitative assessments and scientific findings are not only essential for improving the understanding of local residents, but also help to create a common understanding to build consensus among stakeholders with different interests [1)]. For example, a disaster risk map is an effective means to build consensus among various stakeholders when developing land use plans. By presenting the level of disaster risk and the extent of the disaster, the impact of a disaster on living areas becomes clear, and the importance of developing land use plans becomes apparent. In addition, visualization using GIS of what benefits will be generated by land use change will facilitate discussion among stakeholders.

Scientific data should be presented to promote understanding among local residents that the physical protection functions provided by forests take longer to manifest themselves than those provided by *Chisan* facilities, and that there is a high degree of uncertainty regarding their effectiveness. Then, taking cost-effectiveness into consideration, it is advisable to consider which hazardous areas should be covered with *Chisan* facilities and which areas should be forested and preserved in expectation of the disaster prevention and mitigation functions of forests.

Zoning of forest

The natural conditions and social needs for forests in areas where land use plans are developed are diverse, and usually a single forest is expected to fulfill the multiple functions of that forest. The process of zoning forests by focusing on the most significant functions among multiple functions is called forest zoning (Figure P03-3). By zoning forests, efficient and effective forest management can be implemented to fulfill the functions assigned to the zone.

As a specific procedure for forest zoning, first, the expected functions of the forest are identified based on the existence of regulations under the laws of the country and an evaluation of the functions of the forest, such as its high productivity and contribution to disaster risk reduction. Furthermore, zoning should be established for each function, taking into consideration local requirements for the functions of forests. In particular, zoning should be conducted while paying attention to areas that should be preserved for forest-based disaster risk reduction.

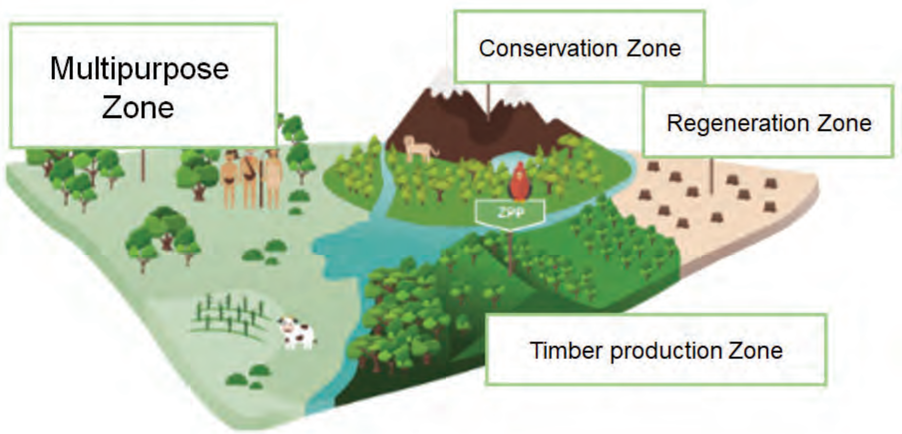


Figure P03-3 Example of forest zoning

4

Chapter 4 Technology for Strengthening Disaster Risk Reduction Functions of Forests

In developing countries where there is room for improvement of disaster risk reduction measures, deepening understanding and awareness of the disaster risks associated with land, and implementing preventive forest management projects through planned land use and forest conservation, will lead to a reduction in disaster prevention cost and stability in people's lives in the future. In terms of investment in the future, this is considered to be extremely cost-effective.

This chapter introduces methods for applying Japan's forest management (*Chisan*) technologies and remote sensing technologies to strengthen the disaster risk reduction functions of forests, as well as methods for evaluating the functions of mangroves, which are key to climate change mitigation and adaptation strategies in coastal ecosystems.

Recipe - P04

Landslide risk mapping

It's important for developing countries to be prepared for disasters, even when they don't have many resources. Using the latest technology, like artificial intelligence (AI), can help predict the likelihood of a disaster. Google Earth Engine (GEE) can identify landslides and changes in land use. Using satellite data that is available to the public, it can also determine what level of rainfall causes landslides. GEE can also be used to create maps showing landslide risk. These maps are created using spatial information derived from remote sensing and public data. These maps are evaluated by considering forest disturbance and rainfall amounts during landslide events.

Needs and challenges for landslide risk mapping

Climate change is causing typhoons to grow in size, increasing the frequency and intensity of heavy rainfall. With this increase, there is concern that countries with mountainous terrain will experience more frequent landslides (Figure P04-1). Since developing countries must take disaster countermeasures with limited resources, it is important to evaluate hazard levels by considering the likelihood of disaster occurrences and human activities. However, in developing countries, it is

Figure P04-1 Landslides in northwestern Vietnam caused by heavy rains in 2017 difficult to assess the risk because the necessary spatial information to assess the risk is not yet available. Additionally, there is a limit to the amount of information that can be collected on the ground. Therefore, the challenge is how to extract the disaster risk reduction functions of population distribution and ecosystems from existing remote sensing data such as satellite images. It is also necessary to develop reliable risk assessment technologies that utilize the latest technologies, such as Artificial Intelligence (AI).

Risk assessment of landslide disaster

When preparing a risk map, it is necessary to conduct risk assessments using existing spatial information. Google Earth Engine (GEE) is a particularly powerful tool for extracting landslide sites and identifying land use changes that require time-series analysis. GEE allows users to analyze data in Google's cloud environment without downloading open-source satellite data and to download only the results. Additionally, information such as the amount of rainfall required to cause a landslide in each region is also essential for risk assessment.

When assessing risk, it is necessary to consider the degree of importance of factors that are deemed to have an impact. One method for determining the importance of these factors is to use satellite images to identify landslide sites (the objective variable) and then use the information obtained from the satellite

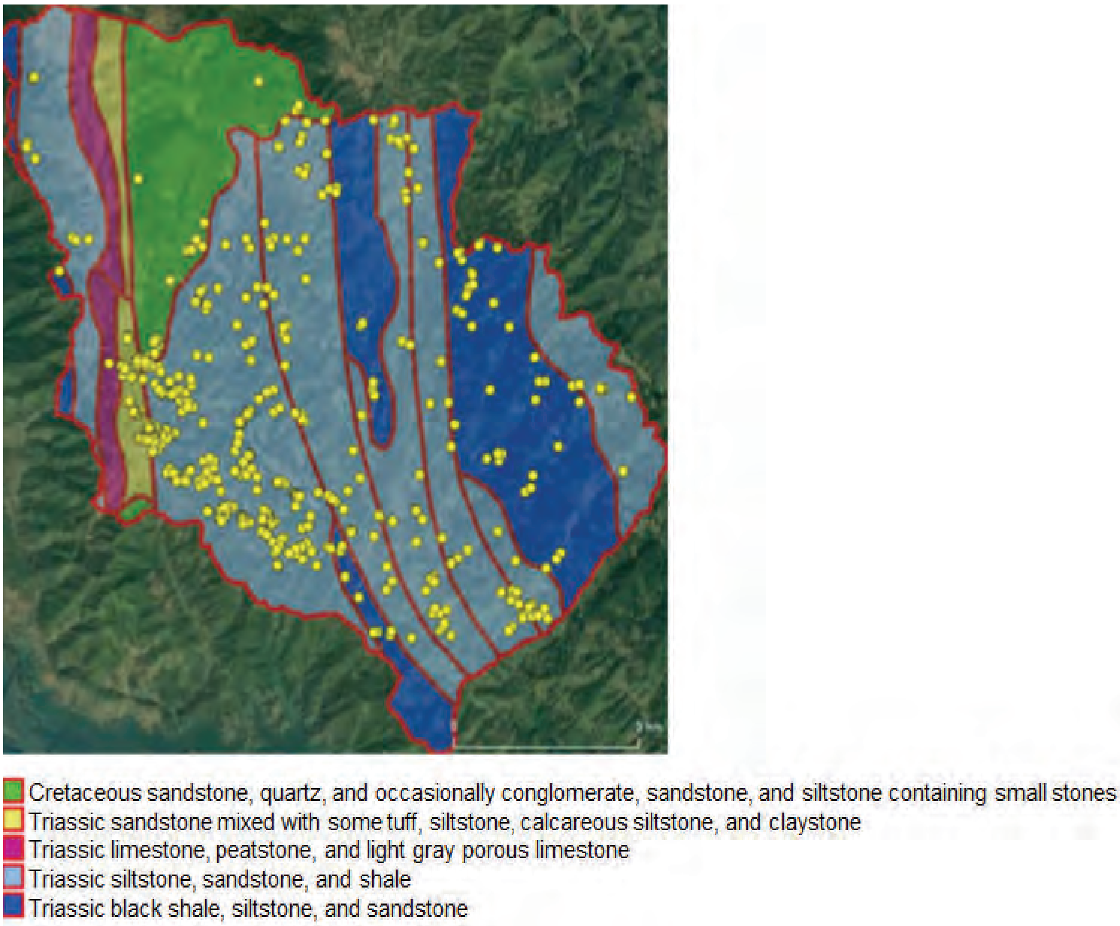


Figure P04-2 Geology and locations of landslides images, such as land use classification, road influence, elevation, calculated slope, azimuth, and geological information obtained from geological maps, as landslide factors (the independent variables) (Figure P04-2). The importance of these factors can then be calculated using machine learning methods such as Decision Trees and Random Forests. However, the results of machine learning methods, such as Decision Trees and Random Forests, can vary depending on the items in the dataset used and the settings during analysis. Therefore, caution is required when handling the results. When conducting risk assessments based on these results, keep in mind that the results (i.e. the risk map) must be verified on site before they are used. On the other hand, if a certain trend can be recognized in each result, it can be considered to be generally reliable.

Nevertheless, even after conducting a risk assessment, it may still not meet local needs. To avoid this, it is necessary to understand local disaster awareness, consider the balance with local social and economic conditions, and present the best possible solution. For this reason, risk assessments should be conducted through exchanges of opinions with local residents.

Use of Google Earth Engine in extracting landslide areas

GEE is a service that allows the free analysis and use of open source satellite data in Google's cloud environment. It has a rich set of tools and an API. First, input data for land cover classification is prepared in GEE. This input data consists of satellite data (e.g., Sentinel-2 data) from before and after a heavy rainfall event that caused landslides as well as teacher data for land cover classification. An image is created for each band before and after landslides, an image is created by removing clouds from the time series data for a certain period. Normalized vegetation index and income moisture index images are also created from these data. Difference images of the normalized vegetation and moisture index before and after the landslide are also created. A land cover classification map will then be created using machine learning model and the teacher data for land cover classification. New landslide areas are extracted.

Estimating land use and forest disturbance by machine learning

Forests can control landslides, but this ability is believed to be lost when previously forested areas are converted for other uses, such as agriculture and development. However, past land use transitions are not well understood in many developing countries. Therefore, it would be useful to estimate forest disturbance and land use annually using satellite imagery for time-series analysis. This method uses available historical data to extract information on changes in vegetation over time and employs training data and machine learning models. This analysis will provide important information for assessing the risk of landslides and other disasters which is related to the development of forest management techniques that reduce disasters.

Assessment of rainfall at the time of landslide

Landslides are triggered by rainfall infiltration into the voids of permeable layers and resultant increase in pore water pressure. Characteristics of landslide-triggering rainfall are important indices for evaluating the associated hazard risk. In developing countries, it has been difficult to assess rainfall during landsliding due to the lack of ground meteorological observation stations and radar observation systems. However, recent satellite-based global precipitation data have been made publicly available, offering the possibility of determining rainfall with a high risk of causing slope failure. By analyzing time-series satellite rainfall data to identify rainfall amounts and patterns during landslide events, it is possible to evaluate the potential rainfall amounts and patterns that pose a high landslide risk.

Preparartion of risk maps for landslide

In developing countries, the assessment of landslide risk is challenging due to the absence of spatial data, which is crucial for evaluating the potential for landslides. Consequently, a risk map for landslides has been developed. This map is based on forest disturbance and land use change, both of which are estimated by a machine learning model. The model is trained on remote sensing data, spatial information obtained with the data, and publicly available data. One method of preparing risk maps is to use a digital elevation model (DEM), slope and aspect calculated from the DEM, land use, roads, and geology as explanatory variables, and to use machine learning models to calculate the importance of the landslide site visually deciphered from satellite imagery. The supervised classification process is executed through the utilization of Random Forest, and the outcome of the risk assessment are mapped from the model that is constructed based on these results.

Recipe - P05

Application of Japanese forest management and *Chisan* technology

Chisan technology is highly applicable in terms of financial burden for developing countries that are trying to promote disaster preparedness, because it does not rely excessively on concrete structures. However, it is also a technology that is unlikely to be effective unless accompanied by appropriate land use planning, land use restrictions, and awareness-raising to improve disaster prevention and environmental awareness among residents. Appropriate land use layout is necessary for forest-based disaster risk reduction, and zoning is important for this purpose. However, even when forests are used for disaster risk reduction, it is necessary to install simple *Chisan* facilities. In addition, since it is not possible to reduce the risk of disasters in all hazardous areas by changing the land use layout, it is also necessary to install appropriate *Chisan* facilities in such areas.

Necessity of applying Japanese forest management and *Chisan* technologies

Cases of frequent sediment-related disasters in mountain regions caused by inappropriate land use during rapid economic growth of a nation can be observed in many parts of the world, including Japan. In general, traditional land use rules tend to be disregarded during periods of economic growth when industrial activity increases and the population rapidly grows, and land with high disaster risk is used, leading to the occurrence of sediment-related disasters (Figure P05-1). In Japan, the increase in demand for timber and firewood and charcoal associated with modernization during the Meiji period (1868-1912) and reconstruction after World War II led to excessive use of mountain lands, which in turn led to frequent

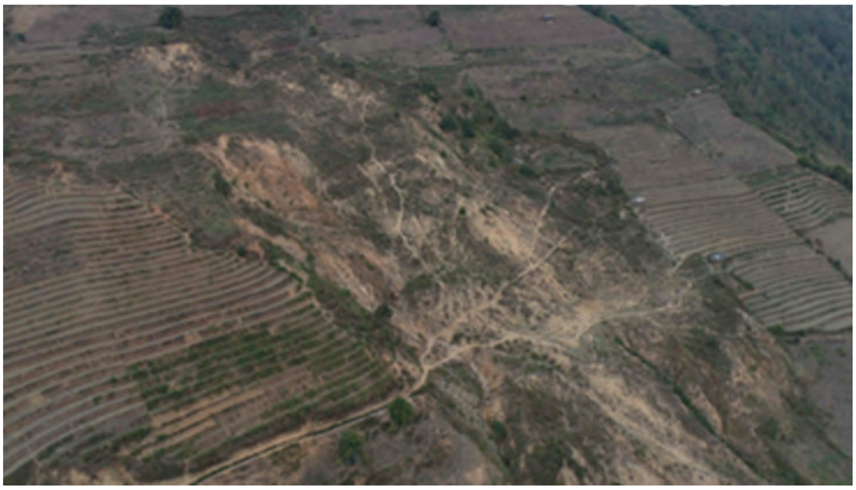


Figure P05-1: Examples of sediment-related disasters in mountain regions used exclusively for agricultural purposes sediment-related disasters in mountain regions. Learning from this history, Japan has implemented disaster prevention measures through "*Sabo*" and "*Chisan*" projects. The former aims to preserve devastated watersheds and directly protect lives and property from mudslides and other landslides by building disaster prevention facilities, while the latter aims to increase the resilience of mountain areas through forest maintenance and development to protect lives and property from disasters, as well as to reserve water sources and protect and shape the living environment. Based on its rich experience, Japan's *Chisan* projects have developed unique *Chisan* technologies that maximize the disaster risk reduction functions of forests by combining forest maintenance and supplementary facilities. The technology is not limited to increasing resilience against sedinemt-related disasters in mountain regions. Disaster prevention forests (protection forests) such as landslide prevention forest, flood damage prevention forest, tidal wave prevention forest, windbreak forest, and shifting sand prevention forest which have been established around residential areas and in coastal areas, provide a buffer zone to protect living spaces from natural hazards such as sediment runoff, flood, tsunami, storm surge, and strong winds. In this way, the disaster risk reduction functions of forests developed with *Chisan* technology are extremely wide-ranging and diverse, and because they do not overly rely on concrete structures, they are expected to be highly applicable to developing countries seeking to implement full-scale disaster countermeasures in the future from the perspective of reducing concerns about excessive financial burdens.

Chisan technology and land use planning

Developing countries in Southeast Asia, where economic development has been remarkable in recent years, have historically suffered from not only landslides but also floods due to their rainy climates, and there are concerns that future climate change may lead to large-scale landslide and flood disasters. As an example, in Vietnam, an exceptional number of typhoons and tropical cyclones continuously approached and landed in October and November of 2020, causing serious landslide and flood disasters in mountainous and coastal areas. According to the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), the series of disasters have directly affected approximately 1.5 million people in the country, including 243 dead or missing. The development of forests in mountainous areas through *Chisan* technology is expected to mitigate flood damage caused by rising river beds by reducing sediment runoff from mountainous areas, thereby making a significant contribution to comprehensive disaster prevention measures for the entire country, including not only sediment-related disasters but also flood damage. Furthermore, the technology is also expected to contribute to global warming countermeasures through REDD-plus by fixing carbon in forests.

While the *Chisan* technology has such a wide range of advantages, it is also a technology system that is difficult to be effective without appropriate land use planning, land use restrictions, and awareness-raising among local residents for disaster prevention and environmental awareness. For example, even if disaster prevention forests are established around residential areas, without appropriate use restrictions, private overexploitation may be left unchecked and lead to the destruction of disaster prevention forests (the so-called tragedy of the commons). However, in today's world where the Sustainable Development Goals (SDGs) are being emphasized, this characteristic of the land use planning and awareness-raising required for the land use control technology can rather be an advantage in that it can easily lead to increased disaster awareness among the residents.

In monsoon Asia, a region characterized by heavy summer precipitation and prone to natural disasters, appropriate land use restrictions may limit economic activities locally and in the short term, but from a long-term national perspective, there is no doubt that they will lead to the safety of the population. In developing countries where the formulation of disaster risk reduction measures will be in full swing, the early introduction of knowledge and awareness of the disaster risks of the land, and the introduction of *Chisan* technology through forest maintenance and development in mountainous areas, and coastal forest conservation measures for disaster risk reduction against storm surge damage in coastal areas, will contribute to disaster prevention in the future. This will lead to a reduction in future disaster prevention budgets and stabilization of the civilian population, and is considered to be extremely cost-effective in terms of investment in the future.

In order to implement highly effective zoning with high potential for agreement between the government and residents, it is necessary to assess the disaster risks latent in the land as accurately as possible based on scientific knowledge, and to disseminate this information to residents in a prompt and effective manner. For this purpose, it is essential to utilize information technology, which has developed remarkably in recent years, based on an understanding of local ecosystems and social and cultural backgrounds.

Preparation for introduction of forest management and *Chisan* technology

(1) Confirmation of landslide areas and landslide risk by remote sensing

Using the maps of landslide areas and landslide risk prepared in Recipe - P04, determine the occurrence status and risk levels of collapse in the area where forestation and *Chisan* technology is to be introduced.

(2) Awareness survey of local residents

Understanding and participation of local residents are essential for disaster risk reduction of natural disasters in the community. In such cases, local residents' awareness of disaster risk reduction will lead to their participation in disaster risk reduction measures. Therefore, a survey to find out the expectations of local residents toward the government for disaster risk reduction measures will be conducted. A survey to determine their awareness of disaster will also be conducted by asking the possibility of natural disasters, their thoughts on the economic damage and impact on their lives and livelihoods in the event of a natural disaster, the degree of effectiveness and expected costs of disaster prevention measures, and whether they would take such measures on their own.

(3) General situation in the field:

・River turbidity:

River turbidity is easily affected by land use changes in the upstream watersheds. In addition, erosion of slopes and streams increases the risk of flood inundation as sediment discharged from upstream areas accumulates on the riverbed and raises its elevation. For this reason, the turbidity of the river should be observed to determine the status of sediment runoff in the upstream area.

・Road slopes and drainage facilities

In developing countries, slopes formed by cut and fill work in road construction are often left without protection measures, and in terms of road drainage. In the absence of crossing drains in road drainage systems, ditch water becomes concentrated and is discharged only through culverts located at stream crossings. This concentration of large water volumes at single discharge points often leads to erosion at culvert outlets and overflow onto road surfaces. Such outlet erosion and road overflow can, in turn, trigger landslides. Therefore, the management conditions of road slopes and drainage facilities in the target area will be observed.

(4) Quantitative evaluation of slope failure risk due to road construction

Numerical analysis to reproduce rainfall infiltration into slopes and the resulting reduction in soil shear strength, using slope conditions (topography, soil layer thickness, permeability, soil physical properties, etc.) as parameters, is applied to both cases of road construction and non-road construction, and the changes in slope safety factor are compared and verified.

(5) Forest zoning for disaster risk reduction

・Land use layout and forest management for pre-disaster prevention

In order to utilize forests for disaster risk reduction, appropriate land use layout is first necessary and zoning is important for this purpose. Particular attention should be paid to land use above and below areas where people live and important infrastructure. At the same time, forests need to be properly managed in terms of thinning methods and rotation periods to ensure that they fulfill their functions for disaster risk reduction, and to enhance their functions.

・*Chisan* facilities for disaster prevention

The forest management system should be designed to reduce the risk of disasters during the period of forest creation. In order to reduce the risk of disasters in the meantime, even when forests are used for disaster risk reduction, it is necessary to establish simple *Chisan* facilities. In addition, since it is not possible to mitigate all disaster risks by changing the land use layout, plans should be made to ensure that appropriate *Chisan* facilities are also installed in such areas.

Recipe - P06

Disaster risk reduction functions of mangroves

As the risk of disasters in coastal areas increases due to sea level rise and frequent large typhoons, there are high expectations for mangroves to fulfill their disaster risk reduction functions. Since damage would occur to trees if the external forces received from waves and wind exceed the destruction limits of individual trees, it is important to consider the placement of coastal disaster protection forests as disaster prevention infrastructure based on an understanding of the limits of braking and uprooting trees. In order to evaluate the disaster risk reduction functions of mangroves over a wide area, it is necessary to calculate the extent of mangroves to determine the width of the forest bands and the cumulative area of mangroves in relation to the direction of waves. Since the environmental condition of mangroves for suitable growth sites varies greatly depending on the species, it is advisable to conduct preliminary planting trials to examine the conditions for suitable growth sites before the full-scale planting.

Necessity of mangrove conservation for disaster risk reduction

Mangroves are distributed in the intertidal zone of tropical and subtropical coastal areas and serve as a buffer zone between the sea and the land. In other words, mangroves provide various ecosystem services such as carbon sequestration (global warming mitigation) based on their high primary productivity, production of wood and fuel, and provision of habitats for organisms originating from both land and sea, as well as disaster risk reduction in coastal areas such as wind protection, tide protection, and wave attenuation. On the other hand, the recent sea level rise (SLR) caused by global climate change and the frequent occurrence of large typhoons have resulted in stronger storm surges than ever before, increasing the risk of disasters in coastal areas, and this has raised further interest in the disaster risk reduction functions of coastal areas, including mangrove ecosystems.

It is known that mangroves, which only grow in the upper areas of intertidal zone, have long played a role in disaster risk reduction in coastal areas by providing wind protection, tide protection, wave force attenuation, and erosion protection, as well as coastal forests composed of the terrestrial trees such as black pine [1), 2), 3), 4)]. In the current climate change era, when there are concerns about SLR and increased risk of coastal disasters caused by large typhoons, mangroves distributed along the coasts of tropical and subtropical regions have the potential to prevent erosion of coastal areas due to SLR caused by climate change and reduce the risk of storm surge caused by typhoons, which are expected to become stronger due to rising sea water temperatures, as part of climate change adaptation measures

INFO

1) Kaizu, M (1988) *[Geomorphology of the Ganges Delta and storm surge disasters]*. Journal of Geomorphology, 107, 137–141.

INFO

2) Sato, K. (1992) *[Mangrove forests, Coastal forests of Japan: Multifunctional environmental roles and their applications]*. In H. Murai et al. (Eds.) (Soft Science, 513 pp.).

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3) Sato, K. (2010) *[Marine utilization science and seawater chemistry: Insights from mangrove coastal forests]*. Journal of the Japanese Society of Sea Water Science, 82–90.

INFO

4) Matsuda, Y. (2011) *[Mangrove environmental physics]*. Tokai University Press. 378 pp.

Figure P06-1 Shrimp farming ponds created by developing mangroves (Left: intensive farming, right: extensive farming)

for disaster risk reduction [5), 6), 7)].

However, the current situation is that mangroves are being lost or degraded due to port development, construction of shrimp- and fish-ponds, and commercial logging (Figure P06-1) [8)], and furthermore, coastal erosion and surface erosion are becoming apparent in some areas. Therefore, as an action to reduce the hazard of coastal areas exposed to the risk of SLR, conservation activities in coastal areas through afforestation/reforestation of mangroves have been actively promoted in recent years [9)].

Against this background, with regard to disaster risk reduction of coastal areas against storm surge damage caused by SLR, there is an urgent need to understand the disaster risk reduction functions of mangroves and to develop mangrove conservation measures against anticipated risks.

Uprooting resistance of mangroves to waves and wind

Mangroves act as resistant bodies against waves, wind, and other fluids, and attenuate external forces from waves and wind. If the external force from waves and wind is less than the tree's resistant limit, the tree will continue to act as a resistor, but if the external force exceeds the tree's limit, the tree will be damaged by stem breakage or uprooting. Since mangroves are often damaged by external forces such as strong winds, storm surges, and high waves, it is important to understand the destruction limits of these trees and consider the placement of coastal disaster prevention forests as disaster prevention infrastructure in order to maintain mangroves and their multifaceted functions in the coastal area.

Tree-pulling experiments to quantify the uprooting resistance of mangroves have shown that the critical turning moment, an indicator of uprooting resistance to wind and waves, is dependent on tree species and tree size. The mangroves such as *Sonneratia caseolaris* and *S. apetala*, which spread horizontally cable-type roots in the muddy and sandy sediment, show weaker uprooting resistance than *Rhizophora stylosa*, which radially spreads many prop roots around their stems. When mangroves are planted for conservation in coastal areas, uprooting resistant properties of mangroves should be considered in the selection of species for tree planting.

INFO

5) International Federation of Red Cross and Red Crescent Societies (2011) Breaking the waves. Impact analysis of coastal afforestation for disaster risk reduction in Viet Nam, Geneva 51pp.

INFO

6) International Federation of Red Cross and Red Crescent Societies (2011) Planting protection. Evaluation of community-based mangrove reforestation and disaster preparedness programe, 2006-2010, Geneva 67pp.

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7) Huxham M., Dencer-Brown A., Diele K., Kathiresan K., Nagelkerken I., Wanjiru C. (2017)Chapter 8: Mangroves and People: local ecosystem services in a changing Climate. In Rivera-Monroy, V. H., Lee, S. Y., Kristensen, E. Twilley, R. R. (Eds.). Mangrove ecosystems: a global biogeographic perspective on structure, function and services. Springer Nature, 245-274

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8) Miyagi, T. (2003) *[Mangroves: Their formation, people, and future]*. Kokon Shoin. 193 pp.

INFO

Ministry of the Environment (Japan) (2021) IPCC AR6 Special Report (Project Planning and Supervision: Office of Decarbonization Innovation Research, General Affairs Division, Global Environment Bureau). 22 pp.

Wide-area evaluation of disaster risk reduction functions of mangroves

In the event of a storm surge caused by a sudden drop in atmospheric pressure due to a typhoon, mangroves can reduce damage in the coastal areas by suppressing wave height that overcome embankments due to the attenuation of wave force caused by vortices generated when waves hit mangrove. In order to evaluate the disaster risk reduction functions of mangroves over a wide area, the extent of mangroves is required to determine the width of the forest band and the average diameter at breast height (DBH), average tree height, tree shape per tree species, and stand density of the mangrove area are required to calculate the projected area of trees in relation to the direction of waves. It is difficult to obtain such an information over a wide area from ground truth surveys, and a remote sensing-based method is required. Mangroves are extracted by satellite data, and the area of mangroves up to the boundary with the embankment or land at a certain width for each possible wave direction in the targeted area is calculated (Figure P06-2). By estimating tree height and stand density, the projected area of all standing mangroves at a certain width for each wave direction can be estimated. The larger this projected area is, the higher the disaster risk reduction function of the mangrove. This method of evaluating disaster risk reduction functions is a method that takes practicality into consideration and allows for a relative evaluation of those functions. In addition, by accumulating information on areas where tidal surge overcoming embankments has occurred, it becomes clear which areas should be prioritized for countermeasures based on this indicator.

Key consideration in mangrove planting

Suitable sites for growing mangrove are determined by ground elevation and

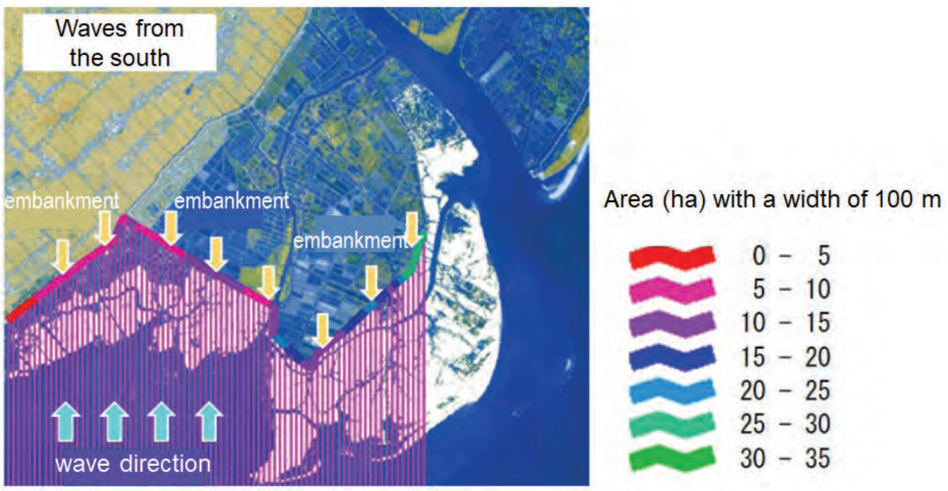

Figure P06-2 Area of mangroves within a 100 m wide polygon extending from the embankment in the direction of the waves tidal environment. The conditions of a suitable site vary by species. However, since there is variation in the site conditions suitable for mangrove growth, it is recommended to conduct preliminary planting trials to examine the conditions of suitable growing areas before proceeding to full-scale planting program. Since the main obstacles to the establishment and growth of mangrove seedlings are the loss or damage of seedlings due to waves, erosion of the ground, and burial of seedlings due to sediment accumulation, it is important to understand the ground environment and tidal trends in advance when planting on degraded coastal areas.

In order to plant mangroves and steadily promote mangrove restoration, the key is to secure healthy seedlings and viviparous seeds for planting (Figure P06-3), as well as to collect seedlings and handle the seeds after collection to ensure seedling production. In many cases, seedlings are grown in nursery fields with natural irrigation using the tides, so the ground should be leveled to a level slightly lower than mean sea level to set up the nursery field. Make sure that seawater does not stagnate in the seedling beds at low tide. If seawater stagnates, solar radiation may cause salinity concentration and water temperature rise, which may induce root system injury and seedling mortality.

When planting mangrove seedlings, be careful not to plant a simple forest of the same tree species by selecting only seedlings of the Rhizophoraceae family, which are easy to prepare and handle. Careful consideration should be given to determining which species to plant and where to plant them, based on the location of the remaining tree species and similar tidal environments.

Figure P06-3 Various types of mangrove fruits and viviparous seeds

Technical

5

Chapter 5
Preparing Risk Maps using Remote Sensing Technology

Developing countries need to establish disaster countermeasures with limited resources, so it is necessary to assess the likelihood of disasters occurring and the degree of risk associated with human activities. However, in developing countries, it is difficult to assess risk levels because the spatial information necessary for risk assessment is not readily available.

In this chapter, a method for preparation of landslide risk maps is introduced that can be used for forest management by overlaying various types of information collected through remote sensing technology and field surveys, such as past landslide history, topography, soil quality, forest cover, and precipitation, on a geographic information system (GIS) in the target area.

Recipe - T01

Extracting landslide areas using Google Earth Engine

Refer to

Recipe-P04
Landslide risk mapping
as a parent Recipe

Google Earth Engine is a service that allows users to analyze and utilize open source satellite data for free using Google's cloud environment and a variety of tools provided by its API. To extract landslide areas using GEE, you must first prepare the input data to be used for land cover classification. Create images with clouds removed from time-series satellite data covering a certain period before and after landslide, and create images of normalized vegetation index and normalized moisture index from these data. Also, create difference images of normalized vegetation index and normalized moisture index before and after collapse. Using these data as input data, create a land cover classification map using a machine learning model and extract new landslide areas.

Preparation of input data using Google Earth Engine

INFO

1) Google Earth Engine
https://earthengine.google.com/noncommercial/?hl=ja

Google Earth Engine (GEE) is a service provided by Google, a global IT company. Non-profit organizations, academic or educational institutions, educators, news media organizations, and certain government agencies can use Google's cloud environment and API with a variety of tools to analyze and use open-source satellite data for free (Figure T01-1) [1]. A key feature is the ability to analyze large

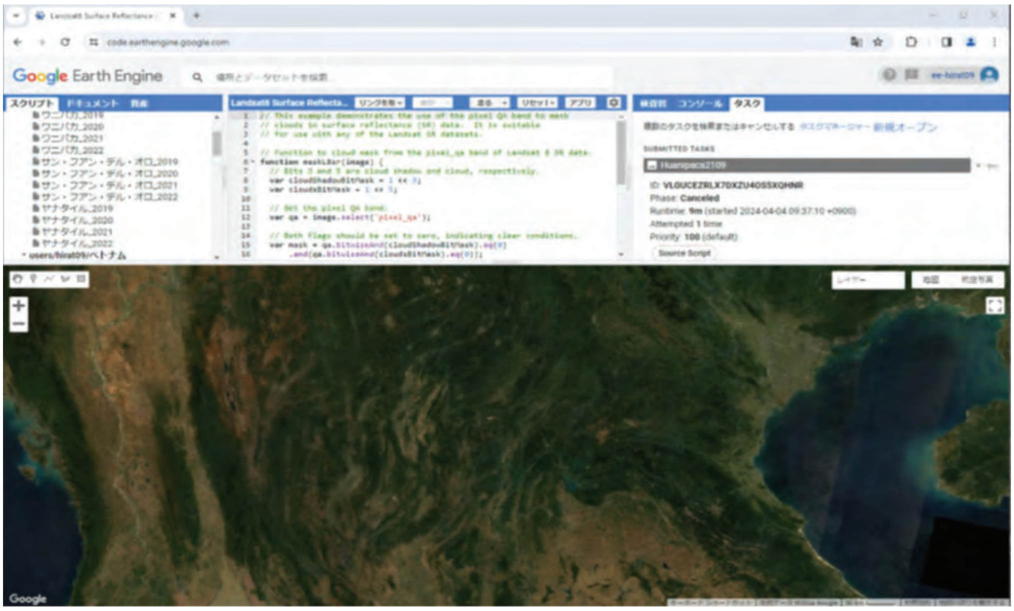

Figure T01-1: Creating cloud-free images with Google Earth Engine [1]

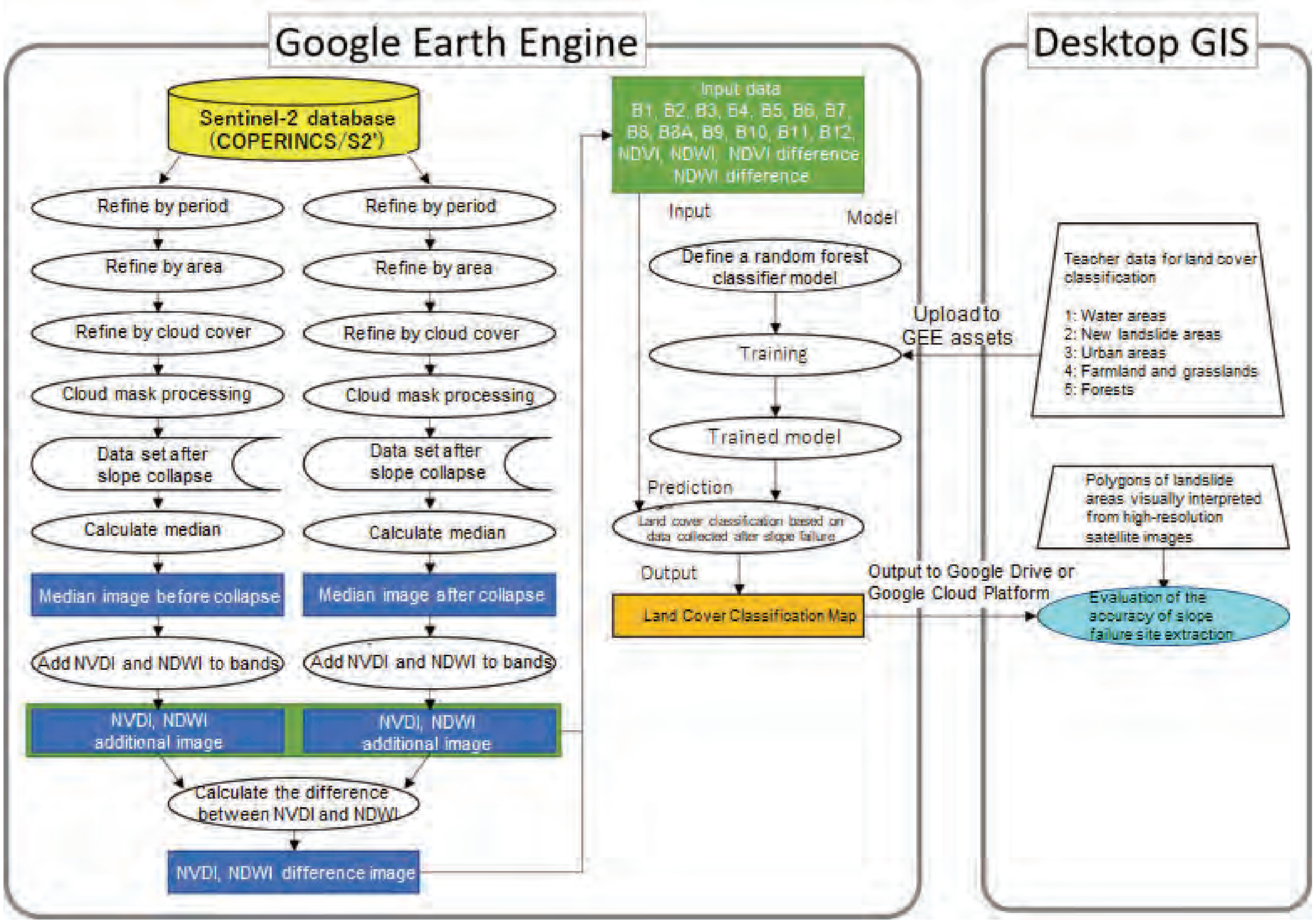

Figure T01-2 Flowchart for extracting landslide sites using Google Earth Engine

amounts of open satellite data without downloading it to your own computer, as computations can be done on Google's cloud servers. Traditional continuous observation using satellite data had two problems. First, it took time to download updated satellite data. Second, it cost money for data storage. This made it hard, especially for using satellite data because of network and cost issues. GEE has largely removed these barriers, opening up new possibilities for monitoring natural disasters.

One problem with optical satellite sensors is that they can't see areas with clouds. This problem can be solved by combining satellite images taken over time to create a mosaic of clear areas (Figure T01-2). To create images without clouds, follow these steps: First, decide which satellite data set from which period to use. Next, set the area to be analyzed. However, in images with a lot of clouds, even areas that are not actually cloudy may often be unsuitable for digital analysis because of the influence of tiny water vapor particles. It is advisable to exclude images with a cloud coverage rate exceeding 30% from analysis. Then, cloud masks are created for each satellite image of the selected specific areas. Sentinel-2 satellite data comes with quality assurance data, including cloud masks. For each satellite dataset, images without clouds are created using the corresponding cloud mask. Then, for each band, the median value is calculated for each pixel from all cloud-free images, and that value is assigned to the pixel. This creates a cloud-free median image. One disadvantage of median images is that they do not accurately capture seasonal changes in land cover. In regions with rainy and dry seasons, for example, farming is often done during the rainy season, while the dry season is often a fallow period. Furthermore, since satellite data is mainly unaffected by clouds during the dry season, cropland is mistakenly often identified as barren without crops when a median image is created. The same is true for tropical deciduous forests that shed their leaves during the dry season. On the other hand, when identifying landslide-prone areas, vegetation is generally present before a landslide occurs, whereas the area becomes bare land afterward, making extraction relatively straightforward.

To extract landslide areas, it is recommended to add Normalized Difference Vegetation Index (NDVI) images and Normalized Difference Water Index (NDWI) images calculated from median images to the median images of each band. Additionally, difference between NDVI images and NDWI images before and after the landslide are also expected to improve classification accuracy. The following should be used as input data for extracting landslide areas: median images of each band before and after the landslide occurrence, as well as NDVI and NDWI images and their respective difference images. However, since short-wavelength bands are inevitably susceptible to the influence of water vapor, which may remain even in the median images. In such cases, it is necessary to exclude the short-wavelength band images from the input data for land cover classification.

Land cover classification for landslide extraction

GEE uses machine learning models for land cover classification. The main machine learning models that can be used are Decision Trees, Logistic Regression, Support Vector Machines, Naive Bayes, and Random Forests. Recently, Random Forests have often been used for land cover classification. Random Forest is an algorithm that combines two techniques: “Decision Trees” and “Ensemble Learning (bagging).” It is a flexible machine learning model that is effective for many types of datasets, because it can easily handle categorical variables and missing data.

Machine learning requires data called “training data.” For conventional land cover classification, training data is required for land cover classes such as water, settlement, cropland, grass, and forest. However, in addition to these classes, the identifying landslide-prone areas requires a new land cover class called “barren” (Figure T01-3).

Evaluation of the accuracy of landslide area extraction

To evaluate the accuracy of landslide site extraction obtained from land cover classification, a verification area must be set and satellite data or aerial photographs with higher ground resolution than the satellite images used for classification must be used to interpret new landslide sites and create polygon data. Overlaying this data on the land cover classification results to evaluate the accuracy of the

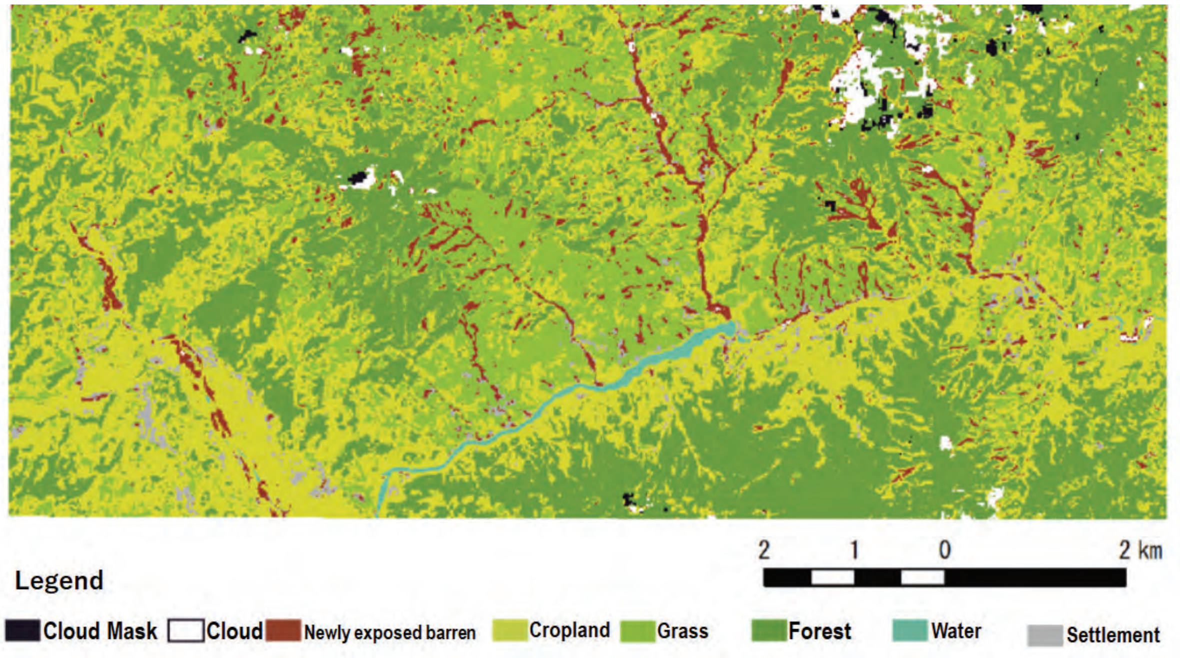

Figure T01-3 Land cover classification map for identifying landslide-prone areas

extraction based on the accuracy rate. The percentage of incorrect classification results is called commission error. In other words, it represents the accuracy of classification (extraction) of landslide sites when the interpretation of the high-resolution satellite data is considered correct. Conversely, the percentage of cases in which the classification results are considered correct, but the interpretation yields a different classification class is called the omission error.

Recipe - T02

Land cover classification and forest disturbance detection using machine learning models

Refer to

Recipe-P04
Landslide risk mapping
as a parent Recipe

Forests provide a function to reduce the risk of landslides. When previously forested areas are converted to agricultural or developed land, this function might be lost. However, in many developing countries, historical land cover changes are not sufficiently mapped. This Recipe introduces a method for detecting annual forest disturbances and classifying land cover changes using time series satellite data and machine learning models. Mapped land cover changes provide important information for assessing the risk of landslides and other disasters, supporting the development of forest management and zoning strategies aimed at disaster risk reduction.

The impact of historical land cover changes on landslide risk

Assessing landslide risk in mountainous areas is important for developing countermeasures and reducing potential damage. While landslides are generally triggered by heavy rainfall, they are also influenced by inherent factors such as slope and land cover (Figure T02-1). In this context, forests play an important role in reducing landslide risk; however, this function might be diminished or lost when previously forested areas are converted to other land covers such as agricultural or developed land. Furthermore, recently restored forests provide limited capacity to mitigate landslide risk. Therefore, understanding both current land cover and

Figure T02-1: Landslides caused by various factors

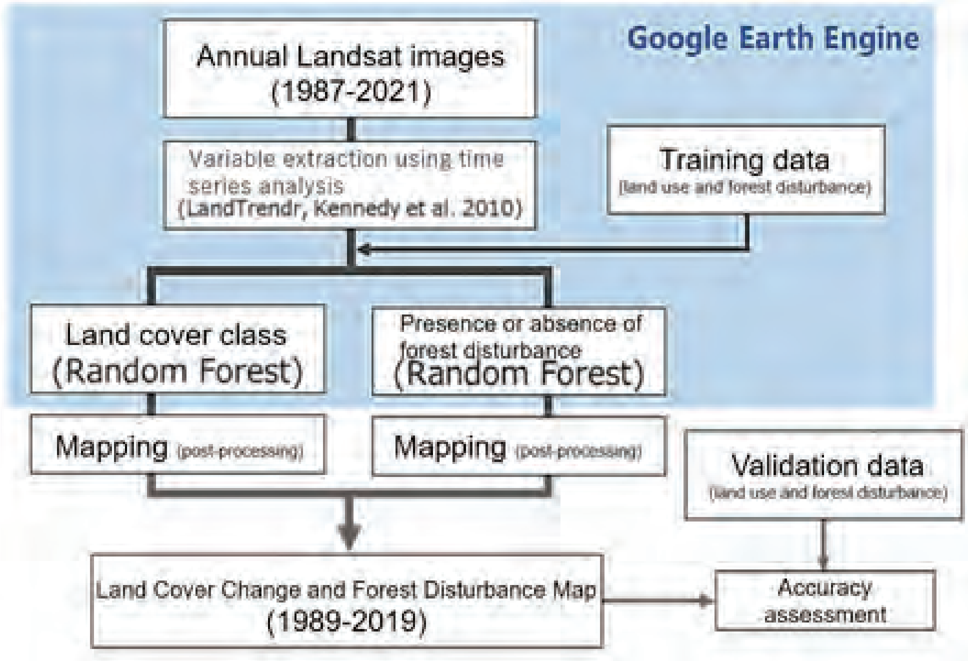

Figure T02-2: Method for creating land cover change and forest disturbance maps

historical land cover changes is important to assess landslide risk during heavy rainfall events. However, in many developing countries, historical land cover changes have not been sufficiently mapped.

Methods for mapping historical land cover changes using satellite images

This Recipe introduces a method (Figure T02-2) for detecting annual forest disturbances and classifying land cover changes based on satellite data and machine learning models. This method employs time series analysis to identify spectral changes in historical satellite data.

Landsat satellite data serve as the primary data source for forest disturbance detection and land cover classification, offering a spatial resolution of 30 m and more than 30 years of historical observations. Annual image composites are generated by calculating the median values of each spectral band at each pixel location. From these composites, five spectral indices are calculated (Normalized Burn Ratio: NBR [1)], Tasseled Cap Brightness: TCB, Tasseled Cap Greenness: TCG, Tasseled Cap Wetness: TCW, Tasseled Cap Angle: TCA). Among these, the NBR is selected as an input spectral index for the pixel-based change detection algorithm [2)], as it is sensitive to forest disturbance. The change detection algorithm first detects potential breakpoints in time series to divide the data into temporal segments. Subsequently, Random Forest models are used to classify both forest disturbances and land cover classes for each segment using derived spectral indices. To develop the Random Forest models, training data are collected from the study area, and then each unit is labeled with the land cover class and disturbance presence/absence by visual interpretation. After applying the Random Forest models to the

INFO

1) Key CH, Benson NC (2006) Landscape assessment (LA): Sampling and analysis methods. Fort Collins, CO, USA

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2) Kennedy RE, Yang Z, Cohen WB (2010) Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr -Temporal segmentation algorithms. Remote Sens Environ 114: 2897-2910

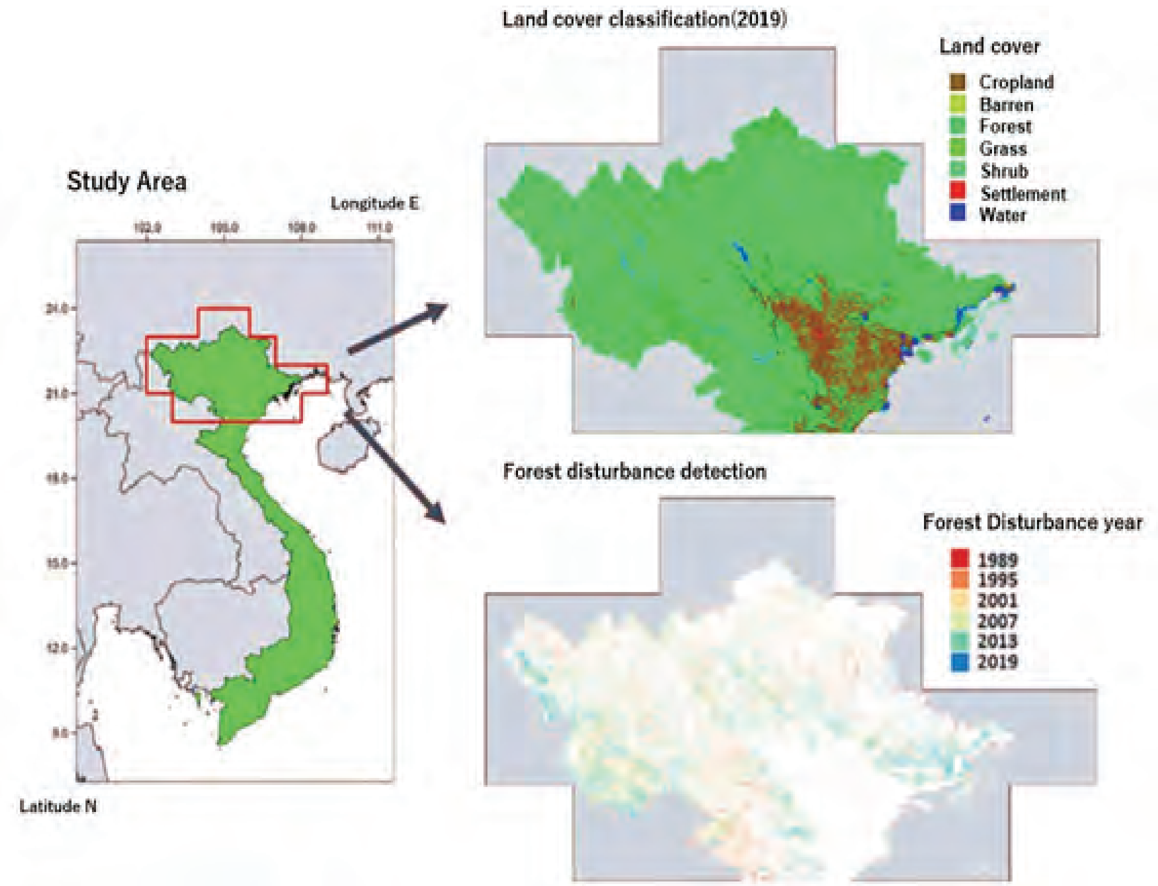

Figure T02-3 Land cover classification (top right) and forest disturbance year (bottom right) in northern Vietnam

entire study area, forest disturbances smaller than 5 pixels are removed, as these are assumed to be false positives. The irrelevant land cover changes are also corrected. The accuracy of disturbance detection and land cover classification is assessed using a stratified random sample, which is also labeled by visual interpretation.

An example application of this approach was demonstrated in the mountainous region of northern Vietnam, where landslides have frequently occurred in recent years. Landsat satellite data acquired between 1987 and 2021 was used for the analysis. A stratified random sample of 1,400 pixels was collected, and then land cover class and disturbance presence/absence were assigned to each sample unit through visual interpretation, which served as training data for Random Forest models. Validation data were collected in the same manner, consisting of 385 pixels. Based on these data, annual forest disturbance and land cover changes from 1989 to 2019 were mapped for the entire study area (Figure T02-3). Land cover changes between the beginning and the end of the study period revealed that forest recovery was dominant process, and that land cover changes occupied only a small proportion following forest disturbances such as logging. In cases where land cover change occurred, conversions to grass/shrub accounted for the largest proportion, followed by conversions to settlement and cropland. The map also indicated that substantial cropland areas had been recovered to forest. The

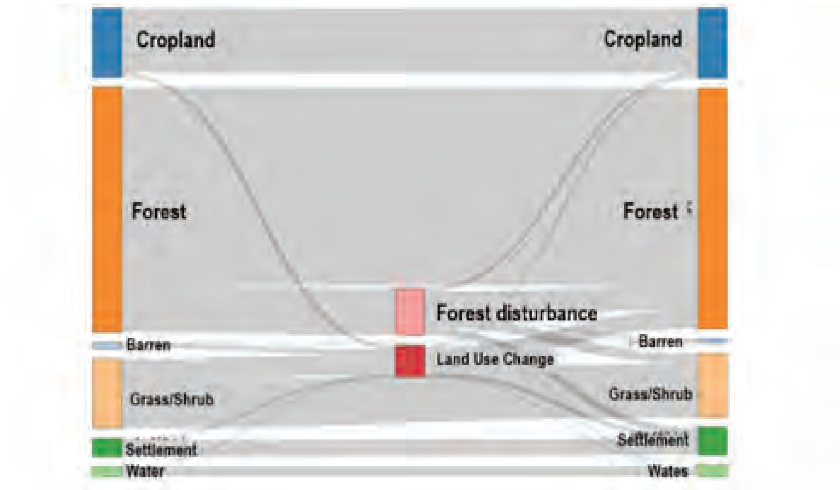

Figure T02-4 Changes in estimated land cover area from the beginning of the priod to the end of the period (1989-2019) (the vertical width of the figure is the percentage of area in each class)

Changes from the beginning of the period (left) to the and of the period light for each land cover and the changes that occured during the period forest disturbance vs. land cover) as a percentage of area, expressed as a vertical scale.

increase in forest area from other land cover classes was almost equal to the decrease caused by forest conversion to other land cover classes, resulting in a relatively stable forest area within the study area. (Figure T02-4). This case study demonstrated the effectiveness of the proposed approach for mapping land cover changes using time series satellite data.

Application to landslide risk assessment

The proposed approach is capable of mapping large-scale land cover changes. Mapping historical land cover changes in mountainous areas is useful for investigating the relationship with landslides, identifying potential causes, and developing landslide risk maps. Such information can contribute to the formulation of forest management and zoning strategies aimed at disaster risk reduction.

Recipe - T03

Evaluation of landslide-triggering rainfall

Refer to

Recipe-P04
Landslide risk mapping
as a parent Recipe

Landslides are triggered by rainfall infiltration into the voids of the permeable layer and resultant increase in pore water pressure. Characteristics of landslide-triggering rainfall are important indices for evaluating the associated hazard risk. In developing countries, it has been difficult to evaluate rainfall during landsliding due to the lack of ground-based meteorological observation stations and radar observation systems. However, recent satellite-based global precipitation data have been made publicly available, enabling the identification of rainfall patterns with a high risk of landsliding. By analyzing time-series satellite rainfall data to identify rainfall amounts and patterns during landslide events, it is possible to evaluate the potential rainfall amounts and patterns that pose a high landslide risk.

Satellite rainfall data (GSMaP)

Characteristics of landslide-triggering rainfall are important indices for evaluating the associated hazard risk. In developing countries, it has been difficult to evaluate rainfall during landsliding due to the lack of ground-based meteorological observation stations and limited spatial rainfall data from radar observations.

In recent years, it has become possible to identify landslide-triggering rainfall

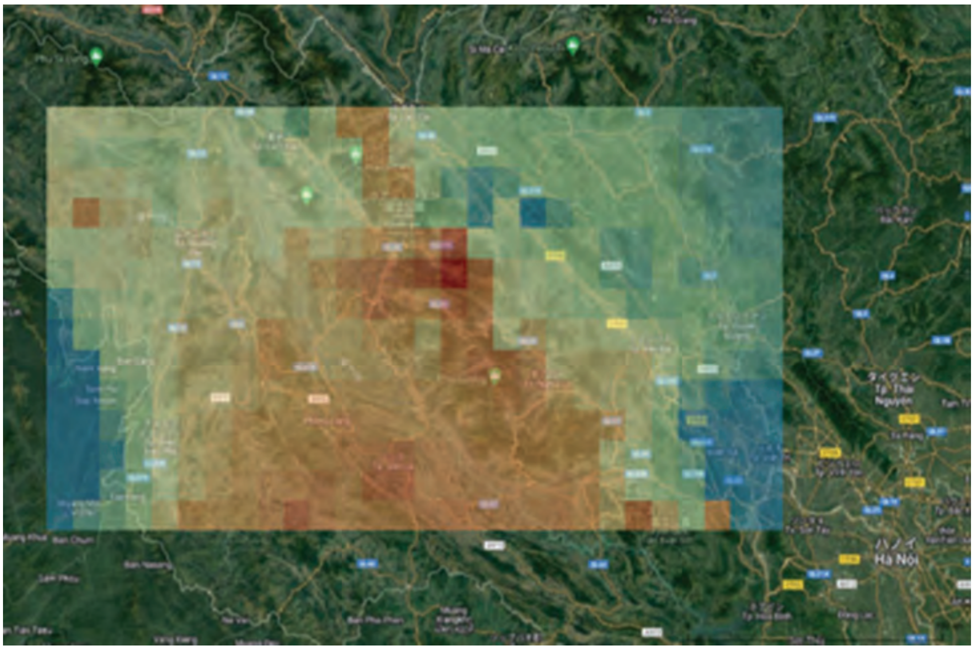

Figure T03-1 Hourly rainfall data from satellite observations obtained from GSMaP using satellite rainfall data from the Japan Aerospace Exploration Agency (JAXA). Since 2017 JAXA has released satellite rainfall data as the Global Satellite Mapping of Precipitation (GSMaP) [1]. The GSMaP data is a relatively high-precision, high-resolution global precipitation product, which comprehensively utilizes rainfall radar and infrared radiometer data from geostationary satellites, with multiple microwave radiometer observations and applies a precipitation estimation algorithm based on statistic approaches. The product is distributed as a global hourly precipitation map with a resolution of 0.1° latitude and longitude (Figure T03-1).

By registering on the GSMaP website, users can obtain and utilize hourly rainfall data for any period in any desired area since 2000. This product is available even in regions with sparse rainfall observations, it is expected to be useful in developing countries where meteorological observations are insufficient.

As described above, satellite rainfall data have the advantage of being available regardless of region, but it has been pointed out that intense rainfall tends to be underestimated as a technical issue [2]. In this context, there is a risk that characteristics of landslide-triggering rainfall cannot be robustly determined. Therefore, it is necessary to develop new methods to characterize landslide-triggering rainfall using satellite rainfall data, while taking this underestimation issue into account.

Evaluation of satellite rainfall data

To evaluate landslide-triggering rainfall using satellite rainfall data, it is important to verify whether the satellite rainfall data correlate with ground-based measured rainfall values. Therefore, a validation was carried out focusing on Vietnam. As ground-based spatial rainfall data, 0.1° grid (approximately 10 km) daily precipitation data collected and provided under the Data Integration and Analysis System (DIAS), developed and operated under a subsidy program by the Ministry of Education, Culture, Sports, Science and Technology of Japan, were used. The measured rainfall data were provided through REMOCLIC [3] covering daily precipitation from 1980 to 2010 and are publicly available through DIAS (Figure T03-2). However, the data after 2010 are not available, which limit their use for evaluating current landslide hazard risk.

Therefore, the satellite rainfall data were compared with the measured rainfall data for the period from 2000 to 2010, to investigate the rainfall thresholds at which underestimation occurs in the satellite rainfall. Since the measured rainfall data were distributed as daily precipitation, the satellite rainfall data were aggregated to daily values. The comparison was conducted in Ho Bon Village, Mu Cang Chai District, Yen Bai Province, Vietnam, where numerous landslides occurred due to heavy rainfall in early August 2023, resulting in road disruptions and human casualties. The results show that, across all grids compared, the satellite rainfall data exhibited smaller precipitation values than the DIAS (measured) rainfall data in the range above the 90th percentile of daily rainfall (Figure T03-3). Moreover,

INFO

1) GSMaP
https://sharaku.eorc.jaxa.jp/GSMaP/index_j.htm

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2) Long Trinh-Tuan, Jun Matsumoto, Thanh Ngo-Duc, Masato I. Nodzu & Tomoshige Inoue (2019) Evaluation of satellite precipitation products over Central Vietnam, Progress in Earth and Planetary Science volume 6, Article number: 54.

INFO

3) REMOCLIC. (2016) VnGP - Vietnam Gridded Daily Precipitation Data(0,10°×0.10°)[Data set⌋.(DIAS)
https://doi.org/10.20783/DIAS.270

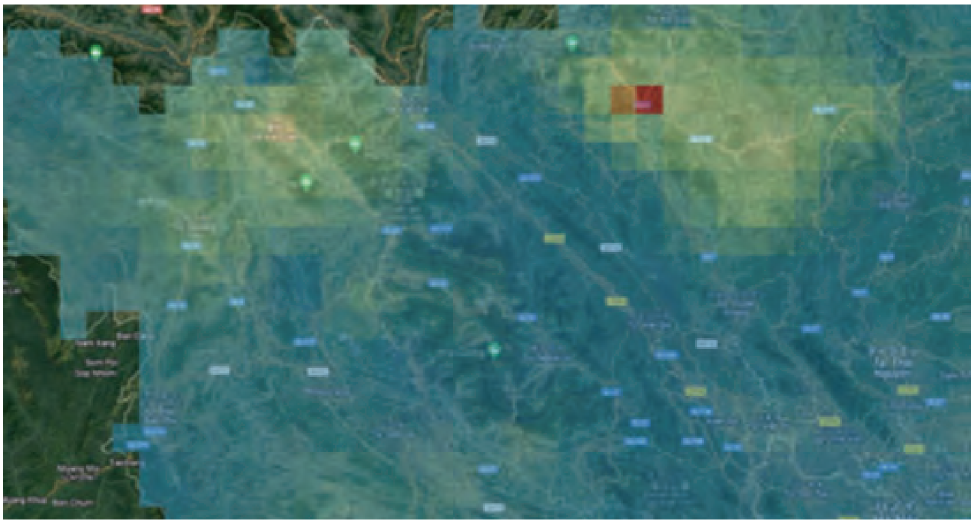

Figure T03-2 Measured daily rainfall data obtained from DIAS

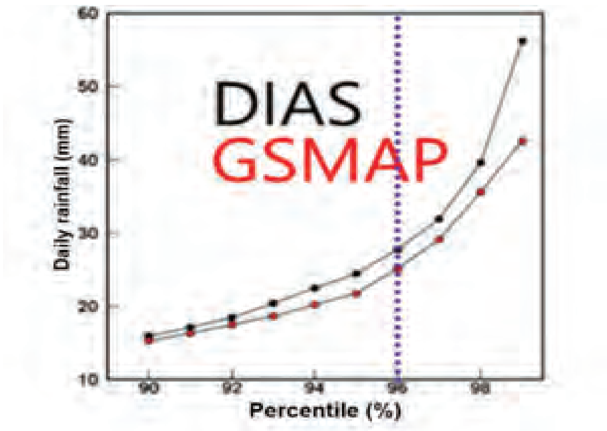

Figure T03-3 Example of comparison results between measured rainfall data (DIAS) and satellite rainfall data (GSMaP)

both datasets showed a substantial precipitation increase when daily rainfall exceeded the 96th percentile (Figure T03-3).

Relationship between landslides and rainfall

Landslide triggering is affected by various factors such as hillslope morphology, lithology, vegetation, and hydrological settings. On hillslopes, permeable layers allow rainfall infiltration, whereas impermeable layers impede this process. Landslides may occur when infiltrated rainfall increases pore water pressure around the interface between the permeable and impermeable layers, thereby reducing the resistance force against the driving force of hillslope materials. Thus, it is important to identify the rainfall threshold at which the driving force exceeds the resistive force.

In the case of Vietnam, precipitation values comparable to the 96th percentile were observed in several successive days in early August 2023, which triggered numerous landslides. Thus, the high percentile rainfall, where precipitation sharply increases in the satellite rainfall data, can serve as a proxy threshold to characterize landslide-triggering rainfall (Figure T03-4). Rainfall exceeding the 96th-percentile

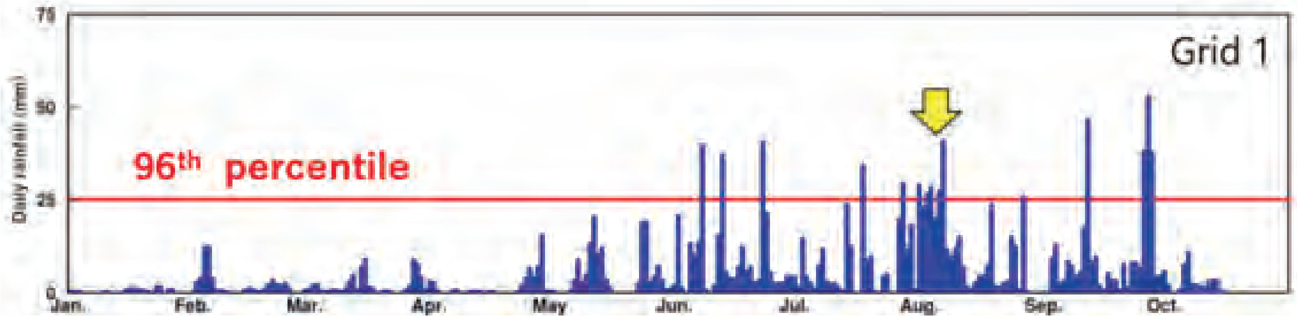

Figure T03-4 Daily rainfall based on satellite observations (Jan - Oct 2023)

The yellow arrow indicates the period of the landslide occurrence. This period corresponds to the period of several days of rainfall exceeding the 96h percentile. in contrast, only one or two days of rainfall exceeding the 96 percentile did not trigger landslide.

value for only 1–2 days was observed multiple times in 2023, but no landslides occurred during these relatively short periods. This indicates that in this region, continuous heavy rainfall over several days is highly likely to trigger landslides. Therefore, it is necessary to establish a more reliable threshold on the basis of detailed analysis of the relationship between long-term rainfall characteristics and landslide occurrence.

Recipe - T04

Preparing a risk map for landslides

Refer to

Recipe-P04
Landslide risk mapping
as a parent Recipe

In developing countries, it is difficult to assess the risk of landslides because spatial information for evaluating the risk of landslides is not readily available. Therefore, a method to create a risk map for landslides is shown based on forest disturbance and land use changes estimated by a machine learning model using remote sensing data, spatial information obtained from that data, and publicly available data. In creating the risk map, we use visual interpretation of landslide sites from satellite images, and calculate the importance using machine learning with DEM, slope and aspect calculated from DEM, land use, roads, and geology as explanatory variables. We perform supervised classification using random forest, and map the risk assessment results based on the model constructed from the results.

Understanding the risk of disasters through remote sensing

Developing countries need to establish hazard countermeasures despite having limited resources. Therefore, it is necessary to assess hazard risk by considering the likelihood of hazards and human activities. However, it is difficult to assess risk in developing countries because the spatial information necessary for risk assessment is not readily available. Also, it is hard to collect information on the ground. So, the challenge is figuring out how to use satellite images and other remote sensing data to understand how ecosystems work and help with disaster risk reduction. We need to develop reliable risk assessment technologies using AI and other advanced technologies. This recipe shows how to prepare a risk map for landslides based on remote sensing data, terrain (Digital Elevation Model: DEM), geological information, local information on landslides and forest degradation, time series analysis, and machine learning models that estimate forest disturbance and land use changes from satellite images.

Data used to prepare risk maps

(1) Interpretation of landslides

Using satellite images from Google Maps, identify locations where landslides occurred due to heavy rain by visual inspection on the free GIS software called QGIS, and extract them as polygon data (Figure T04-1).

(2) DEM

The availability of DEMs varies among developing countries. If there is a DEM for the target area, that data can be used. However, if no DEM is available, a DEM

Figure T04-1 Visual reading of landslide site

created from satellite data must be used. For data from optical satellites, it is not just a DEM but a DSM (Digital Surface Model), which includes the height of ground features. For example, in forests, it represents the height of the forest canopy surface rather than the ground. Free DEMs include SRTM created by the Space Shuttle mission, NASADEM, which supplements Shuttle Radar Topographical Mission (SRTM) with Aster G-DEM or ALOS elevation data due to data gaps in mountainous areas, and AW3D30 created by JAXA from ALOS data. These DEMs have a resolution of 1 second, which is about 30 meters near the equator. If you need a high-resolution DEM, there is the paid AW3D Standard Edition terrain data. The AW3D Standard Edition terrain data is a 3D map that represents the topography of land areas worldwide at the world's highest standard resolution of 2.5 m/5 m. It uses satellite images captured by the 3D stereoscopic sensor of JAXA's Land Observation Technology Satellite “Daichi (ALOS).”

Use the prepared DEM to calculate the slope and aspect with GIS software. Also, create CS maps [1] and contour maps (Figure T04-2) to understand the terrain conditions of the landslide area.

(3) Land use

If there are land use maps or land cover maps for the target area, use that data. In these cases, the land use map/land cover map must have been created relatively recently and accurately show the current situation. If you don’t have land use map or land cover map, use QGIS or similar software to visually interpret land use (forests, young forests, terraced fields, grasslands, settlements, etc.) from Google Maps satellite images and create polygon data.

(4) Geology

If there is existing geological information for the target area, use that data. Otherwise, use geological maps provided by national geological survey agencies or institutions that create national digital information. Alternatively, use the 1:1,000,000 world geological map available on the OneGeology [2] portal. This map was created by the British Geological Survey in collaboration with geological survey research institutions around the world.

(5) Roads

For road networks, if there is existing data, use it. If not, use QGIS or similar

INFO

1) A CS 3D topographic map is created by generating a slope map and a curvature map from a DEM (Digital Elevation Model), coloring each of them, and then overlaying them with transparency to produce a three-dimensional representation of the terrain. In this map, ridge lines are shown in warm colors, valley lines in cool colors, steep slopes and low elevations in dark tones, and gentle slopes and high elevations in light tones.

INFO

2) OneGeology Portal https://portal.onegeology.org/OnegeologyGlobal/

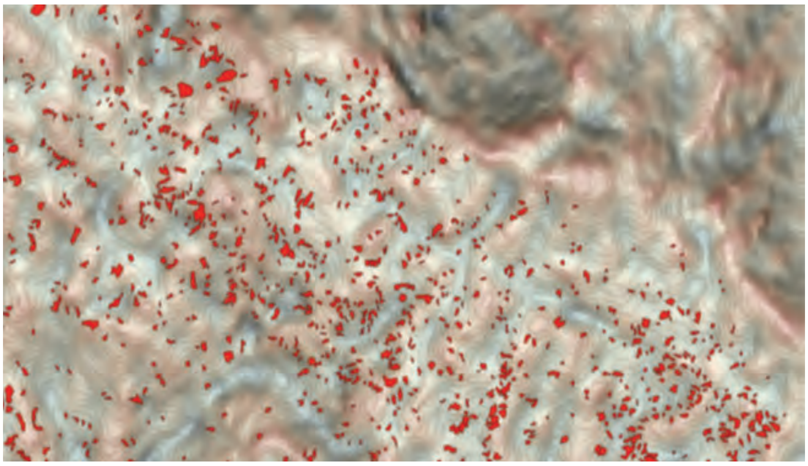

Figure T04-2 CS map, and contour map created from DEM

tools to visually interpret satellite images from Google Maps and create polyline data.

Method for preparing risk maps

For landslide areas identified through the visual interpretation of satellite imagery, calculate the importance of landslide factors (explanatory variables) such as DEM, slope and aspect calculated from DEM, land use, roads, and geology using machine learning (Decision Trees, Random Forests). Specifically, the target area is divided into 10m meshes. A dataset is created by aggregating the presence or absence of a landslide (the objective variable) and each explanatory variables (land use, elevation, slope, aspect, geology, roads, etc.) for each mesh. This dataset is then used for machine learning (Figure T04-3). The results machine learning models, such as Decision Trees and Random Forest, may vary depending on the items in the dataset and the settings used during analysis. Therefore, caution is required when interpreting the results, and when conducting risk assessments based on them. It is necessary to take this into consideration and verify the results (risk map) on-site before actually using them. On the other hand, if a certain trend is recognized in each result, it can be considered to be generally reliable.

When conducting risk assessments, it is necessary to consider the importance of factors that are deemed impactful. Therefore, the importance of each factor in relation to collapse is estimated using unsupervised classification with machine learning (Decision Trees and Random Forest). Random Forest is used to map the assessment results. Supervised classification is performed using the datasets organized by survey area. Risk assessments are conducted based on the models constructed from the results and mapped (Figure T04-4).

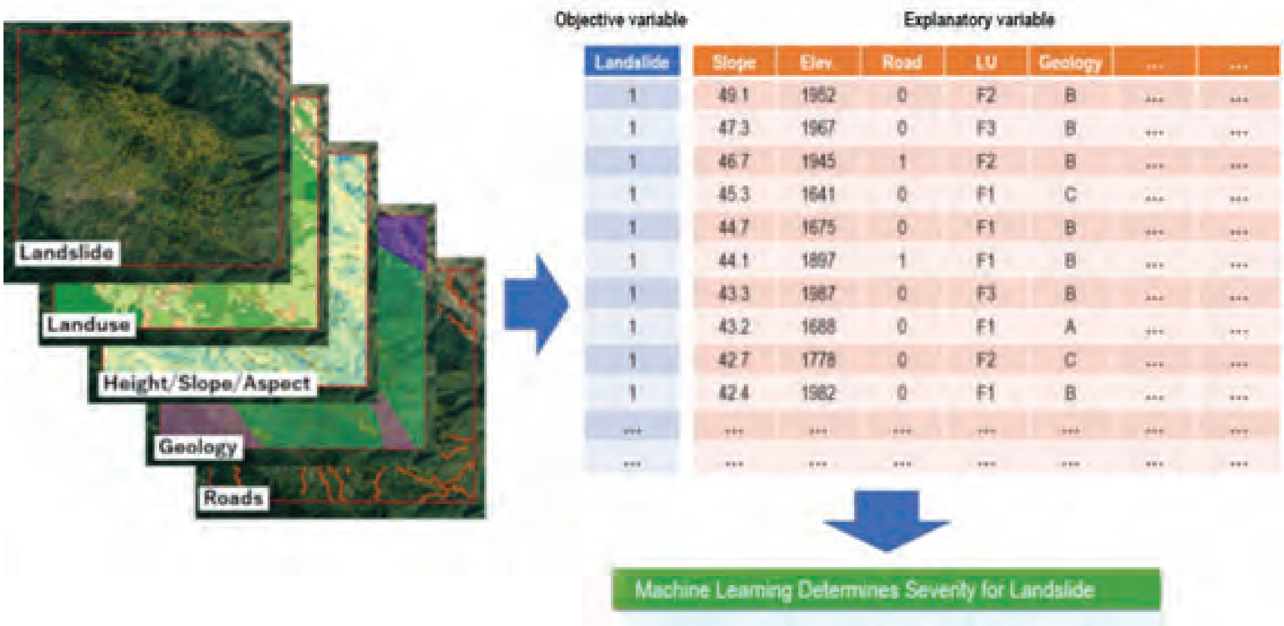

Figure T04-3 Determination of importance by machine learning for risk mapping

Figure T04-4 Risk map of landslide

6

Chapter 6 Application of Japanese Forest Management and *Chisan* Technologies

Japan's forest management and *Chisan* technologies have been developed through a long history of combating sediment-related disasters in mountaion areas. Japan's *Chisan* projects are an important part of the country's land conservation policy, aiming to protect the lives and property of citizens from sediment-related disasters through forest maintenance and afforestation, as well as to conserve water sources and preserve and create living environments. To apply this technology and expertise to developing countries where natural disasters are becoming more severe due to climate change, this chapter introduces survey methods to clarify the awareness of local residents who are targets of disaster risk reduction measures. It also explains methods for obtaining parameters for numerical analysis related to landslide occurrences on road slopes with high incidence rates. Furthermore, it examines the applicability of Japan's *Chisan* facilities to developing countries and explains the methodology for developing forest management plans that serve as criteria for land use decisions.

Recipe - T05

Survey on local residents' awareness of disaster risk reduction

Refer to

Recipe-P05
Application of Japanese forest management and *Chisan* technology as a parent Recipe

In order to apply Japanese *Chisan* technologies to developing countries, considering the natural environmental conditions and social circumstances of the target countries, it is important to understand the actual land use, disaster prevention awareness, and disaster prevention actions of the local residents in the target areas. This survey aims to clarify local residents' awareness of disaster risk reduction by conducting interviews to uncover their understanding of the role of forests in reducing natural disaster risks, their expectations of the government regarding disaster risk reduction measures, and their perceptions regarding economic damage, impact on daily life, and disaster prevention measures in the event of a natural disaster.

The necessity of conducting a survey of local residents' awareness

In order to apply Japan's *Chisan* technologies to developing countries while considering the natural environmental conditions and social circumstances, it is important to understand the actual land use, disaster prevention awareness, and disaster prevention actions of local residents in the target area. Therefore, it is necessary to conduct interviews with local residents on topics such as socioeconomic conditions, awareness of forests' protective functions against natural disasters, needs and expectations of the government, disaster prevention awareness, and disaster prevention actions (Figure T05-1).

Survey on local residents' expectations of forest disaster risk reduction functions and the government

In order to clarify local residents' expectations and awareness regarding the functions of forests in mitigating the risks of flash floods, debris flows, and landslides, the following questions can be considered.

- Do well-maintained forests have the effect of mitigating risks?
- Are restrictions on logging along rivers effective in mitigating risks?
- Is restricting logging on steep slopes effective in mitigating risks?
- Is restricting the conversion of forests to farmland effective in mitigating risks?

A five-point Likert scale can be used, and respondents are asked to select one option from the available answers: “Strongly disagree”; “Mildly disagree”; “Neither agree nor disagree”; “Mildly agree”; “Strongly agree”, and then respondents should be asked to describe their opinions on the effectiveness of these measures.

In a survey conducted in Vietnam, more than 90% of respondents strongly agreed with the disaster prevention function of forests. It is clear that local residents recognize that logging leads to frequent natural disasters, soil erosion, and flash floods. However, while local residents generally recognize the importance of forests for disaster prevention, it is also clear that they want to expand farmland. This trend is expected to be similar in many developing countries.

In order to clarify expectations for the government regarding disaster risk reduction, it is advisable to ask whether respondents expect the following measures: “increase in forest area,” “permanent or temporary construction for disaster prevention,” “strengthening of disaster prevention education,” “provision of weather warnings for heavy rain,” “preparation of evacuation facilities during heavy rain,” and “support for disaster victims.”

Subjective risk perception, disaster risk reduction costs, and awareness of disaster risk reduction actions

Many disaster prevention studies have investigated how local residents’ perceived severity of disaster occurrence and damage, as well as their awareness of disaster prevention costs, influence their disaster prevention actions.

Ask residents how likely they think it is that natural disasters such as flash floods, debris flows, and landslides will occur within the next 10 years, and ask them about the likelihood of their buildings, farmland, and durable assets being affected. Additionally, questions should be asked about their thoughts on the economic damage caused by natural disasters and the impact on their lives and livelihoods.

Regarding the response efficacy, one can ask how effective they believe the following measures are in protecting their homes from flash floods, debris flows, and landslides. The survey inquires about the expected effectiveness of these measures, the anticipated costs, and how likely they would implement these measures themselves.

- Sharing knowledge and experience with others
- Collaborating with neighbors and helping each other
- Actively collecting weather information
- Moving valuables from the first floor in preparation for flooding
- Knowing dangerous areas and evacuation sites
- Evacuating early if advised by the village
- Preparing tools (flashlights, shovels, raincoats, etc.), food, and medicine in preparation for flooding
- Reinforcing the home

Figure T05-1 Local redidents interview

Recipe - T06

Conditions contributing to roadside slope landslides

Refer to

Recipe-P05
Application of Japanese forest management and *Chisan* technology as a parent Recipe

In mountainous regions of developing countries, roadside slope landslides are frequently observed, raising concerns about increased slope disaster risks and increased sediment runoff due to road construction. In Japan, it is recommended to install cross ditches at short intervals to disperse side ditch water, but in developing countries, side ditch water is often drained through culverts at stream crossings. To scientifically and quantitatively evaluate the increased risk of landslides due to road construction, it is necessary to perform numerical analysis that reproduces rainfall infiltration into slopes and the resulting decrease in soil shear strength. To execute such numerical analysis, it is necessary to confirm that the landslide processes observed in the field align with the collapse processes targeted by the numerical analysis, and to identify the various slope conditions that serve as parameters.

Increased risk of slope landslides due to road construction

The main economic activities in mountainous areas are primary industries such as agriculture, livestock farming, and forestry. Roads, including forest road networks, are an indispensable part of the social infrastructure of the region as they enable the efficient transportation of agricultural products and timber as well as the proper management of forests. In addition, in developing countries, many ethnic groups traditionally live in mountainous areas, and roads in mountainous areas are indispensable for daily life, so local people take the initiative in maintaining and managing them. However, with the rise in industrial activity driven by rapid economic growth, there have been cases of unregulated road

Figure T06-1 Landslide due to road opening construction that disregards traditional rules, raising concerns about increased disaster risks. Along roads, cut slope landslides are frequently observed, and there are concerns about increased risk of slope disasters and increased sediment runoff due to road construction (Figure T06-1).

Roadside slopes and drainage facilities in developing countries

Cut slopes of roads are often left unprotected in a "cut-and-leave" state. In tropical and subtropical regions, rapid decomposition of organic matter, significant fluctuations in moisture levels, and heavy rainfall can cause soil layers to erode, exposing underlying weathered bedrock. In some geologically stable slopes, vegetation such as ferns may eventually cover the surface over time. Weathered bedrock peels off during rainfall, producing fine gravel and sand through surface erosion as it moves downward and accumulates.

A drainage system using side ditches and culverts is commonly applied to engineered roads. Side ditches are primarily categorized into concrete, stone-lined, and unlined ditches. Note that unlined ditches tend to be installed in straight sections with gentle slopes, while concrete and stone-lined ditches tend to be installed in curved sections with steep slopes. The basic idea of drainage is to collect road surface water and seepage water from cut slopes into side ditches, guide it to catch basins installed at stream crossings, and drain it to the stream through culverts along with stream water. According to Japan's forest road regulations, it is recommended to install cross ditches at short intervals to divert road surface runoff and prevent excessive drainage into streams, which may otherwise induce erosion, landslides or debris flows. However, in developing countries, cross ditches are rarely installed, and excessive amounts of water often flow into streams (Figure T06-2). If there is very little unstable sediment in the stream, concentrating drainage in the stream could be an option. However, it is necessary to estimate the drainage volume based on local rainfall intensity, mountain slope runoff coefficients, and the catchment area of each culvert, while also considering the vulnerability of the downstream section to erosion, to determine the necessity of dispersed drainage via cross ditches. The slope of the culvert required to prevent sediment accumulation inside the culvert is approximately 20% for a culvert with a diameter of approximately 60 centimeters [1].

INFO

1) H. Minematsu and O. Akita (1987) A new Design Criterion for a Forest Road Culvert. J. Jpn. For. Soc. 69(12): 489-491

Figure T06-2 Basic drainage system using ditches, catch basins, and culverts

Parameters for numerical analysis of slope conditions

One method for quantitatively evaluating the increase in landslide risk due to road construction is to apply numerical analysis that reproduces rainfall infiltration into the slope and the resulting decrease in soil shear strength to both cases where the road is constructed and where it is not, and then compare and verify the changes in the slope's safety factor. To conduct such numerical analysis, it is necessary to confirm that the landslide process at the site matches the failure process targeted by the numerical analysis, and to obtain parameters for the analysis (topography, soil layer thickness, permeability, soil physical properties, etc.).

(1) Creation of DSM using unmanned aerial vehicle aerial photography

To understand the topography of mountain slopes, aerial photography is conducted using unmanned aerial vehicles (UAVs), and a digital surface model (DSM) is created through image analysis (Figure T06-3). Typically, DEMs are used for topographical analysis, but since UAVs cannot create DEMs due to ground cover, DSMs are used as a substitute. Airborne markers are installed at recognizable locations on aerial photographs, and coordinates are obtained using GPS positioning. These locations are then used as ground control points (GCPs) to assign geographic coordinates to the DSM.

The created DSM enables the calculation of slope inclination along survey lines (lines crossing the slope).

(2) Soil profile survey

The portable dynamic cone penetration test involves dropping a weight of (5 ± 0.05) kg from a height of (500 ± 5) mm to penetrate the ground with a cone, and recording the number of drops required to penetrate 10 cm (Nd value). The Nd value serves as an indicator of ground hardness. Generally, soil layers have lower Nd values than bedrock layers, but the reference Nd value for distinguishing between soil layers and bedrock layers varies depending on the survey site. Therefore, to obtain a reference value for the portable dynamic cone penetration test, a vertical soil profile approximately 2 m deep near the point where the portable dynamic cone penetration test is conducted, and the soil profile is observed.

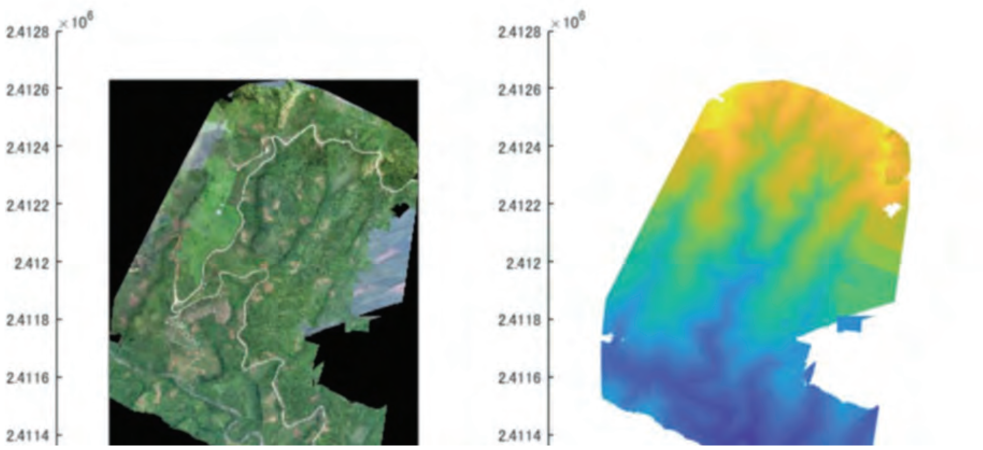

Figure T06-3 Ortho image and DSM created from UAV aerial photograph

(3) Estimation of soil layer thickness using the portable dynamic cone penetration test

The portable dynamic cone penetration test is performed at intervals of approximately 10 m along the survey line, and the soil layer thickness at each point is estimated by applying the Nd value as a criterion for the soil layer.

(4) Measurement of permeability coefficients in soil layers and bedrock layers

At the locations where soil profile surveys were conducted, samples are collected from both the soil layer and bedrock layer, and saturated permeability coefficients are determined using falling-head permeability tests. For the soil layer, one sample each is collected from three depths (5 cm, 15 cm, and 25 cm), and for the bedrock layer, three samples are collected from a depth of 140 cm.

(5) Measurement of soil physical properties

At the locations where soil profile surveys were conducted, samples were collected from the soil layer (depth of 80 cm) and bedrock layer (depth of 140 cm), and physical properties such as wet density (unit weight), dry density, porosity, cohesion, and shear resistance angle were measured. The shear resistance angle and cohesion were determined using unconsolidated undrained triaxial compression tests.

(6) Recording and observation of landslide sites throughout the survey area

Observe the location and scale of landslides along the road. This will reveal the collapse patterns associated with roads commonly seen in the area.

Numerical analysis for evaluating the stability of roadside slopes

Evaluate the stability of roadside slopes using numerical analysis with parameters obtained in the field as input values. The terrain model used for analysis is created from the DSM obtained in (1). The soil layer structure of the slope is modeled based on the results of (2) soil profile surveys and (3) portable dynamic cone penetration tests, and parameters such as permeability coefficients and soil properties are assigned to each layer based on the results of (4) permeability coefficient measurements and (5) soil physical property measurements. In reality, the soil layer structure is likely to vary even in a single catchment area, but if data is limited, it is assumed to be uniform. The rainfall pattern used as input is obtained from data from nearby rainfall observation stations, etc. The numerical analysis method should ideally be a coupled seepage and deformation analysis that integrates the analysis of water movement on slopes and the decrease in the safety factor. However, if this is difficult due to the large amount of calculations required, water movement analysis is first performed using coarse terrain data to identify high-risk slopes where saturation is likely to increase, and then deformation analysis is performed on those sections. By reorganizing the terrain model for the case without road slopes and performing numerical analysis in the same manner, and comparing the safety factor trends between cases with and without roads, the reduction in safety factor due to the presence of roads can be quantitatively evaluated.

Note that such numerical analysis involves handling surface collapse triggered by an increase in soil saturation, so multi-point observation of the collapse site as mentioned in (6) should be conducted to confirm that most of the cut slope landslides in the target area match the collapse form, then proceed.

Recipe - T07

Effective application of Japan's *Chisan* facilities

Refer to

Recipe - P05
Application of Japanese forest management and *Chisan* technology as a parent Recipe

In Japan, *Chisan* facilities play an important role in national land conservation policies, such as preventing sediment-related disasters in mountainous regions, maintaining and creating forests, conserving water sources, and preserving living environments. However, in developing countries, *Chisan* facilities are not common, and their sediment-related disaster prevention functions are not fully utilized. This is due to issues such as cost and a lack of specialized technology and knowledge. In developing countries, the prevalence of surface drainage works is relatively low. Since rectangular gabions, which are cube-shaped baskets made of iron wire filled with stones, are already widely used, there is little room left for the export and application of Japan's *Chisan* technologies related to rectangular gabions. Among the facilities with high potential for future application, slope greening works are noteworthy. Mountain slope greening can be divided into greening foundation work, which creates or improves the foundation for vegetation growth, and vegetation work, which introduces vegetation.

Chisan as a national land conservation policy in Japan

Japan's *Chisan* projects are an important national land conservation policy that aims to protect the lives and property of the people from sediment-related disasters through forest maintenance and afforestation, as well as to conserve water sources and preserve and provide living environments. Japan's *Chisan* projects have a history of over 100 years and have made a significant contribution to the conservation of regional forest environments. As part of *Chisan* projects, the following structures are installed: hillside works, torrent works, check dams, etc. Additionally, measures include the management of forests with poor growth conditions, wall works on unstable slopes, and check dams to prevent vertical and horizontal erosion of streams adjacent to unstable slopes. These structures contribute to the long-term formation of forests and are also positioned as disaster prevention facilities to suppress excessive sediment runoff downstream [1)].

On the other hand, in developing countries, *Chisan* facilities are not common, and the disaster mitigation functions of forests are often not fully utilized. One reason for this is that some forest conservation facilities require enormous costs, which is a significant financial burden for developing countries. Additionally, the design and construction of *Chisan* facilities require specialized technical skills and knowledge, and developing countries often lack the human resources with such expertise.

INFO

1) Conservation Division, Private Forest Department, Forestry Agency 2022 *[A guide to Chisan: Toward national resilience]*.

The widespread use of rectangular gabion in Asia

In developing countries in Asia, rectangular gabions are the most widely used *Chisan* facilities. Rectangular gabions are structures made by filling a cube-shaped basket made of iron wire with stones. They are used as a type of slope protection to prevent erosion of slopes caused by spring water and surface water, and are also often used as retaining structures after slope collapses or landslides. There are three main reasons for the widespread use of rectangular gabions in developing countries. First, they are low-cost; second, the necessary materials are readily available; and third, they are easy to construct and require a short construction period. These conditions are important considerations for developing countries facing economic challenges. Since roadside countermeasure facilities centered on rectangular gabions are already widely adopted, there is little room left for the export or application of Japanese *Chisan* technology related to rectangular gabions.

While rectangular gabions are widely used in developing countries, surface drainage works are relatively less common. Since the water drainage is the most important measure for slope stability and surface erosion prevention on roadside slopes left unattended after cutting, there is a high potential demand for Japan's survey and construction technologies aimed at effective surface water drainage. Furthermore, while afforestation activities are being actively carried out on slopes degraded by clear-cutting, etc., technologies to improve the growth environment of vegetation, such as topsoil stabilization, are necessary for forest restoration in degraded areas. From this perspective, there is expected to be demand for technologies and facilities related to vegetation ground works, such as fence, step works, and cover works.

Chisan facilities expected to be applied in developing countries

The Forestry Agency of Japan's *Chisan* technical standards aim to improve technical standards and rationalize operations by establishing basic technical requirements for planning, surveying, designing, and constructing forest management and conservation projects [2]. The latest revision was made on May 1, 2023, and the content includes general provisions, hillside conservation, afforestation for disaster prevention, and landslide prevention. In the hillside conservation project section, guidelines for the appropriate selection and placement of *Chisan* facilities are outlined alongside the basic principles of such projects. Specific *Chisan* facilities are classified into torrent works (check dams, revetment works, groin works, and cannal works) and hillside works (hillside ground works, hillside vegetation works, and rockfall prevention works), which are further subdivided, with a total of 28 types of *Chisan* facilities listed in Table T07-1.

The transferability of existing facilities in Japan to developing countries is evaluated based on three criteria: 1) current local use, 2) material costs, and 3) technical difficulty, using a four-tier rating system of ◎, ○, △, and × (Table T07-1). In the same table, grading works and wire mesh gabion retaining walls (i.e., rectangular gabions) receive high ratings in terms of low material costs and minimal technical requirements for construction, and their adoption is progressing in Vietnam. On the other hand, stream-crossing structures such as check dams require large amounts of concrete and are costly, so there are still challenges to their widespread adoption.

Hillside vegetation works are expected to have high transferability in the future. Hillside vegetation works aim to restore vegetation on slopes and stabilize them through the covering effect of vegetation and the binding effect of root systems. They are effective facilities for forest restoration in degraded areas. It is divided into vegetation ground works, which establish or improve the growth foundation

INFO

2) Forestry Agency (2023) *[Technical standards for Chisan: General rules and mountain Chisan works]*.

Table T07-1 List of Existing *Chisan* Facilities and Assessment of Their Transferability in Developing Countries

Type I	Type II	Type III	Type IV	objective	Local use	Cost	Difficulty	Applicability	Miscellaneous
Torrent work	Dam work			Prevention of vertical erosion of stream beds, stabilization of mountain foothills, prevention of sediment runoff, and adjustment	○	×	×	×	Observed as groundsill on site
	Revetment works			Prevention of lateral erosion of river banks, prevention of landslides, foundations for mountain slope structures	×	×	×	×	
	Groyne work			Regulation of water flow, prevention of stream bank erosion, prevention of bank scouring	×	×	×	×	
	Cannel work			Fixed flow path, regulated longitudinal gradient	×	×	×	×	
Hillside Work	Hillside Ground Work	Grading work		Shaping irregular mountain slopes	◎	○	○	○	
		Wall work	Concrete wall work	Preventing unstable soil movement, correcting slope gradients, and dispersing surface runoff	×	×	×	×	Require concrete
			RC wall work		×	×	×	×	Require concrete
			Mortar-based wall work, air-filled wall work		○	△	×	△	
			Gabion work		◎	○	△	○	=gabion
			Log wall work		×	○	△	△	
			Frame wall work		×	×	×	×	
		Burial work		Stabilization of cut soil, etc.	×	△	×	△	Construction within accumulated sediment
		Channel work		Prevention of slope erosion, soil strength reduction due to infiltration, and increase in pore water pressure	○	△	○	○	Observed on roadside
		Conduit work		Prompt removal of groundwater and seepage water	×	△	×	△	
		Stretcher work		Prevention of weathering, erosion, minor peeling, and collapse of slopes	○	×	×	×	Require stone, concrete
		Slope frame work		Prevention of slope erosion and collapse	×	×	△	×	Require concrete, anchor
		Anchor work		Preventing slope collapse and ensuring the stability of structures	×	×	×	×	Require anchor
		Reinforced soil work		Stability of natural ground or embankment by placing reinforcement material	×	×	×	×	Require reinforced soil
		Mortar (concrete) spray work		Preventing further collapse and stabilizing slopes (focusing on slopes that cannot be greened)	○	△	△	△	Confirmed onsite (lath before spraying)
	Hillside Vegetation Work	Vegetation groundwok	Fence work	Preventing erosion of topsoil on slopes and creating favorable conditions for planting trees	○	○	○	○	
			Step work	Rainwater dispersion on collapsed slopes, prevention of surface erosion, and improvement of vegetation growth environment	×	○	○	○	
			Cover work	Prevention of erosion and collapse caused by rainfall and freezing, and improvement of the germination environment for vegetation	×	○	○	○	
			Light-weight slope frame work	Rainwater dispersion, slope erosion prevention, early introduction of vegetation	×	×	△	△	
		Planting work	Seed spray work	Early greening through sowing	×	○	○	○	
			Vegetation work	Creation of forests with high erosion prevention capabilities through tree planting	○	○	○	○	
Rockfall Prevention Work	Rockfall Prevention Work			Removal of pumice and cracked exposed rocks, prevention of rockfalls caused by lake bottoms	×	○	△	△	
	Rockfall protection Work			Direct prevention of rockfalls on slopes from the source to the conservation target	×	×	△	×	
	Afforestation			Prevention and mitigation of rockfalls caused by tree roots and trunks	○	○	○	○	

Figure T07-1: Slope greening expected to be applied (left: fence work, right: reinforcement work)

for vegetation, and planting works (seed spray works and vegetation works), which introduce vegetation. However, in this context, we focus on the former, vegetation ground works, which are versatile and applicable to various regions. Vegetation ground works are facilities installed to stabilize slopes and promote vegetation in degraded mountainous areas, consisting of various types of works such as fence works, step works, cover works, and lightweight slope frame works (Figure T07-1). This method is characterized by its low cost, the use of locally available materials, and its simplicity, making it easy to construct. These features are very similar to the reasons why rectangular gabions became popular in Vietnam.

Fence works involve installing fences made of logs on slopes, primarily to prevent the movement of surface soil. Using logs, fences approximately 40 cm high are constructed above ground level to prevent soil movement on slopes. This method is particularly used to establish suitable growing conditions for vegetation and is not suitable for areas subject to significant soil pressure, but it effectively prevents surface soil movement.

Step works are a method of arranging narrow strips along contour lines on a slope to form a stepped slope. This method disperses rainwater on the slope, prevents soil erosion, and establishes an environment suitable for planting. A common form of step works is log ridge construction, which is approximately 10 cm high and often has seedlings planted on the back side. Other materials used for grid work include sandbags and stones.

The similarities between fence works and step works lie in their function as vegetation ground works to protect hillslopes and promote plant growth, and their high material procurement efficiency due to the absence of concrete. The difference between the two is that fence works primarily prevent surface soil movement, while step works prevent soil erosion over a wide area by dispersing rainwater on slopes, thereby contributing to the promotion of vegetation over a broader area. Additionally, structurally, fence works have a fence-like shape, while step works have a stair-like shape along the slope.

Recipe - T08

Formulation of forest plans for forest-based disaster risk reduction

Refer to

Recipe - P05
Application of Japanese forest management and *Chisan* technology as a parent Recipe

In mountainous regions of developing countries, forests are often developed for the expansion of farmland to improve livelihoods, and there is a tendency to disregard traditional land use rules related to disaster prevention. Therefore, when formulating land use plans that take disaster prevention into consideration, it is necessary to simultaneously develop forest plans. Forest plans include elements such as current status assessment, goal setting, management activity planning, monitoring and evaluation, stakeholder participation, and legal and policy frameworks. When developing forest plans that take into account forest-based disaster risk reduction, it is necessary to consider the following: balancing disaster prevention and livelihoods, actively maintaining and creating forests on slopes with a high risk of landslides, strengthening disaster prevention functions by maturing protected forests, shortening the period of bare land after logging in production forests, and introducing *Chisan* facilities according to the degree of slope degradation.

What is forest planning?

Forest planning is a process of establishing specific guidelines and strategies for the systematic and sustainable protection, management, utilization, and regeneration of forests. The main purpose of a forest plan is to achieve both the sustainable use of forest resources and the conservation of ecosystems. Forest planning includes elements such as current status assessment, goal setting, management activity planning, monitoring and evaluation, stakeholder participation, and legal and policy frameworks.

Current status assessment: A detailed assessment of the current state of the forest. This includes forest area, tree species composition, tree age composition, biodiversity, soil quality, water resources, and forest health.

Goal setting: Setting short-term and long-term management goals. These goals include timber production, recreation, wildlife conservation, water resource protection, and the provision of ecosystem services.

Management Activity Planning: Plan specific management activities necessary to achieve the set goals. This includes activities such as afforestation, thinning, selective cutting, post-harvest regeneration, pest and disease control, fire protection measures, and the development of recreational facilities.

Monitoring and Evaluation: Regularly monitor the implementation of the plan and evaluate its outcomes. As needed, revise the plan and improve management methods.

Stakeholder Participation: It is important that all relevant stakeholders, including local residents, forest owners, government agencies, companies, and NGOs, participate in the formulation and implementation of the plan. This will increase the feasibility of the plan and gain the support of the local community.

Legal and policy framework: Forest plans are formulated based on national and regional laws and policies. This ensures that the implementation of the plan is legally supported and enforced.

Forest plans are an important tool for achieving a balance between environmental protection, economic benefits, and social benefits, and they form the basis for promoting sustainable forest management.

Forest plans are formulated based on spatial and time scales. In terms of spatial scale, various scales can be considered, ranging from national scale to administrative unit scale, community level management scale, and forest stand scale for afforestation and logging. In terms of time scale, various time scales can be considered, ranging from plans based on decades or even 100 years to achieve ideals, visions, and zoning, to plans for afforestation at the forest stand level over a period of several months to several years. For example, plans to achieve goals such as ideals and visions are formulated on a time scale of several decades to 100 years at the administrative unit or national level, while zoning should be considered at the community level and administrative unit level. Furthermore, forest management plans for afforestation sites must be formulated on a seasonal basis for implementation and on an annual basis until harvest.

Forest planning system in Japan

The forest planning system in Japan is based on the Forest Act (1951), which stipulates the formulation and implementation of forest plans with the aim of protecting forests and ensuring their proper use.

First, the Basic Plan for Forest and Forestry is established as a national-level plan to promote the sustainable management and utilization of forests and forestry in Japan. This plan is formulated based on the Forest and Forestry Basic Act (1964) and outlines the basic direction and specific measures for the conservation, development, and utilization of forest resources. Next, the National Forest Plan is formulated to concretize the Basic Plan for Forest and Forestry and establish forest management policies at the national level. Furthermore, the Regional Forest Plan is formulated to reflect the National Forest Plan at the prefectural level and to outline forest management policies tailored to local conditions. The Regional Forest Plan includes forest classification, logging rules, afforestation plans, and disaster prevention measures. The Municipal Forest Management Plan is a specific forest management plan formulated at the municipal level and is created to maintain consistency with the higher-level Basic Plan for Forest and Forestry and Regional Forest Plan. Finally, Forest Management Plans are specific plans formulated by forest owners and managers for the purpose of proper conservation, maintenance, and utilization of forests. These plans are formulated in accordance

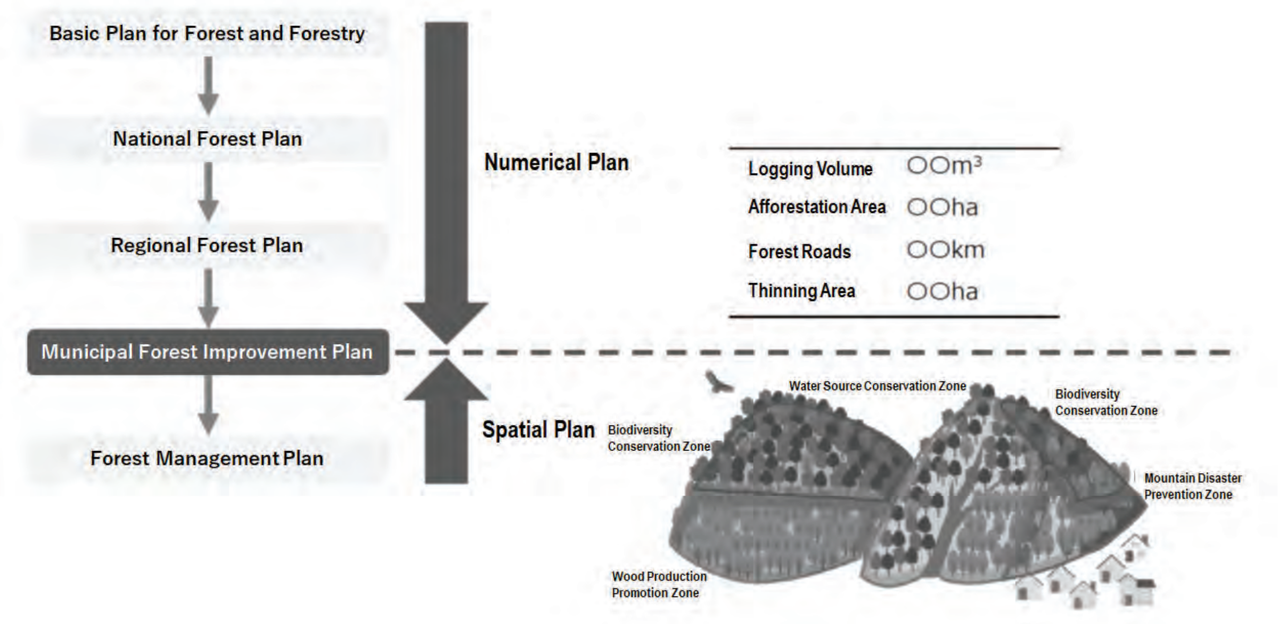

Figure T08-1 Forest Planning System in Japan [1)]

with Regional Forest Plans and are an important tool for achieving sustainable forest management. The aim is to promote the sound recycling of forest resources, maintain and improve the multifaceted functions of forests, and revitalize the regional economy (Figure T08-1) [1)].

Japan's forest planning system is designed to achieve consistent forest management from the national to the regional level and down to individual forest owners based on a multi-layered planning system, providing a basic framework for achieving sustainable forest management, including appropriate logging and regeneration, biodiversity conservation, and strengthening disaster prevention functions.

INFO

1) Yamada, Y. (2021) *[Regional forest planning and municipal forest maintenance planning]*. In K. Tanaka, S. Yoshida, N. Shiraishi, & N. Matsumura (Eds.), Shinrin keikakugaku nyūmon [Introduction to forest planning] (p. 208). Asakura Shoten.

Basic concepts of forest planning for forest-based disaster risk reduction

In mountainous regions of developing countries, forests are often cleared for the expansion of farmland to improve livelihoods, and there is a tendency to disregard traditional land use rules related to disaster prevention. Therefore, when formulating land use plans that take disaster prevention into consideration, it is necessary to simultaneously establish forest plans. The basic concepts for this are listed below.

- Balance disaster prevention and livelihoods.
- Actively promote the forest maintenance and restoration on slopes with a high risk of landslides.
- In protected forests, promote the transition from young forests to mature forests to strengthen disaster prevention functions.

- In production forests (short-rotation forests such as pine, acacia, and eucalyptus), minimize the period of bare land after logging.
- On slopes near protected areas such as residential zones, prioritize the installation of *Chisan* facilities based on the severity of slope degradation.
- For slopes along roads, consider the balance between the usefulness of the land as farmland and the disaster risk to the road.
- Present prototype improvement plans to stakeholders such as administrative agencies and residents, incorporate their opinions, and seek mutually agreeable solutions.

Based on this approach, it is desirable to formulate guidelines for disaster-resistant zoning and protective forests, as well as management plans for production forests.

Criteria for forest planning

When formulating forest plans for forest-based disaster risk reduction, it is necessary to understand the current land use situation and also use the following information as judgment criteria for plan formulation.

- Risk maps for slope landslides
- Distribution of road networks that increase the slope landslides risks
- Relationship between land use (forests, bare land, farmland, etc.) and infiltration rate
- Relationship between land use and sediment runoff volume
- Socioeconomic conditions
- Road networks and local residents' living routes
- Residents' awareness of disaster prevention and forests, etc.

In regions seeking to establish forest plans for forest-based disaster risk reduction, if land use plans or forest plans already exist, it is advisable to revise such plans based on the aforementioned decision-making criteria while fostering consensus among stakeholders, including local residents. This approach enables the realization of land use that balances forest-based disaster prevention and mitigation with the promotion of regional economic activities.

7

Chapter 7 Disaster Risk Reduction Functions of Mangroves against High Tide Damage

The conservation and restoration of mangroves are not only an effective means of mitigating climate change by their high carbon sequestration capacity, but are also expected to contribute to climate change adaptation measures, including disaster risk reduction for national land conservation, such as reducing the risk of storm surges caused by typhoons that are expected to become more powerful due to sea level rise and rising sea temperatures caused by climate change, and preventing coastal erosion.

In this chapter, the disaster risk reduction functions of mangroves in coastal areas against storm surge damage, which is a key component of climate change adaptation strategies in coastal ecosystems, then key considerations for mangrove planting is summerized.

Recipe - T09

Surveying local residents' awareness and perceptions of mangroves for disaster risk reduction

Refer to

Recipe - P06
Disaster risk reduction functions of mangroves as a parent Recipe

The success of mangrove conservation and afforestation/reforestation projects hinges on understanding how local communities perceive the role of mangroves. When selecting survey methods, it is preferable to use approaches that involve direct engagement with residents. Survey participants should include groups most likely to influence mangrove-related activities, such as those living nearby or with relevant livelihoods. It is also essential to assess the human, natural, technical, material, and financial resources required for effective project implementation. Key concerns include cases where inappropriate species are planted in unsuitable locations, and where restoration efforts proceed without incorporating lessons learned from similar initiatives—leading to inefficiencies and resource waste.

The need for awareness surveys among local residents

The success of mangrove conservation and afforestation/reforestation projects designed to address social challenges, including climate change and natural disasters hinges on understanding how local residents perceive the role of mangroves. This is because, as Anderson and Renaud (2021) emphasize, the long-term effectiveness of nature-based solutions (NbS) consistently relies on a broader range of public acceptance outcomes, which are shaped by factors related to the measure itself, individual perceptions, and social context [1].

Effective long-term management of mangroves, as one form of NbS, requires close communication and mutual understanding with local residents. A review of the ethnobiology, socio-economics, and management of mangroves points out that restoration programs that treat local residents merely as a labor force for planting—without involving them in the long-term management of the restored ecosystem and the diverse ways in which they use it—are less likely to succeed [2]. Moreover, both the review and a review of the current state and sustainability of community-based mangrove management highlight that coastal residents experiencing chronic poverty and marginalization may depend on mangroves and possess deep cultural ties and traditional knowledge, and management approaches that exclude these groups are also unlikely to be successful [2), 3].

Therefore, in mangrove conservation and afforestation/reforestation projects aimed at addressing climate change and natural disaster risks, it is essential to explore ways to enhance their functions for climate change adaptation and natural disaster risk reduction while taking into account how local residents use mangroves

INFO

1) Anderson, C.C., Renaud, F.G. (2021) A review of public acceptance of nature-based solutions: The 'why', 'when', and 'how' of success for disaster risk reduction measures. Ambio 50, 1552–1573.

INFO

2) Walters, B.B., el al. (2008) Ethnobiology, socio-economics and management of mangrove forests: A review. Aquat. Bot. 89, 220–236.

INFO

3) Datta, D.,et al. (2012) Community based mangrove management : A review on status and sustainability. J. Environ. Manage. 107, 84–95.

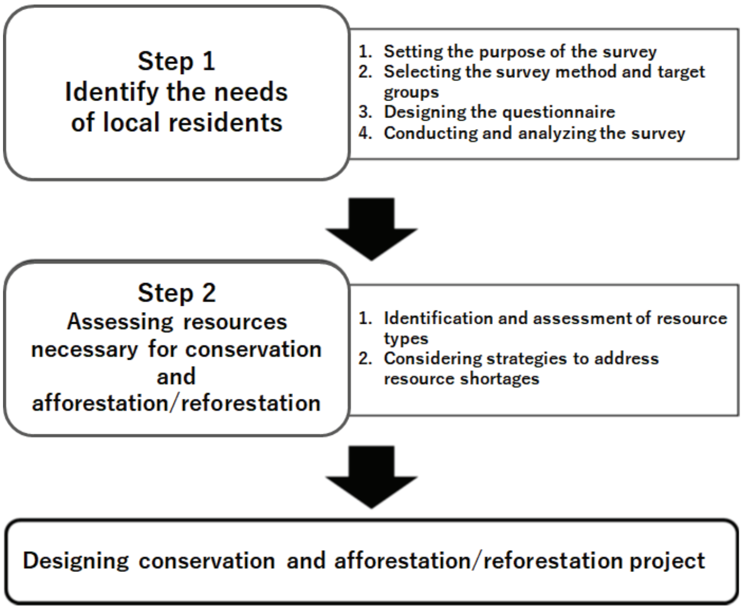

Figure T09-1: Awareness survey and resource assessment of local residents required when designing mangrove conservation and afforestation/reforestation projects

to obtain specific benefits. Understanding the degree to which local residents rely on mangroves—both economically and culturally—for their livelihoods is essential. Equally crucial is understanding how they perceive, and to what extent they recognize the importance of mangrove conservation and afforestation/reforestation in relation to climate change adaptation and natural disaster risk reduction within their local context. This is the first step toward project success.

To this end, it is important to design projects that reflect the intentions and socio-economic conditions of local residents. The following sections outline commonly required methods for conducting awareness surveys and resource assessment, which are generally required when designing mangrove conservation and afforestation/reforestation projects (Figure T09-1).

Understanding the needs of local residents

(1) Defining the purpose of the survey

As the first step, it is important to clearly define the purpose of the survey. Here, the objective is to understand the needs and concerns of local residents in relation to implementing mangrove conservation and afforestation/reforestation projects for disaster risk reduction.

(2) Selection of survey methods and target groups

When selecting survey methods, it is preferable to choose approaches that involve direct interaction with local residents, such as questionnaire-based surveys, key informant interviews, focus group discussions, and participatory workshops[4),5)]. Online questionnaire surveys may be considered an alternative that does not require face-to-face engagement, but in developing countries, limitations such as lack of access to computers or smartphones and unstable internet connectivity

INFO

4) Angelsen, A., et al. eds. (2011). Measuring livelihoods and environmental dependence: Methods for research and fieldwork, Earthscan. Center for International Forestry Research (CIFOR), London.

INFO

5) Poverty Environment Network (2007) PEN Technical Guidelines - version 4 - May 2007. Center for International Forestry Research (CIFOR).

must be taken into account. The choice of survey methods and the number of surveys that can be conducted will depend on the available budget and timeframe. If multiple methods can be combined, more comprehensive and detailed survey results can be obtained.

The survey should include groups among local residents who are likely to have a significant influence on mangrove conservation and afforestation/reforestation. These may include residents living near mangrove areas, farmers, fishers, community leaders, women, and youth. Since the required number of respondents varies depending on the survey method, an appropriate sample size should be determined accordingly. If similar surveys have already been conducted and their results are available in reports or academic publications, they can serve as useful references when selecting survey methods and target groups.

(3) Designing survey questions

Survey questions should be designed to focus on the importance of mangroves, their uses, and residents' awareness of conservation and restoration activities. The aim is to explore the value that local residents attribute to mangroves and the types of support they consider necessary. While the primary focus here is on the role of mangroves in disaster risk reduction, if it is known in advance that residents also value other functions, it is equally important to consider those uses when exploring ways to enhance disaster risk reduction functions. Therefore, the overall volume of questions should be carefully balanced, and additional elements should be included within a manageable scope.

(4) Conducting and analyzing the survey

Based on the selected methods, the survey should be conducted with local residents to gather their opinions and experiences, and to understand their awareness and needs regarding mangroves. When conducting the survey, it is essential to obtain informed consent. Informed consent is a key principle of research ethics, involving the provision of sufficient information to participants about the survey's purpose, content, potential burdens, and data storage procedures, ensuring their understanding and voluntary agreement. Participants have the right to withdraw their consent at any time. While verbal explanation and agreement are commonly used, a written consent form with detailed explanations and participant signatures is also widely practiced.

Data collected through such social surveys often includes personally identifiable information. To protect privacy, the data must be processed to ensure that individuals cannot be identified. Once the anonymized data is prepared for use and sharing, it can be analyzed to gain insights into the awareness, needs, priorities, and concerns of local residents.

Assessment elements for mangrove conservation and afforestation/reforestation

(1) Identification and assessment of resource types

The necessary resources for mangrove conservation and afforestation/reforestation projects should be assessed, including human resources, such as the labor and skills of local residents; natural resources, such as mangroves themselves and the surrounding environment; specialized knowledge, such as the techniques and know-how required for afforestation/reforestation and conservation; material resources, such as seedlings; and financial resources.

(2) Considering strategies to address resource shortages

After conducting the above assessment, if resource shortages are identified in specific areas, strategies should be developed to address them. For example, in the case of financial shortfalls, funding options such as international aid and strategic partnerships should be explored. If there is a clear lack of experience or local knowledge, partnerships should be established with local residents, government agencies, and local NGOs to support project implementation. Their insights and experiences should be leveraged to establish cooperative relationships that will lead to more effective projects.

Common challenges across both steps

Common challenges include cases where, despite adequate scientific knowledge about suitable planting sites and species [6)], mangrove restoration projects sometimes end up planting inappropriate species in unsuitable locations [7)]. Restoration efforts are also sometimes undertaken without incorporating lessons learned from similar projects, resulting in duplicated efforts and wasted resources [2)]. Additionally, there have been reports of seedlings provided by national or local governments being of non-native species [8)], or being planted in open-access areas simply because there are no land rights issues—even when those sites are known to be ecologically unsuitable [9)]. These problems may stem from insufficient training on mangrove restoration within government agencies and a lack of understanding among officials [7)]. Moreover, when planting is driven by business interests, activities originally intended for the maintenance and management of mangroves may shift toward the maintenance and management of projects, leading to cases where planting is carried out despite knowledge that the trees will not survive. To address these issues on the ground, it is essential to conduct proper resource assessments, educate stakeholders based on the findings, and foster mutual understanding and cooperation among all involved parties [10)].

INFO

6) Ellison, A.M. (2000) Mangrove restoration: Do we know enough? Restor. Ecol. 8, 219–229.

INFO

7) Woodhouse (2022) Lessons and guidance for policy from MAP's community-based ecological mangrove restoration best practice, in: XV World Forestry Congress: Building a Green, Healthy and Resilient Future with Forests. Food and Agriculture Organization of the United Nations, Seoul.

INFO

8) Pham, T.T., et al. (2022) The Effectiveness of Financial Incentives for Addressing Mangrove Loss in Northern Vietnam. Front. For. Glob. Chang. 4, 1–16.

INFO

9) Primavera, J.H., Esteban, J.M.A. (2008) A review of mangrove rehabilitation in the Philippines: Successes, failures and future prospects. Wetl. Ecol. Manag. 16, 345–358.

INFO

10) Activities that use the survey results to raise awareness and promote local participation include educational and outreach programs.

Recipe - T10

Quantitative evaluation of uprooting resistance of coastal mangroves to waves and winds

Refer to

Recipe - P06
Disaster risk reduction functions of mangroves as a parent Recipe

Trees act as resistant bodies against fluids such as waves and winds, attenuating the external forces exerted by waves and winds. If the external forces exerted by waves and winds are less than the physical resistance of the trees, the trees will continue to act as resistant bodies, but if the external forces exceed the physical resistance of the trees, damage will occur to the trees. By conducting tree-pulling experiment to measure the critical turning moment of mangroves at the coastal front, it is possible to quantify and compare the uprooting resistance of mangroves to waves and winds. The uprooting resistance of mangroves depends on tree species, tree sizes, and environmental conditions. In particular, *R. stylosa*, which radially spreads many prop roots around its stem and grows in sandy sediments, tends to have higher uprooting resistance than *S. caseolaris* and *S. apetala*, which spread horizontal cable-type roots in muddy sediments.

The necessity of quantitative evaluation of uprooting resistance of mangroves

Trees act as resistant bodies against fluids such as waves and winds, attenuating their effects. If the fluid forces (external forces) acting on the trees are below their physical resistance, the trees continue to function as resistant bodies. However, if the external forces exceed their physical resistance, the trees may suffer damage such as stem breakage or uprooting. To maintain mangroves and their multifaceted functions in coastal areas, it is important to understand the uprooting resistance of these mangroves and consider the placement of coastal disaster prevention forests as disaster prevention infrastructure. This is because mangroves often suffer damage from strong winds, high tides, and high waves, which can result in the loss or decline of coastal disaster risk reduction functions.

What is a tree-pulling experiment ?

A tree-pulling experiment is conducted to assess the uprooting resistance of trees against waves and winds. It involves measuring and determining the maximum turning moment (M_{max}: kN·m) of mangroves growing along the shoreline through field surveys, which serves as an indicator of their uprooting resistance. An example of the experimental procedures and the calculation method for the uprooting resistance indicator value M_{max} are shown in below.

A polyester soft sling (note the safe working load) is attached to the stem of the targeted tree at ca. 1 m above the ground, connected to a steel wire with hand winch, which was pulled by human power until the peak tensile loading force was reached (Figures T10-1 and T10-2) [1), 2), 3)]. The tensile loading force can be measured

INFO

1) Peltola H, Kellomäki S, Hassinen A, Granander M (2000) Mechanical stability of Scots pine, Norway spruce and birch: an analysis of tree-pulling experiments in Finland. For. Eco. Manage. 135:143-153

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2) Nicoll. B. C., Achim. A., Mochan. S., and Gardiner. B. A. (2005) Does steep terrain influence tree stability? A field investigation. Canadian Journal of Forest Research 35:2360-2367.

INFO

3) Kamimura K, Shiraishi N (2007) A review of strategies for wind damage assessment in Japanese forests. J. For. Res. 12:162-176

using a 20 kN capacity load cell (SW3-20kN, Imada Co., Ltd.), and the data can be recorded using a 50 Hz data logger (eZT, Imada Co., Ltd.). Based on the tensile loading force measured by the load cell and the weight of the targeted tree at each 1-meter height, the turning moment due to the tensile loading force (M_{pulled}, kN·m, Equation 1) and the turning moment due to the weight of the targeted tree ($M_{gravity}$, kN·m, Equation 2) are calculated as reported by Nicoll et al [2]. Furthermore, the total turning moment with the root base as the center point of uprooting (M_{total}, kN m, Equation 3) was calculated as the sum of M_{pulled} and $M_{gravity}$.

$$M_{pulled} = F H_p \cos(\beta - \alpha) \quad (1)$$
$$M_{gravity} = g\, m\, H_g \sin\beta \quad (2)$$
$$M_{total} = M_{pulled} + M_{gravity} \quad (3)$$

where F is the tensile loading force on the tree applied by the winch (kN), H_p and H_g are the height of pulling point and the center of gravity of the measured tree (m), β and α are the angles between the vertical direction and the stem and between the horizontal direction and the pulling direction, m is the mass of the tree (kg), and g is the gravitational acceleration (9.8 m/s^2). The angles α and β are measured from the video images recording during the tree-pulling experiment. Generally, as the tensile loading force on the measured tree increases, M_{total} also increases. Measurement of the tensile loading force on the measured tree begins before the tree-pulling with hand winch, and it ends when the loading force reaches its peak and begins to decrease, or when the stem angle (β) exceeds 30 degrees, which prevents further continuation of tree-pulling experiment. M_{max}, an indicator of uprooting resistance to waves and winds, is determined as the maximum value of the recorded M_{total}, i.e., the critical turning moment. Therefore, by determining M_{max} using the above procedures, it is possible to quantify uprooting resistance of mangroves.

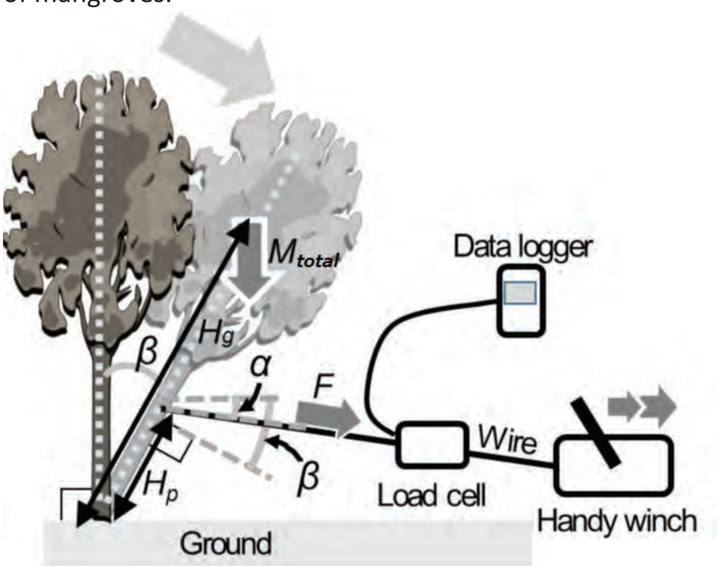


Figure T10-1 Schematic of the measurement items used to calculate the total turning moment for root base (M_{total}) for the measured tree

Figure T10-2: Photos of Tree-pulling experiment of *S. caseolaris*

INFO

4) Ono K, et al. (2024) Resistance to uprooting among mangrove trees at the Urauchi River mouth, Japan, an the Red River delta, Vietnam: A mechanical analytical comparison based on an in-situ tree−pulling experiment. Japanese Journal of Forest Environment 66: 17-26

INFO

5) Komiyama. A., Poungparn. S., and Kato. S. (2005) Common allometric equations for estimating the tree weight of mangroves. Journal of Tropical Ecology. 21:471-477.

Uprooting resistance of mangroves by species

The uprooting resistance of mangroves, i.e., M_{max}, varies depending on the tree species and tree size (Figure T10-3) [4]. It is also influenced by the site environment conditions. The relationship between M_{max} and tree size generally shows an increasing trend across all mangrove tree species as $D_{0.3\ m\ APR}$, DBH, $D_{0.3\ m\ APR}{}^2H$, DBH^2H, and TAB increase ($D_{0.3\ m\ APR}$, DBH, H, and TAB represent the diameter at the 0.3 m height above prop root for *R. stylosa*, the diameter at breast height, tree height, and total aboveground biomass, respectively). For *R. stylosa*, *S. caseolaris*, and *S. apetala*, the regression equations and adjusted determination coefficients ($R^2{}_{adj}$) between M_{max} and $D_{0.3\ m\ APR}$ or DBH, $D_{0.3\ m\ APR}{}^2H$ or DBH^2H, and TAB are shown in Table T10-1.

Generally, allometric relationships are observed in terrestrial forest trees. Mangroves also exhibit similar relationships when allometric equations are developed with $D_{0.3\ m\ APR}$, DBH, and H as dependent variables [5), 6)]. According to these results, parameters related to tree size serve as relative indicators of the quantity of underground roots supporting the mangrove stems and represent

Table T10-1 Relationships between tree size traits and the critical turning moment (M_{max}) by mangrove species.

R. stylosa	$M_{max} = 9.60 \times 10^3\ D_{0.3\ m\ APR}{}^{2.80}$	($R^2{}_{adj} = 0.908$, $p < 0.0001$*)
	$M_{max} = 3.41 \times 10^2\ D_{0.3\ m\ APR}{}^2H + 160$	($R^2{}_{adj} = 0.882$, $p < 0.0001$*)
	$M_{max} = 3.54 \times 10^{-1}\ TAB - 1{,}329$	($R^2{}_{adj} = 0.842$, $p = 0.0003$*)
S. caseolaris	$M_{max} = 2.70 \times 10^2\ DBH^{1.98}$	($R^2{}_{adj} = 0.919$, $p < 0.001$*)
	$M_{max} = 4.26 \times 10^2\ DBH^2H + 350$	($R^2{}_{adj} = 0.971$, $p < 0.0001$*)
	$M_{max} = 8.12 \times 10^{-2}\ TAB - 357$	($R^2{}_{adj} = 0.967$, $p < 0.0001$*)
S. apetala	$M_{max} = 5.93 \times 10^2\ DBH^{2.19}$	($R^2{}_{adj} = 0.886$, $p = 0.0003$*)
	$M_{max} = 6.18 \times 10^2\ DBH^2H + 271$	($R^2{}_{adj} = 0.976$, $p < 0.0001$*)
	$M_{max} = 8.25 \times 10^{-2}\ TAB - 466$	($R^2{}_{adj} = 0.913$, $p < 0.0001$*)

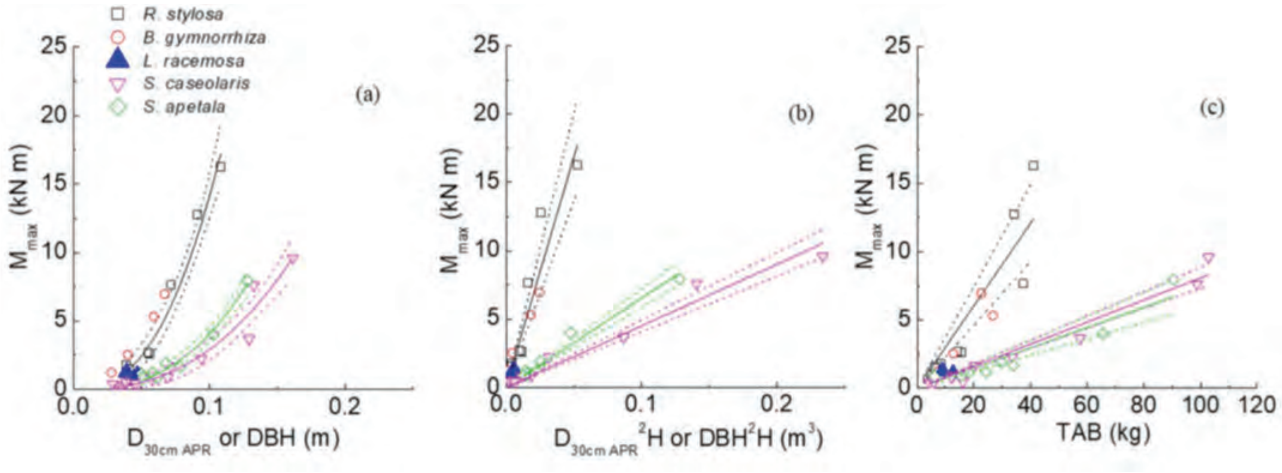


Figure T10-3 Relationships of the critical uprooting moment (M_{max}) with (a) stem diameter ($D_{0.3m\ APR}$ or *DBH*), (b) square of stem diameter multiplied by *H* ($D_{0.3\ m\ APR}{}^2H$ or DBH^2H), and (c) total aboveground biomass (*TAB*) [4)].

uprooting resistance resulting from root-soil interaction.

When M_{max} is used as an indicator of uprooting resistance, *R. stylosa*, which horizontally spreads many prop roots around its stem, tends to have higher uprooting resistance than *S. caseolaris* and *S. apetala*, which radially spread cable-type roots in muddy and sandy sediments regardless of the values of $D_{0.3\ m\ APR}$ and *DBH*. Similarly, the specific gravity of the stem is thought to influence M_{max} through the bending ability and stiffness of stems in response to external forces. Therefore, in tree-pulling experiment, it is necessary to take into account the sediment conditions of their substratum and differences in specific gravity of stems among mangrove species.

INFO

6) Komiyama. A., Ong. J. E., Poungparn. S. (2008) Allometry, biomass, and productivity of mangrove forests: A review. Aquatic Botany. 89:128-137.

Recipe - T11

Disaster risk reduction function evaluation using remote sensing

Refer to

Recipe -P06
Disaster risk reduction functions of mangroves as a parent Recipe

The sum of normal tide levels and storm surge heights does not exceed the height of the seawall, but when the sum of these heights plus the height of high waves exceeds the height of the seawall, the seawall is overtopped, causing flooding damage to residential areas inside the seawall. When mangroves are present at the front of the seawall, the wave force is attenuated by the vortex generated when waves hit the mangrove trees (vortex viscosity effect), thereby suppressing waves that would otherwise overflow the seawall and mitigating damage. To evaluate the disaster risk reduction functions of mangroves on a wide scale, it is necessary to calculate the width of the mangrove forest belt and the projected area of the mangroves relative to the direction of the waves, and remote sensing techniques are effective for this purpose.

Conditions for mangroves to fulfill their disaster risk reduction functions

When typhoons or developed low-pressure systems pass through, the tide level may rise significantly, which is called a storm surge. Storm surges occur due to two effects: the suction effect, where the sea level rises as a result of the higher-pressure air around the center of the typhoon or low-pressure system pushing down on the seawater, while the lower-pressure air at the center sucks up the seawater; and the blow effect, where strong winds accompanying the typhoon or low-pressure system blow seawater toward the coast from the open sea, causing the sea level near the coast to rise.

While tidal surges have a cycle of approximately 10 minutes to several hours, short-cycle waves caused by strong winds are referred to as high waves. Tidal surge damage is caused by the combination of the normal tidal levels (astronomical tides) caused by the gravitational pull of the moon and sun, the rise in sea level due to tidal surges and high waves, and the height of seawalls (Figure T11-1) [1]. According to

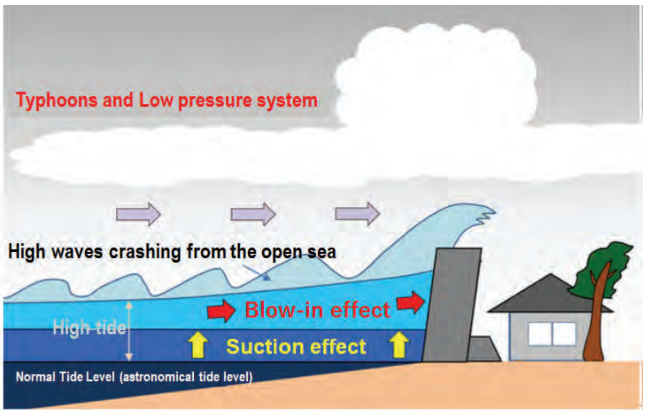


Figure T11-1 Damage caused by tidal levels, high tides, and high waves [1]

INFO

Japan Meteorological Agency
https://www.data.jma.go.jp/kaiyou/db/tide/knowledge/tide/takashio.html

the IPCC report, the rate of sea level rise from 2006 to 2015 was unprecedented in the past 100 years, rising at a rate of 3.6 mm/year, which is about 2.5 times the rate of sea level rise in the 20th century [2]. If sea levels continue to rise at this pace, the rise will add to astronomical tides, increasing the frequency of storm surge damage.

When the combined height of normal tides and storm surges exceeds the height of the seawall, both tides and storm surges have long-term fluctuations, causing seawater to flood over the seawall and into the land for an extended period, resulting in significant damage. On the other hand, even if the combined height of the normal tide and high tide does not exceed the height of the seawall, there are cases where the combined height of the normal tide, high tide, and high waves exceeds the height of the seawall. In such cases, without mangroves, seawater from high waves will flood the land, causing damage. On the other hand, if mangroves are present, the wave force is attenuated by the vortices generated when waves hit the mangrove trees (vortex viscosity effect), thereby suppressing waves that would otherwise overflow the seawall and mitigating damage. (Figure T11-2) [3].

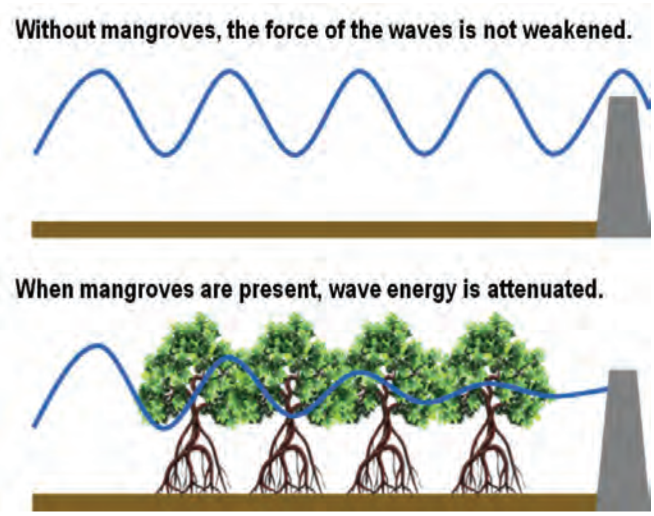


Figure T11-2 Wave attenuation by mangroves Created from 3)

The disaster risk reduction functions of the vortex viscosity effect of mangroves depend on the area of mangrove trees hit by waves. Therefore, factors such as the width of the mangrove forest strip relative to the direction of the waves, the tree shape of each species including the root system, diameter and height of the trees, tree density, and tree arrangement influence this effect (Figure T11-3) [4]. Among these, the width of the forest strip has a significant effect on increasing the projected area of mangrove trees relative to the direction of the waves.

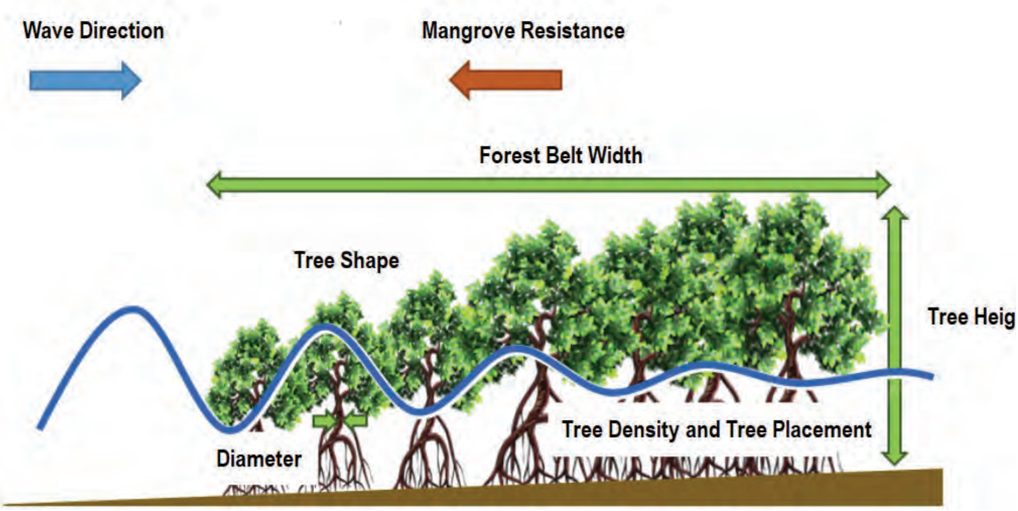


Figure T11-3 Factors affecting the disaster risk reduction functions of mangroves Created from 4)

INFO

2) IPCC (2014) Special Report on the Ocean and Cryosphere in a Changing Climate

INFO

3) Mazda Y, Magi M, Kogo M, Hong PN (1997) Mangroves as a coastal protection from waves in the Tong King delta, Vietnam. Mangrove and Salt Mardhes 1: 127-135.

INFO

4) Kamil EA, Takaijudin H, Hashim AH (2021) Mangroves as coastal bio-sheild: A review of mangroves performance in wave attenuation. Civil Eng. J. 7:1964-1981.

Methods for evaluating the disaster risk reduction functions of mangroves

To evaluate the disaster risk reduction functions of mangroves on a large scale, information on the spread of mangroves is needed to determine the width of the forest belt. Additionally, to calculate the projected area of mangroves relative to the direction of waves, information such as the average diameter and height of the forest stand, tree shape by species, and tree density is required. Obtaining this information on a large scale through ground surveys is challenging, so methods using remote sensing are necessary.

(1) Extraction of mangroves from high-resolution satellites

In order to determine the width of forest belts in relation to wave direction, it is best to extract mangroves using high-resolution satellite classification. There are various definitions of high-resolution satellite resolution, but Landsat satellites with a resolution of 30 m and Sentinel-2 satellites with a resolution of 10 m (monochrome) and 20 m (color) can be used to determine the width of forest strips over a wide area. These data are available free of charge. In addition, when using satellite data to estimate tree density in step (5), satellite data with sub-meter resolution is required, so it is advisable to prepare high-resolution satellite data in step (1).

(2) Calculation of the area of mangroves up to the seawall in relation to the direction of the waves

When waves approach the shore, the distance they travel through the mangroves, i.e., the forest strip width, has a significant impact on wave attenuation. However, waves may change direction due to trees, and it is difficult to capture the location of each individual tree over a wide area. Therefore, rather than capturing the forest strip width as a length, it is more realistic to estimate the area of mangroves within a certain width, which can be more easily reflected in countermeasures. Therefore, the area of mangroves within a certain width relative to the direction of the waves toward the embankment is calculated for various directions from the sea toward the land.

(3) Estimation of forest height (drones, satellite LiDAR, forest age-tree height curve)

As for techniques to estimate forest height over a wide area using remote sensing technology, methods using drones and satellite LiDAR are considered, but drones are limited by the capacity of their batteries, and satellite LiDAR is constrained by its observation system, making it nearly impossible to obtain data for the entire mangrove area. Therefore, classification is performed using texture information from high-resolution satellite data, and the same stand height is assigned to similar areas.

Although such remote sensing technology cannot be used, if the year of planting of the mangroves is clear, it is possible to estimate stand height based on the relationship between stand age and tree height.

(4) Diameter-height curve and tree shape estimation

The diameter-height curve required in step (3) is obtained by measuring the DBH and tree height for each mangrove species. In this case, differences in location may have an impact, so caution is required. The tree shapes for each species required for the accumulation of the projected area of all trees in relation to the direction of the waves in step (6) can be reproduced using multi-view stereo photogrammetry (Structure from Motion: SfM) technology, which uses photographs taken from 360° around a single tree on the ground with a digital camera. For each tree species, assuming that the tree shapes are similar, the similar tree shapes for each tree size are restored from the DBH and tree height.

(5) Estimation of tree density

Depending on the ground resolution of the acquired images, tree density can be estimated using remote sensing technology. The most commonly used method is the local maximum filter method. Sub-meter satellite data can be used to estimate tree densities of 1,000 trees/ha or less, but in stands with higher tree densities, there are not enough pixels in a single tree crown, and many trees do not have local maximum pixels, resulting in extreme underestimation of tree density.

In stands planted based on a planting plan, the planting density can sometimes be determined from planting records.

(6) Accumulation of the projected area of all trees in the direction of the wave

The projected area of all trees in the direction of the wave is an indicator of the degree of wave attenuation. Various models have been proposed for wave attenuation by tree groups, but these are not practical for use in wide-area assessments because the parameters required to implement the models are highly uncertain or difficult to obtain. The cumulative projected area can be used to identify areas with low disaster risk reduction functions provided by mangroves, enabling the determination of priority areas for disaster risk reduction measures.

To calculate the total projected area of all standing trees in relation to wave direction, several wave heights (astronomical tide level + storm surge height + high wave height) are assumed, and the total projected area of trees in the direction of the waves up to the wave height is calculated for each wave direction within a certain width (e.g., 100 m). When trees act as obstacles, waves curve around them and proceed behind them, so the total projected area of all standing trees is used as an indicator.

Recipe - T12

Key consideration in mangrove planting

Refer to

Recipe-P06
Disaster risk reduction functions of mangroves as a parent Recipe

Suitable mangrove habitat is defined by ground elevation and tidal environment, and varies depending on tree species. Therefore, it is advisable to conduct preliminary planting trials to determine the conditions of suitable sites before starting full-scale planting. The key to planting mangroves and steadily promoting mangrove regeneration is to secure healthy seedlings and viviparous seeds for planting, as well as seed collection to ensure seedlings, and seed handling after seed collection. In planting mangrove trees, only seedlings of the Rhizophoraceae family, which are easy to prepare and handle, should not be selected for planting, so that the forest will not become a simple forest of the same species. Carefully determine which species to plant and where to plant them, based on the location of the remaining tree species and similar tidal environments.

INFO

1) Mochida et al. (1999) A phytosociological study of the mangrove vegetation in the Malay Peninsula. -Special reference to the micro-topography and mangrove deposit- TROPICS 8:207-220

INFO

2) Miyagi, T. (2003) *[Mangroves: Their formation, people, and future]*. Kokon Shoin. 193 pp.

Determining suitable planting sites for mangrove growing

Suitable mangrove habitat is defined by ground elevation and tidal environment. Mangroves grow on tidal flats from mean wave level to the highest high wave level, where the influence of waves is weak (Figure T12-1) [1), 2)]. The environmental condition of suitable sites for mangrove growing differs depending on the species. On the other hand, the conditions for suitable mangrove habitat are not yet clear for all countries or regions, because the range of acceptable conditions is wide, and the sedimentation conditions (ground level and soil properties) and tidal

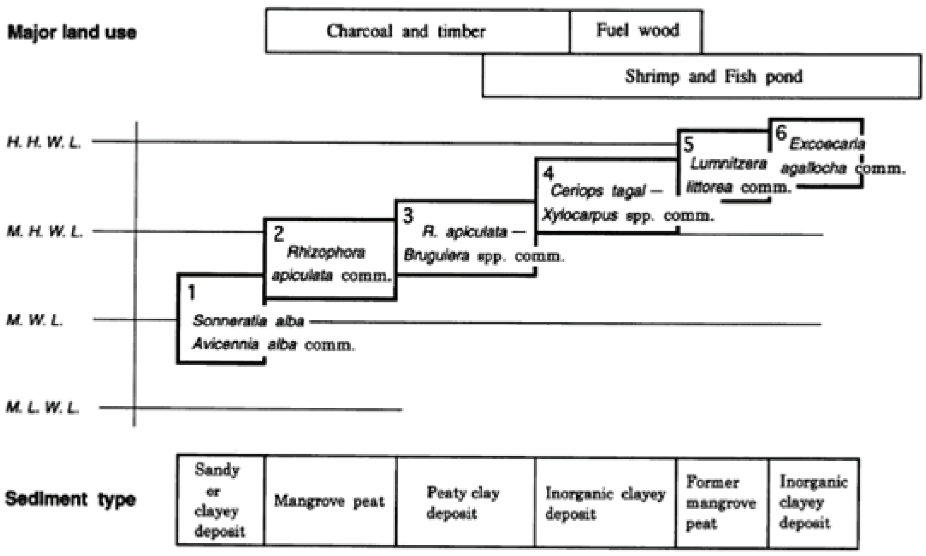


Figure T12-1 Relationships between the mangrove communities zonation, sediments type, major land use and location in the tidal range in Southeast Asia. (Cited by Mochida et al. 1999) Modified [from 1), 2)] environments (tide level, tidal range , flooding frequency, and flooding duration) of mangrove habitats vary widely from country to country and from region to region. Therefore, it is advisable to conduct preliminary planting trials and examine the conditions of suitable growing areas in the region before moving on to full-scale planting.

Factors that hinder the establishment and growth of mangroves are the runoff or damage of seedlings due to waves, erosion of the ground, and burial of seedlings due to sediment deposition. Therefore, it is important to understand the ground environment and tidal trends prior to afforestation in coastal degraded areas [3].

Appropriate seed collection methods and seed handling methods

The key to planting mangroves and steadily promoting mangrove regeneration is to secure healthy seedlings and viviparous seeds for planting, as well as to collect seedlings to ensure seedling production and to handle seeds after collection. Some mangrove species produce viviparous seeds while others do not.

Seed collection (1) - In the case of viviparous seeds

Some mangrove species (e.g., *Bruguiera*, *Rhizophora*, *Kandelia*, and *Ceriops*) produce viviparous seeds. To collect a large number of viviparous seeds at one time, it is more efficient to collect viviparous seeds attached to the mother tree than to pick up viviparous seeds that are fully grown and have fallen to the ground. Instead of forcibly removing the viviparous seeds from the fruit, it is better to soak the lower 1/3 to 1/2 of the collected viviparous seeds in a bucket of water to prevent them from drying out, and wait until the fruit and viviparous seeds separate naturally [4]. Since the appropriate timing for collecting viviparous seeds differs among tree species and regions (Table T12-1), it is advisable to conduct a preliminary survey to determine the appropriate method and timing of seed collection for each proposed planting site.

Seed collection (2) – In the case of Non-vivaporous seed

Among mangroves, the genera *Sonneratia*, *Lumnitzera* and *Heritiera* do not produce viviparous seeds.

Table T12-1 Interregional comparison of flower bud formation, flowering, and maturation of viviparous seeds in *Rhizophra apiculata* Modified from 4)

Area (Country)	Rainy season	Flower Bud Development	Flowering Season	Maturation period of viviparous seeds	From flower bud formation to viviparous seed drop	From flowering to full ripeness
Ko Phuket (Thailand)	Apr-Nov	Aug-Nov	Dec-Apr	Jan-Jul	34-35 m	4-6 m
Ranong (Thailand)	- -	All year	Oct-Feb	Apr-Jun	32 m	5.3 m
Klang (Malaysia)	- -	All year	All year	Jul-Sep	32-33 m	6-7 m
Hinchinbrook Island (Australia)	Jan-May	Aug Sep	Jan-Apr	Jan-Apr	27-31 m	9-10 m
Pulau Halmahera (Indonesia)	- -	- -	- -	- -	42m	9.8 m
Pulhau Bali (Indonesia)	Dec-Apr	All year	All year	Peak at Dec-Mar	23 m	5.7 m

INFO

3) Japan International Forestry Promotion and Cooperation Center (JIFPRO) (2022) *[Mangrove restoration guidebook: Restoration techniques adapted to site conditions and degradation factors]*. Kokusai Kōgyō Co., Ltd. (66 pp.)

INFO

4) Baba, S., & Kitamura, S. (1999) *[Basic knowledge for mangrove plantation: For the restoration of mangrove forests]*. Japan International Forestry Promotion and Cooperation Center (JIFPRO). 139 pp.

Avicennia and *Aegiceras* produce small semi-viviparous seeds that detach from the mother tree by growing a small number of young roots and young shoots (hypocotyls) on the mother tree. In the aforementioned tree species that produce large viviparous seeds, the viviparous seeds themselves can be treated as seedlings, so they can be directly inserted and planted into the planting site. On the other hand, in mangrove species that do not produce vivaporous seeds, the seeds (cryptoviviparous seeds) are small. Therefore, when planting the mangrove seedlings, it is necessary to prepare the seedlings grown in the nursery and then transplant them to the proposed planting site.

Handling of seeds after seed collection

If the seedlings are not planted on the same day they are collected, place the seedlings in a bucket so that the bottom 1/3 of the seedlings are submerged in water. At this time, place the bucket in the shade to avoid direct exposure to the sun. If the bucket is left in the sun, the water in the bucket will heat up and the viviparous seeds will be boiled and die. Also, mangrove seeds and fruits should not be stored in the refrigerator. Many mangrove viviparous seeds will turn brown and die at temperatures below 10-15°C. To store viviparous seeds for 1-2 weeks, keep them in a bucket with the bottom 1/3 of the viviparous seeds immersed in water, in a well-ventilated area, and out of direct sunlight.

Growing seedlings in the nursery

It is reported that more than 110 species of mangroves are distributed in the world [5], but only a few species of them and only in limited regions have been established for seedling growing methods. This is because the conditions of suitable sites are different for each tree species, and each region has a different environment with different tidal trends, ground elevation, flooding frequency, soil, temperature, precipitation, salinity, and so on.

INFO

5) Tomlinson P.B. (1986) The botany of mangroves. Cambridge Univ. Press. pp. 413.

In most cases, seedlings are grown in nursery fields with natural irrigation using tides, so the ground is leveled to a ground elevation slightly lower than mean sea level and the nursery is set up. Make sure that seawater does not stagnate in the seedling beds at low tide. If seawater stagnates, solar radiation may cause salinity concentration and water temperature rise, which may induce root system injury and seedling death. If necessary, drainage channels should be installed around the nursery to ensure drainage. In areas with large tidal ranges, consideration should be given to the distance from seawater inlets and outlets, and bamboo fences should be installed to dampen the water flow to prevent seedlings and soil from being washed away by the inflow and outflow of seawater at high and low tides. In nursery fields set up in locations where there is no rainfall during the dry season and daytime temperatures rise considerably, or where the ground temperature becomes too high at low tide, shading with shade nets or woven nipa palm leaves can mitigate extreme increases in ground temperature and avoid injury due to sunburn. When shading is applied at an intensity of 50% or more, it is recommended that the seedlings be unshaded and acclimatized before planting, and that the seedlings be transplanted. It is not necessary to prepare a specific soil for pot seedlings; soil from the vicinity of the nursery field or sand is acceptable. From the viewpoint of workability and cost saving, it is recommended to use soil that is readily available near the nursery.

Planting mangrove

When planting mangroves, be careful not to select only seedlings of the Rhizophoraceae family, which are easy to prepare and handle, and plant them only, resulting in a simple forest of the same tree species. The species to be planted should be selected based on the species composition of mangroves remaining in the vicinity of the proposed planting site. It is also advisable to carefully consider and determine where to plant which tree species by referring to the relationship between the ground elevation and tree species composition of the remaining mangroves and identifying a site environment conditions with similar ground elevation and similar tidal environment to that of the remaining tree species (Table T12-2).

Factors that can affect the growth and survival of the planted seedlings after planting include entanglement with drift debris, barnacle attachment, outbreaks of the scale insects, feeding damage by crabs and water buffalos, runoff of the seedlings and erosion of ground due to tides and waves. Possible countermeasures include periodic patrols to remove drift debris, replanting of fallen seedlings, replanting of dead seedlings, and installation of bamboo fences to protect the ground against wind and tide.

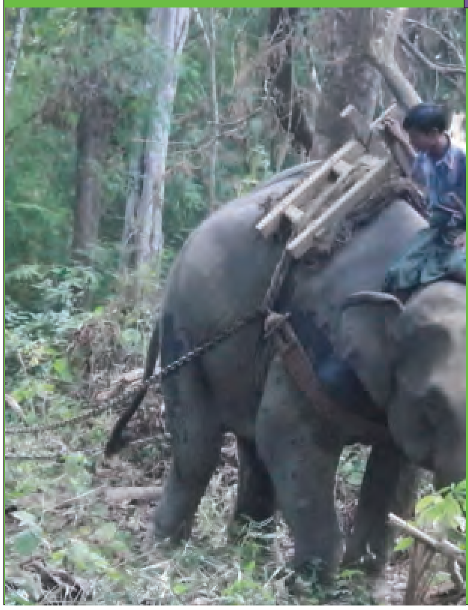
Table T12-2 Planting methods and points to note for different types of seedlings

Seedling Type	Planting Method	Points to note when planting
Viviparous seeds	Direct insertion	•Generally, seedling cultivation in a nursery bed is not necessary, and viviparous seeds can be planted directly into the planting site. •If you do not plant the collected viviparous seeds immediately, do not leave them in direct sunlight. Instead, place them in a well-ventilated shaded area to prevent sunburn. •If the soil is soft, simply insert the viviparous seeds directly into the soil. •If the soil is hard, use a guide rod to create a hole and insert the seeds into it without damaging them. The hole should be slightly smaller than the diameter of the viviparous seeds. •Plant the seeds at a depth where they will not be washed away by the tide, i.e., at a depth where the lower third of the seed's total length is buried. •When planting the long viviporaus seeds (up to 80 cm in length), secure them to stakes made of bamboo or similar material using hemp rope to prevent them from being blown over by the wind or washed away by the tide.
Seedling	Hole Planting	•Plant in a hole that is the same size as the pot. •If the hole is too shallow, the planted seedlings will fall over and be washed away, so adjust the height of the root base of the potted seedlings to the same level as the ground. •When planting pot seedlings, be sure to remove the pot. If you plant them in the pot, the roots will not be able to grow and the seedlings will not grow well, so be careful. •When removing the pot, do not disturb the soil inside the pot. Also, be careful not to damage the roots protruding from the pot. •Do not leave the removed pot's plastic bag at the site: take it home. Leaving the plastic bag behind may cause it to be carried away by waves and wrap around the planted seedlings, potentially damaging them.
Naturally established seedlings		•If the density of seedlings that have drifted ashore and are established is high, thin them out.

Reference

8

Chapter 8 Trends in Forest-based Disaster Risk Reduction in Developing Countries



In Asia, there are several initiatives to utilize forest-based disaster risk reduction, a number of which have received technical support and advice from Japan. Through these projects, a wealth of information that will be useful in considering the future potential for overseas expansion of *Chisan* technology has been gained.

This chapter focuses on six countries in the Asian region-Vietnam, Myanmar, Indonesia, Thailand, the Philippines, and India-where natural disasters frequently occur. The Chapter provides an overview of the characteristics of natural disasters in these countries, the national frameworks for forest-based disaster risk reduction, and key consideration for project implementation.

Recipe - R01

Initiatives in the Socialist Republic of Vietnam

For detail, refer to

F-DRR Country Report (2020) Vietnam (in Japanese only)

About 47% of Vietnam's land area is forest (in 2020), of which about 70% is natural forest and about 30% is plantations, and forest area and the proportion of plantations has been increasing since the 1990s. The country has a tropical monsoon climate with high temperature and heavy rainfall, and natural disasters, particularly typhoons and tropical cyclones, cause floods, rapid rise of small rivers, and mudslides. The Central Committee for Natural Disaster Prevention and Control and the National Committee for Search and Rescue play a central role in disaster risk reduction. Vietnam has a history of increased flood damage due to rapid deforestation until the 1990s. The 5 million hectare afforestation plan implemented by the government since then is one of the forest-based disaster risk reduction.

Situation surrounding the country and forests

The Socialist Republic of Vietnam is located in the eastern part of the Indochina Peninsula in Southeast Asia. The country is long and narrow, measuring 1,200 kilometers from north to south. It borders China to the north, Laos to the west, and Cambodia to the southwest. Geographically, the country is divided into eight regions (from north to Northeast Vietnam, Northwest Vietnam, Red River Delta, North Central Coast, South Central Coast, Central Highlands, Southeast Vietnam, and Mekong River Delta). Approximately 47% of the country's land area is forest (in 2020), of which about 70% is natural forest and about 30% is plantations, and forest area and the percentage of plantations has been increasing since the 1990s.

In the mountainous areas from the north to the central part of the country, subtropical evergreen forests including Fagaceae are distributed, while deciduous forests such as Dipterocarpaceae are distributed in the lowland areas. Mangroves grow in the Mekong Delta. Natural forests were closed by the Prime Minister's declaration in 2016, and in principle there is no timber production from natural forests. On the other hand, plantations are mainly planted with species such as

Figure R01-1 Mangrove in Vietnam

acacia, melaleuca, and rubber tree, and the amount of logging is increasing every year. Vietnam's timber industry is characterized by active export and import of timber.

In Vietnam, the forestry sector's policy for combating climate change is also positioned in various strategies and plans. The Ministry of Agriculture and Rural Development (MARD) has set a goal of increasing the forest coverage to 45% by 2020 through conversion of unused land to forest and expansion of mangroves in coastal areas. In addition, the policy of working on REDD-plus (Reducing emissions from deforestation and forest degradation in the developing countries) was also indicated.

It also stated a policy to address disaster prevention using forests from the perspective of adaptation to climate change. The Nationally Determined Contribution (NDC) (2016) in the Paris Agreement set forth the implementation of protection, restoration, afforestation, reforestation and quality improvement of coastal forests, including mangroves, especially in coastal estuary areas and the Mekong River Delta and Red River Delta. These areas are also considered vulnerable to disasters, and ecosystem-based adaptation is underway (Figure R01-1).

Characteristics of natural disasters in Vietnam

Various natural disasters occur in Vietnam (Figure R01-2), especially the number of floods, rapid rise of small rivers, and mudslides caused by typhoons and tropical cyclones [1]. Damage from floods and storms is particularly large in the central region (north-central and south-central parts of the country). This is thought to be due to the fact that storms often hit directly and that flood control measures have not kept pace with the urbanization associated with economic growth.

Vietnam has a history of increased flood damage due to a rapid decrease in forest area until the 1990s. The Five Million Hectare Reforestation Programme

INFO

1) GLIDEnumber https://www.glidenumber.net/glide/public/search/search.jsp

Figure R01-2 Natural Disaster in Vietnam

(Programme 661) implemented by the government after that is one of the measures for disaster risk reduction using forests. Japan International Cooperation Agency (JICA) is the main overseas donor for natural disaster countermeasures, including forest-based disaster risk reduction. Major related projects include the "Project for Rehabilitation of Natural Forest in Degraded Watershed Area in the North of Vietnam" (2003-2008) by JICA to develop and identify afforestation technologies to restore natural forests in the target areas [2)], the "Forest Fire Rehabilitation Project" (2004-2007) to establish reforestation technologies necessary for restoration of forest fire sites [3)], and the "Project for Afforestation on the Coastal Sandy Area in Southern Central Viet Nam (phase2)" (2009-2015) to develop technologies to restore forests in agricultural and fishery villages caused by movement of flying sand, strong winds and sand [4)], and the "Vietnam Disaster Preparedness Project" (1997-2017) by Japan Red Cross to establish resilience in disaster-vulnerable communities against disaster risks and the impacts of climate change, among others [5), 6)].

INFO

2) JICA (2008) Terminal Evaluation Report of the Project for Rehabilitation of Natural Forest in Degraded Watershed Area in the North of Vietnam (RENFODA)

INFO

3) JICA (2007) Project Completion Report of the Forest Fire Rehabilitation Project in the Socialist Republic of Vietnam

INFO

4) JICA (2016) Ex-post Evaluation Report of the The Project for Afforestation on the Coastal Sandy Area in Southern Central Viet Nam (Phase II)

INFO

5) JICA (2014) Activity Report of the Vietnam Disaster Management Project 2013

INFO

6) JICA (2015) Activity Report of the Vietnam Disaster Management Project 2014

INFO

7) JICA (2018) Final Report (Summary): Information Collection and Verification Survey for Formulating the Disaster Prevention Sector Strategy in the Socialist Republic of Viet Nam

State functions on forest-based disaster risk reduction

Central Steering Committee for Natural Disaster Prevention and Control (CSCNDPC) and the National Committee for Search and Rescue (NCSR), which were established in 2015, play a central roles in disaster prevention in Vietnam [7)]. The CSCNDPC is composed of representatives from central ministries and agencies, the Vietnam Disaster Management Authority (VNDMA) under MARD plays a major role as the secretariat. It supports the government and the Prime Minister in directing and managing national disaster management and is responsible for coordination among relevant sectors. the NCSR is chaired by the Deputy Prime Minister and the Ministry of Defense Relief Bureau serves as its secretariat. It is responsible for directing search and rescue operations for disasters at the national level. As for local governments, a "Commanding Committee for Natural Disaster Prevention and Control, and Search and Rescue (CCNDPC/SR)" is established in every province, district, and commune. The irrigation branch of the Department of Agriculture and Rural Development (DARD) in each district acts as the secretariat.

Key consideration for implementing forest-based disaster risk reduction activities

In implementing forest-based disaster risk reduction in Vietnam, there are several challenges that need to be addressed, including the lack of forecasting and detailing capabilities for extreme weather events (flash floods, landslides, coastal erosion, etc.), technical requirements for installing equipment in mountain areas for disaster risk reduction and insufficient financial resources, lack of knowledge on the relationship between forests and natural disaster mitigation (appropriate species, area, forest distribution, etc.), and lack of constraints on forest harvesting (road construction, harvested area, etc.) have been identified as challenges.

International support for disaster risk reduction to date has utilized *Sabo* technology for direct conservation of conservation targets in the short term, but *Chisan* technology for medium- to long-term disaster risk reduction through appropriate land use planning in mountain watersheds and utilization of forest functions has multifaceted benefits, including ecosystem conservation and utilization and maintenance of mountain resources. The significance of *Chisan* technology is becoming increasingly recognized internationally.

Vietnam has a certain amount of basic data (Table R01-1). However, more detailed data than those at the national level are needed in order to utilize *Chisan* technology for disaster risk reduction as well as for post-disaster countermeasures. For example, data on rainfall, annual sediment discharge, annual water level fluctuations, etc. at the watershed level fall into this category. Such data have not been required in the local countries and have not yet been developed. It is necessary to identify the target area and watershed and start by collecting detailed local information.

Table R01-1 Status of infrastructure data development in Vietnam

Data Class		Data type	Data name, timing, frequency, etc.	Competent authority/ organization
vegetation and topography data	altitude	Digital, Analog	Topographic map, scale 1:50,000 (2000)	MONRE
		Digital	DEM data (resolution 30m) (2016)	MONRE, GDLA
	river and coastline	Digital, Analog	Topographic map, scale 1:50,000 (2000)	MONRE
	watershed, ridge	Digital	TAB files (Mapinfo)	VNFF
	administrative boundary	Digital, Analog	Topographic map, scale 1:50,000 (2000)	MONRE
		Digital	Shape/TAB files (latest is 2020-2021)	MOHA, local gov.
	road and railways	Digital, Analog	Topographic map, scale 1:50,000 (2000)	MONRE
	land cover class	Digital	2016, 2017	MARD
	land use class	Digital	Every five years (work in progress as of 2019)	MOHA, local gov.
	forest class	Digital	Forest classification map, scale 1:50,000 and 1:100,000, updated every five years	MARD
	vegetation	Digital	(Details unknown)	MARD
	geological and soil class	Digital, Analog	Scale 1:200,000 (2005)	MONRE
Meteorological data	rainfall	Digital	Hourly	MONRE
	river flow	Digital	by water level observation station	MONRE
	temperature	Digital, Analog	Hourly	MONRE
	solar radiation	Digital	-	MOIT, Ministry of Energy
	weather map	Digital	-	MONRE, Spanish Agency for International Development Cooperation (AECID)
	location and details of the disaster	Digital	-	MONRE, Vietnam Institute of Geosciences and Mineral Resources

Recipe - R02

Initiatives in the Republic of the Union of Myanmar

For detail, refer to

F-DRR Country Report (2020) Myanmar (in Japanese only)

Natural disasters in Myanmar include a high number of floods caused by typhoons and tropical cyclones. The Paris Agreement's 2030 target states that initiatives in the forestry sector will not only preserve greenhouse gas sinks but also prevent soil erosion, thereby reducing the risk of floods and landslides for people. The "Hazard Profile of Myanmar," compiled by the government and other relevant agencies in 2009, proposes disaster prevention and mitigation approaches for major disasters, including their frequency and scale within Myanmar, geographical characteristics (vulnerable areas), and disaster risk reduction approaches. The utilization of forests includes mangrove planting to counteract tsunami and storm surge damage, planting fast-growing trees in arid areas to mitigate drought, and forest conservation and reforestation in areas with high flood risk.

Situation surrounding the country and forests

The Republic of the Union of Myanmar is a country located in the western part of the Indochina Peninsula in Southeast Asia. Due to its elongated north-south shape and rugged terrain, there are significant climate differences among regions. Generally, areas below 2,000 meters in elevation have a tropical monsoon climate, 2,000 to 2,500 meters have a subtropical climate, and above 3,000 meters have a subalpine climate. Coastal regions are highly rainy with annual precipitation exceeding 5,000 millimeters. On the other hand, inland regions have a tropical savanna climate with annual precipitation of less than 1,000 millimeters, making them prone to drought.

About 44% of Myanmar's land area is covered by forests (as of 2020), most of which are natural forests, but the proportion of planted forests has been increasing in recent years [1]. Deciduous forests, which account for about 40% of the forest, are the most important because they include economically valuable tree species such as teak, which is the main tree species in the country (Figure R02-1). Myanmar's forests provide high-value timber, non-timber forest products, rich biodiversity, and ecosystem services such as water conservation.

Figure R02-1 10-year-old teak forest

INFO

1) FAO (2020) Global Forest Resources Assessment 2020: Main report. Rome.

The forest rate has decreased from about 60% in 1990 to about 44% in 2020. The causes of deforestation and degradation include slash-and-burn agriculture, collection of firewood and charcoal, illegal logging, conversion to agricultural land, mining development, and urban infrastructure development. Additionally, mangroves cover 500,000 hectares in coastal areas but are disappearing at a faster rate than in neighboring countries.

In Myanmar, forestry initiatives for climate change mitigation are incorporated into various strategies and plans. The National Adaptation Program of Action (NAPA) (2012) identifies 32 adaptation projects that the country should prioritize, and forestry is one of the most important areas to focus on. Specifically, these include strengthening the resilience of forests vulnerable to climate change through reforestation, reforestation and ecosystem restoration by local communities in degraded watersheds in the central dry zone, mangrove restoration by local communities in coastal areas, and ecosystem restoration by local communities in the Inle Lake and Inle Lake basins in the northern hill country. In addition, the Paris Agreement's Nationally Determined Contribution (NDC) (2016) state that efforts in the forestry sector not only preserve GHG sequestration but also prevent soil erosion, thereby reducing the risk of flooding and landslides for people. Examples of adaptation initiatives include community-led reforestation to restore degraded forests, improve livelihoods in degraded watersheds, coastal areas, and northern hilly regions, and implement mangrove restoration projects to strengthen disaster resilience in coastal and delta regions.

Characteristics of natural disasters in Myanmar

Natural disasters in Myanmar are characterized by frequent floods and rapid rises in small rivers caused by typhoons and tropical cyclones, as well as a high number of landslides (Figure R02-2) [2].

In response to multiple disasters that caused numerous deaths, including Tropical Cyclone Nargis in 2008, relevant government agencies and other related organizations in Myanmar (such as the Myanmar Engineering Council and the Myanmar Geoscience Society) compiled the “Hazard Profile of Myanmar" with the support of the British government. The report covers nine types of disasters—tropical cyclones, droughts (in arid regions), earthquakes, fires, floods, forest fires, landslides, storm surges, and tsunamis—and addresses their frequency and scale in Myanmar, their geographical characteristics (vulnerable areas), and proposals for disaster risk reduction approaches [3].

State functions on forest-based disaster risk reduction

In Myanmar, disaster prevention agencies have been established in response to large-scale disasters, such as the 2004 Indian Ocean earthquake off the coast of Sumatra, Indonesia, and the 2008 tropical cyclone Nargis, which caused 140,000 casualties in Myanmar. The lead agency for disaster prevention is the National Disaster Prevention Central Committee (NDPCC), established in 2005 and reorganized in 2013. Under the NDPCC, the National Disaster Prevention Working Committee (NDPMWC) is responsible for implementing disaster response policies. Although it is an inter-ministerial organization, the Ministry of Social Welfare, Relief, and Resettlement plays a central role. Other key members include the Ministry of Information, the Ministry of Education, and the Ministry of Home Affairs [4].

Each relevant ministry and agency have been assigned specific roles related to disaster prevention (Table R02-1). The role of the Ministry of Natural Resources and Environmental Conservation (MONREC), which oversees forests, in disaster

INFO

2) GLIDEnumber https://www.glidenumber.net/glide/public/search/search.jsp

INFO

3) Govt. Myanmar, et al. (2009) Hazard Profile of Myanmar

INFO

4) Tabira, Y. (2020) Disaster management system of the central government of Myanmar after the transition to civilian rule and future challenges. Journal of Regional Safety Studies, 21, 189–198.

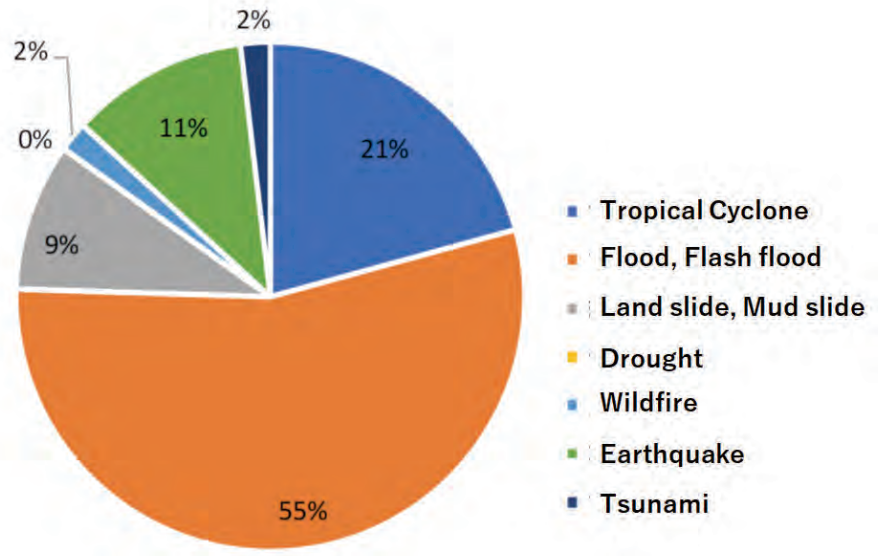


Figure R02-2 Percentage of disasters occurring in Myanmar (1990–2019) Created from 2)

Table R02-1: Roles of relevant ministries and agencies in disaster prevention measures (by type of disaster) [5)]

Disaster Type	Jurisdiction over non-structural objects	Jurisdiction over structural objects
Tsunami	Department of Meteorology and Hydrology (Ministry of Transport and Communication), Ministry of Social Welfare, Relief & Resettlement, Department of Education Planning and Training (Ministry of Education)	Ministry of Construction, Department of Irrigation (Ministry of Agriculture, Livestock and Irrigation), Local government
Earthquake	Ministry of Social Welfare, Relief & Resettlement, Ministry of Health, Ministry of Education, Department of Meteorology and Hydrology (Ministry of Transport and Communication), Myanmar Engineering Council	-
Strong wind	Department of Meteorology and Hydrology (Ministry of Transport and Communication),	-
Flood	Department of Irrigation (Ministry of Agriculture, Livestock and Irrigation), Department of Meteorology and Hydrology (Ministry of Transport and Communication), Ministry of Social Welfare, Relief & Resettlement	Department of Irrigation (Ministry of Agriculture, Livestock and Irrigation).
Landslide	Department of Irrigation (Ministry of Agriculture. Livestock and Irrigation), Department of Meteorology and Hydrology (Ministry of Transport and Communication), Ministry of Social Welfare. Relief & Resettlement	-
Drought	Department of Irrigation (Ministry of Agriculture, Livestock and Irrigation), Department of Meteorology and Hydrology (Ministry of Transport and Communication), Ministry of Social Welfare, Relief & Resettlement, Department of Forest (Ministry of Environmental Conservation and Forestry)	-
Forest Fire	Fire Service Department, Forest Department (Ministry of Natural Resources & Environmental Conservation)	Fire Service Department, Local government

Table R02-2 Roles of relevant ministries and agencies in disaster prevention measures (by phase before and after a disaster) [5)]

Ministry	Plan, Readiness, Mitigation	Disaster Relief Activities and Emergency Response	Recovery and reconstruction
Ministry of Social Welfare, Relief & Resettlement. Ministry of Health	•Dissemination of information and guidance on disaster mitigation plans •Implementation of state-level disaster management training •Public education and awareness activities, and other capacity building	•Responsibility and supervision of emergency disaster response •Rescue operations, distribution of emergency supplies, and evacuation support for socially vulnerable groups •Transmission of early warnings to the grassroots level	•Support for resettlement and reconstruction for disaster victims, and support for socially vulnerable groups
Ministry of Transport and Communication	•Disaster mitigation plans for maritime and air traffic •Establishment of a system for issuing early warnings based on meteorological, water level, hydrological, and seismic observation data (Department of Meteorology and Hydrology)	•Ensuring maritime and air traffic safety •Collecting meteorological, water, hydrological, and seismic observation data, and issuing and disseminating early warnings (Department of Meteorology and Hydrology)	•Restoration and reconstruction of maritime and aviation facilities •Support for restoration and reconstruction through the provision of relevant information (Department of Meteorology and Hydrology)
Ministry of Agriculture. Livestock and Irrigation	•Monitoring and maintenance of earthworks, dams, embankments, and Irrigation facilities •Implementation of forest protection in cooperation with other ministries	•Monitoring of earthen embankments, dams, levees, irrigation facilities, etc. •Temporary evacuation camps. installation of water storage facilities	•Distribution of seeds and agricultural equipment to farmers •Survey and repair of earthen embankments, dams, etc.
Ministry of Construction	•Development of public infrastructure that is resistant to disasters	•Ensuring access to disaster areas via roads, bridges, etc.	•Urban planning for the restoration of public infrastructure and the resettlement of disaster victims
Ministry of Natural Resources & Environmental Conservation	•Sustainable forest management, disaster reduction plans related to forests •Environmental protection-related work (National Environment Commission)	•Evacuation of equipment and personnel related to forests, ensuring safety	•Survey and restoration of forest resources and forestry equipment

prevention includes planning, preparation, and mitigation measures; disaster relief activities and emergency response; and recovery and reconstruction (Table R02-2) [5)].

Support needs

Myanmar is prone to typhoons, tropical cyclones, floods, and flash floods, and the support needs for these natural disasters include early flood forecasting and warning systems and flood prevention plans and measures for widespread flooding caused by typhoons and tropical cyclones, early flood forecasting and warning systems and flood prevention plans and measures for flash floods in mountainous and semi-arid areas, the introduction and improvement of preemptive hard measures against landslides, and community disaster prevention measures against landslides.

However, following the military coup in February 2021, the Japanese government has suspended new ODA projects, excluding humanitarian aid.

INFO

5) JICA (2012) Country Disaster Management Profiles: (Basic Information Collection and Confirmation Survey on ASEAN Regional Disaster Management Cooperation)

Recipe - R03

Initiatives in the Republic of Indonesia

For detail, refer to

F-DRR Country Report (2020) Indonesia (in Japanese only)

Natural disasters in Indonesia include a high number of earthquakes, floods, flash floods, and slope failure. As part of the Paris Agreement's 2030 goals, Indonesia plans to advance REDD+ as a mitigation measure and implement adaptation measures such as maintaining environmental services to reduce disaster risks. This includes ecosystem conservation and restoration, community forestry, coastal zone protection, integrated watershed management, and climate-resilient urban development. There are several challenges, including the expansion of oil palm plantations contributing to increased flooding, insufficient disaster prevention measures against expected intensification of storm surges, and peatland fires remaining a serious issue, with land clearing for plantation development being a contributing factor.

Situation surrounding the country and forests

The Republic of Indonesia is located near the equator in southern Southeast Asia and has a tropical climate. Due to its location near plate boundaries, it is characterized by a high number of volcanoes.

Approximately 49% of the country's land area is forested (as of 2020), with most of it being natural forest, though the proportion of planted forests has been increasing in recent years. The forest cover decreased from approximately 63% in 1990 to approximately 49% in 2020 [1]. The causes of deforestation and degradation include illegal logging, forest fires, and land conversion for oil palm plantations (Figure R03-1). Since the early 1970s, forest development and timber production have become more active, resulting in the production of over 20 million cubic meters of roundwood annually by the 1990s. This was followed by significant deforestation due to land conversion for agricultural purposes, which has become a global concern. In addition, forest degradation caused by illegal logging and forest fires has become a serious problem. The forests are tropical and are classified into six types by the government according to

Figure R03-1 Large-scale oil palm plantation

INFO

1) FAO (2020) Global Forest Resources Assessment 2020: Main report. Rome.

their vegetation types (mixed hill forests; sub-montane, montane & alpine forests; savanna/ bamboo/ deciduous/ monsoon forests; peat swamp forests; freshwater swamp forests; and tidal forests (mangroves)). Mixed hill forests account for about 65% of natural forests and are the most important forests for timber production. Another notable feature is that mangroves cover a large area of about 3 million hectares, accounting for about 21% of the world's mangrove area.

The role of forests in climate change mitigation is addressed in various national strategies and plans. In particular, reducing emissions from deforestation and forest degradation in developing countries (REDD+) is considered to have significant reduction potential, and policies to address this issue have been outlined. Additionally, in the Nationally Determined Contribution (NDC) under the Paris Agreement, Indonesia has set mitigation targets related to forests and outlined plans to advance REDD+, while also outlining adaptation measures. Specifically, Indonesia plans to implement ecosystem conservation and restoration, community forestry, coastal zone protection, integrated watershed management, and climate-resilient urban development in order to maintain environmental services such as disaster risk reduction.

Characteristics of natural disasters in Indonesia

Indonesia experiences a particularly high number of earthquakes, floods, flash floods, and slope failure. Another characteristic is the frequent occurrence of volcanic eruptions (Figure R03-2) [2].

Disaster risk reduction measures are led by the government. An example of soft measures against landslides and debris flows is the Centre for Volcanology and Geological Hazard Mitigation (CVGHM), which creates hazard maps by overlaying maps of areas at risk of landslides with monthly rainfall forecasts and sends them to local governments every month. Additionally, the National Disaster Management Agency (Badan Nasional Penanggulangan Bencana: BNBP) creates hazard maps

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2) GLIDEnumber https://www.glidenumber.net/glide/public/search/search.jsp

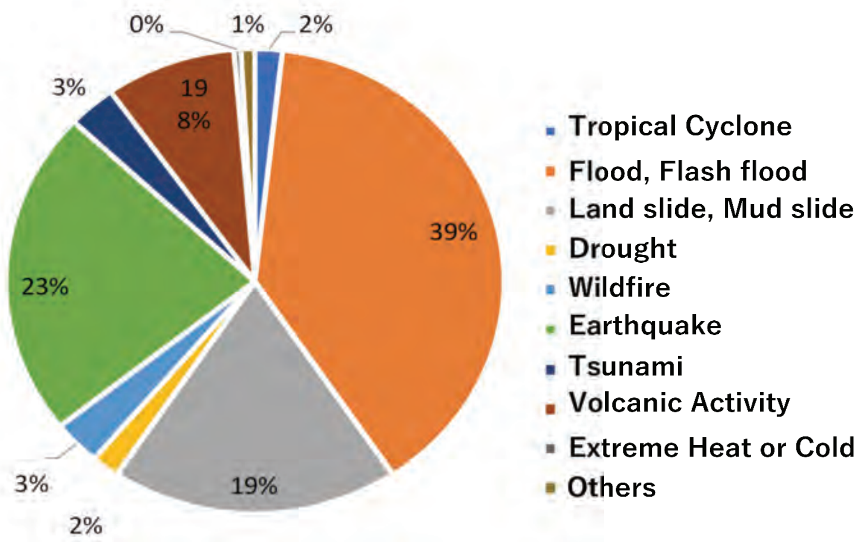

Figure R03-2 Percentage of disasters occurring in Indonesia (1990–2019) Created from 2)

INFO

3) JICA (2012) Country Disaster Management Profiles: (Basic Information Collection and Confirmation Survey on ASEAN Regional Disaster Management Cooperation)

INFO

4) JICA (2004) Indonesia: Forest Fire Prevention Project II – Operational Guidance (Mid-term Evaluation) Survey Report

INFO

5) JICA (2006) Indonesia: Forest Fire Prevention Project II – Terminal Evaluation Report

INFO

6) JICA (2015) Terminal Evaluation Report on the Project on Mangrove Ecosystem Conservation and Sustainable Use in the ASEAN Region

related to landslides [3].

Disaster risk reduction measures utilizing forests include forest fire prevention measures and mangrove planting in coastal areas. One of the main overseas donors for natural disaster countermeasures is Japan International Cooperation Agency (JICA), which has provided technical cooperation through the “Forest Fire Prevention Management Project (phase II)" (2001-2006) [4), 5)] and the “Project on Mangrove Ecosystem Conservation and Sustainable Use in the ASEAN Region" (2011-2014) [6].

State functions on forest-based disaster risk reduction

The government agency responsible for disaster management is BNPB, which was established in 2008 based on the Disaster Management Law (2007). It is responsible not only for coordinating between ministries but also for implementing countermeasures, and it is engaged in disaster prevention, emergency response, and recovery and reconstruction. Local governments (provinces, regencies, and cities) have established local disaster management agencies (Badan Penanggulangan Bencana Daerah: BPBD) as local branches of BNPB [7]. Each province has a designated authority for each stage before and after a disaster, as well as for each type of disaster (Figure R03-1) [3]. The Ministry of Environment and Forestry (KLHK/MOEF) is responsible for forests.

In Indonesia, all kinds of data related to disasters, including spatial and non-spatial information, are available. In particular, data has been compiled under the

Table R03-1 Roles of relevant ministries and agencies in disaster prevention measures (by type of disaster) [3]

Disaster Type	Jurisdiction over non-structural objects	Jurisdiction over structural objects
Tsunami	Indonesian Agency for Assessment and Application of Technology (BPPT) Indonesia Institute of Sciences (LIPI) Bandung Institute of Technology (ITB) Ministry of Research and Technology (MENRISTEK) Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) Geospatial Information Agency (BIG)	Directorate General of Water Resources (Ministry of Public Works and Public Housing (PUPR))
Earthquake	Geological Agency (BG) Indonesian Agency for Mateorology, Climatology and Geophysics (BMKG)	Geological Agency (BG) Ministry of Public Works
Flood and Debris Flow	Directorate General of Water Resources (Ministry of Public Works and Public Housing (PUPR))	Directorate General of Water Resources (Ministry of Public Works and Public Housing (PUPR))
Volcanic Activity	Geological Agency (BG) Centre for Volcanology and Geological Hazard Mitigation (CVGHM)	Directorate General of Water Resources (Ministry of Public Works and Public Housing (PUPR))
Drought	Ministry of Agriculture Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG)	Ministry of Agriculture Ministry of Public Works and Public Housing (PUPR)
Slope Collapse	Geological Agency (BG)	Directorate General of Water Resources (Ministry of Public Works and Public Housing (PUPR))
Slope Collapse	Ministry of Environment and Forestry (MOEF)	Ministry of Environment and Forestry (MOEF)

supervision of the Geospatial Information Agency (BIG) for the formulation of mitigation and adaptation strategies. These data can be used in accordance with the rules of the “One Map Policy" (a nationwide large-scale base map project being promoted under a 2016 presidential decree).

Key consideration for implementing forest-based disaster risk reduction activities

The following issues can be identified in the field of disaster risk reduction in Indonesia [7].

- Large-scale flooding occurs every year during the rainy season, which is thought to be caused in part by large-scale land use changes (such as the conversion of forests to palm oil plantations) accompanying economic development, and measures are needed to address this issue.
- The priority given to flood control measures for disaster risk reduction is low compared to water resource development for other priority issues (food and water security, housing issues), making it difficult to secure budgets.
- There is a shortage of local-level budgets for disaster prevention measures. In addition, disaster risk reduction activities (especially those related to water disasters) by local administrative organizations and communities are insufficient.
- As a measure against storm surges, structural measures such as embankments are being implemented in combination with mangrove planting. However, no measures have been taken to address the increase in storm surge damage due to the expansion of tropical cyclones associated with future climate change.
- Peatland fires remain a serious issue. While natural factors such as El Niño contribute to the expansion of damage, human-induced fires for the development of oil palm plantations and other purposes are also a major cause of fires.

In response to the need for support for these issues, we will examine the applicability of Japan's forest-based disaster risk reduction technologies.

Floods, high tides, and forest (peatland) fires are issues that need to be addressed, and it is recognized that these disasters may increase and become more severe in the future, so it is necessary to take the necessary measures. In Indonesia, oil palm plantation development accompanying economic growth is contributing to disasters through land conversion (forest loss) and controlled burning (increased fire risk). Without implementing policies to maintain and improve community livelihoods, these factors cannot be eliminated. In addition to disaster risk reduction efforts, support for livelihood activities that include the effective use of forest resources is also required.

INFO

7) JICA (2019) Final Report (Summary): Information Collection and Verification Survey in the Disaster Management Sector in the Republic of Indonesia

Recipe - R04

Initiatives in the Kingdom of Thailand

For detail, refer to

F-DRR Country Report (2021) Thailand (in Japanese only)

The most frequent disaster in Thailand is flooding. Due to the gentle slope of the Chao Phraya River, which flows through central Thailand, once flooding occurs, the damage tends to be prolonged. Policy decisions on disaster prevention and mitigation are made by the National Disaster Prevention and Mitigation Committee, an inter-ministerial organization. Soft measures for mountain disasters, etc., are being promoted by government agencies, research institutions, and private companies, including the development of disaster occurrence models based on observation data, the establishment of early warning systems, and the creation of hazard maps. As hard measures, check dams are being installed nationwide in river basins. Additionally, there are cases where collapse debris capture nets and slope reinforcement using geotextiles are being introduced to prevent and mitigate slope disasters.

Situation surrounding the country and forests

The Kingdom of Thailand is located in the central part of the Indochina Peninsula in Southeast Asia and has a tropical monsoon climate. The average annual rainfall is approximately 1,250 mm in the northeast and over 4,000 mm in the southern peninsula [1)]. As of 2015, land use in Thailand consisted of 50% farmland, 30% forest, and 20% other land uses. Forests are further subdivided into “Conservation forests," “National Reserve forests (economic forests)," and “Mangrove forests." [2)] Thailand divides its entire territory into 25 watersheds. Each watershed is classified into one of five categories based on topography, geology, soil, elevation, and slope, with land use regulations and other measures set according to the classification [1)].

In the 1960s, forests covered more than 50% of Thailand's land area. However, due to timber exports, agricultural expansion policies, settlement policies, infrastructure development, urbanization, and resort development, forests declined rapidly from the 1970s to the 1980s. Since 1988, forest conservation policies have been strengthened, and in recent years, forest area has remained stable with no significant changes [1)]. Currently, 31.6% of the country's land area is covered by forests (2020), and more than 80% of these forests are natural forests. However, in recent years, the proportion of planted forests has been increasing [3)]. The deforestation was identified as a cause of the floods that occurred in southern Thailand in 1988, and since 1989, the logging of natural forests has been banned.

In terms of forest policy, the 12th National Economic and Social Development Plan (2017-2021), which is the national five-year plan, sets forth the following goals as part of a growth strategy that takes the environment into consideration

INFO

1) Royal Forest Department (2009) Forestry in Thailand

INFO

2) Department of National Parks, Wildlife and Plant Conservation(2020) Forest reference emission level and forest reference level Thailand

INFO

3) FAO (2020) Global Forest Resources Assessment 2020: Main report. Rome.

for sustainable development: conservation and restoration of natural resources, management of water resources, improvement of environmental quality, and adaptation to climate change, including natural disasters. Additionally, the plan sets a target forest cover rate of 40% (25% conservation forests and 15% economic forests). In particular, the plan aims to expand the area of mangrove forests to 253,000 hectares [4]. Furthermore, Thailand's updated Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2020 indicates that the forestry sector will be involved in both mitigation and adaptation measures for climate change [5]. In particular, with regard to adaptation, specific activities in three of the six priority areas, namely “Water resource management," “Agriculture and food security," and “Natural resources management," include afforestation, community-based forest management, payment for ecosystem services (PES), and implementation of REDD+.

INFO

4) Office of the Prime Minister (2017) The twelfth national economic and social development plan (2017-2021)

INFO

5) Office of Natural Resources and Environmental Policy and Planning (ONEP) (2020) Thailand's Updated Nationally Determined Contribution

Characteristics of natural disasters in Thailand

The most frequent disaster in Thailand is flooding (Figure R04-1) [6]. From the 1970s to the 1980s, there was a rapid decline in forest cover. Since then, landslides and debris flows have become more frequent in mountainous areas, and flooding has increased in rivers. Floods are caused by the southwest monsoon and northwest monsoon from May to September, as well as tropical cyclones, which bring heavy rainfall and prolonged precipitation [7]. In Thailand, the slope of river basins is gentle, and drainage takes time, leading to prolonged flood damage [7]. Landslides (flash floods, slope collapses, landslides, etc.) have also increased in frequency and intensity due to deforestation and the expansion of farming on slopes. Additionally, Thailand has 2,420 km of coastline, and storm surges occur during cyclones and typhoons [7].

INFO

6) GLIDEnumber https://www.glidenumber.net/glide/public/search/search.jsp

INFO

7) Asian Disaster Reduction Center (2020) Thailand Contry Report 2019

The “National Strategy (2018-2037)," the first long-term national strategy established in Thailand, sets forth the vision of becoming “a developed country with security, prosperity, and sustainability in accordance with the Sufficiency

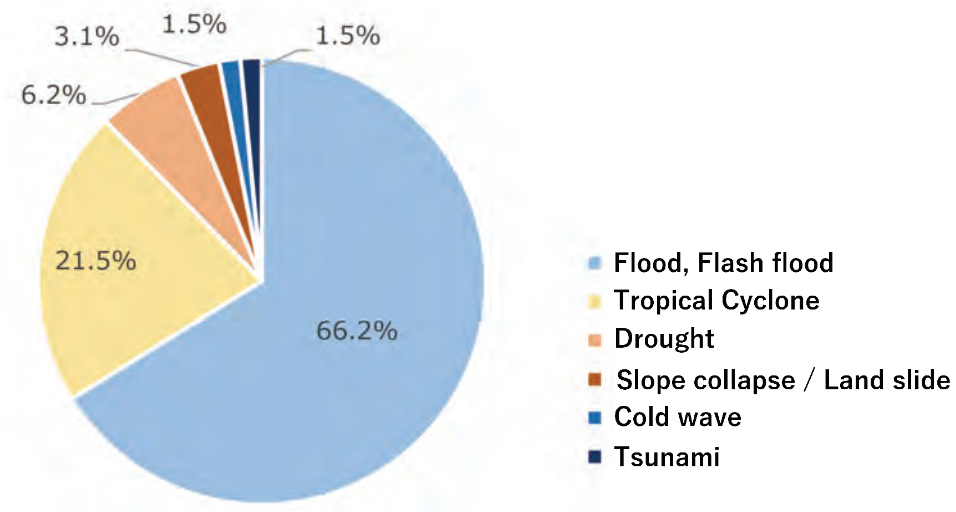

Figure R04-1 Percentage of disasters occurring in Thailand (1991–2020) Created from 6)

Economy Philosophy."

Within this strategy, disaster mitigation and prevention are mentioned as key items in the environmentally friendly development and growth strategy to ensure sustainability [8]. In addition, the 12th National Economic and Social Development Plan (2017-2021), which is formulated every five years, sets forth national sovereignty, security, and enhancement of national trust as one of its goals, including strengthening preparedness for natural disasters. It also indicates disaster risk management as one of the approaches to environmentally friendly growth strategies for sustainable development [4].

INFO

8) Office of National Economic and Social Development Council (2018) National Strategy 2018-2037

In the progress report on the Hyogo Framework for Action prepared by Thailand in 2015, three issues were identified: (1) mainstreaming disaster risk reduction, (2) fostering of "disaster safe culture" at all levels, including communities, and establishing mechanisms that contribute to disaster risk reduction, and (3) establishing a participatory monitoring and evaluation system for disaster risk reduction [9].

INFO

9) Department of Disaster Prevention and Mitigation (2015) National progress report on the implementation of the Hyogo Framework for Action (2013-2015)

Political turmoil has contributed to delays in flood control in Thailand. The flood control plan launched in 2005 was scrapped due to the coup d'état the following year, and the comprehensive flood management plan formulated in 2013 was also shelved due to the coup d'état in 2014. Currently, efforts are being made based on the "20-Year Water Resources Management Master Plan (2018-2037)" formulated in 2018.

State functions on forest-based disaster risk reduction

In 2002, the Disaster Risk reduction Bureau (DDPM) was established within the Ministry of Home Affairs as an agency to plan, manage, and implement disaster prevention measures, from disaster prevention to emergency response and reconstruction. In 2004, the Disaster Prevention Academy (DPMA) was established under the DDPM to be responsible for human resource development. Additionally, following the Indian Ocean tsunami in December of the same year, the National Disaster Warning Center (NDWC) was established to handle disaster forecasting and warning. The Disaster Risk reduction Act enacted in 2007 stipulated that the DDPM's important functions include the formulation and implementation of national disaster risk reduction plans. The National Disaster Risk reduction Committee (NDPMC) was also established as the body responsible for deciding on these plans. The national disaster risk reduction plans decided by the NDPMC are approved by the Cabinet.

As of January 2022, the "National Disaster Risk reduction Plan (2015)" has been published. The DDPM has formulated a revised version of the "National Disaster Risk reduction Plan" that outlines the basic policy for disaster risk reduction from 2021 to 2027, and as of January 2022, it is in the final approval process.

In Thailand, forest protection policies have been strengthened since the floods that occurred in southern Thailand in 1988, and forest protection policies in general are positioned as one of the disaster risk reduction measures. The conservation and management of forests to enable them to function as disaster risk reduction measures are overseen by the Ministry of Natural Resources and Environment (MONRE). Under the supervision of MONRE, the Royal Forest Department (RFD) manages “National Reserve forests (economic forests)," the Department of National Parks, Wildlife and Plant Conservation (DNP) manages “Conservation forests," and the Department of Marine and Coastal Resources (DMCR) manages “Mangrove forests" other than protected forests. The “National Forest Policy" was established in 1985, and a revised draft was announced in 2019. The revised forest policy highlights the importance of forest and other ecosystem services and emphasizes the importance of conservation and restoration [10]. As of January 2022, the revised “National Forest Policy" is still in the approval process.

INFO

10) Ministry of Natural Resources and Environment (2019) National Forest Policy Draft

Key consideration for implementing forest-based disaster risk reduction activities

The needs related to disaster management in the adaptation sector, as outlined in Thailand's updated NDC, are as follows [5].

- Capacity building for ministries and local governments to integrate adaptation measures, including disaster resilience, into their respective plans
- Support for the development, promotion, and implementation of teacher training and education and training programs
- Support for the implementation of integrated water resources management (IWRM) and ecosystem-based adaptation (EbA)
- Development of funding methods and approaches to encourage private sector participation
- Improvement of the capabilities of national and local government officials to create proposals for funding
- Sharing of knowledge and best practices regarding legal frameworks and methods for implementing adaptation measures such as disaster resilience
- Providing knowledge and technical support to promote community participation in the conservation and protection of natural resources, ecosystems, and biodiversity

DDPM has identified the following as support needs for Thailand's disaster risk reduction sector: promoting research and development and improving skills for disaster risk reduction, expanding disaster prevention investment, building effective recovery strategies, providing incentives to involve local stakeholders in disaster prevention, and developing human resources.

Recipe - R05

Initiatives in the Republic of the Philippines

For detail, refer to

F-DRR Country Report (2021) the Philippines (in Japanese only)

The Philippines is one of the countries in Southeast Asia most prone to natural disasters, with the majority of deaths and missing persons caused by disasters such as floods, slope collapse, landslides, and tidal waves resulting from typhoons. The country has enacted a Disaster Risk Reduction and Management Act of 2010 and is establishing a framework based on a new approach of comprehensive disaster risk management that includes disaster risk reduction, in addition to post-disaster recovery. The Philippine Master Plan for Climate Resilient Forestry Development, which includes climate change measures, promotes sustainable forest management and watershed management to enhance climate change resilience, strengthen community resilience to climate change disasters, and improve information management and monitoring and evaluation systems.

Situation surrounding the country and forests

The Republic of the Philippines is a country consisting of 7,641 islands located between 117 and 126 degrees east longitude and 4 and 20 degrees north latitude, with a total area of approximately 30 million hectares. The country has a tropical monsoon climate.

Of the Philippines' total land area of approximately 30 million hectares, forest cover was estimated to be 7.18 million hectares (approximately 24%) as of 2020. This includes 860,000 hectares of natural forests, 5.94 million hectares of secondary forests, and 380,000 hectares of artificial forests [1)]. Forest cover was 60% of the land (17.8 million hectares) in 1934, but decreased to 50% in 1970 and 27% in 1990. From the 1950s to the late 1980s, approximately 170,000 hectares of forest were lost annually, equivalent to a rate of 1.6%. Since the year 2000, forest cover has remained stable or shown a slight increase, but according to Global Forest Watch, at least 150,000 hectares of humid primary forests have been lost between 2002 and 2020 [2)].

Factors contributing to deforestation and degradation since the 1970s include inadequate management by forestry authorities, illegal logging due to a lack of incentives for logging companies, failure to carry out reforestation, and agricultural activities such as non-traditional slash-and-burn farming by itinerant farmers who have encroached on logged areas. Additionally, the conversion of closed forests to open forests has exceeded the conversion of open forests to closed forests, leading to a deterioration in forest quality [2), 3)]. The causes of forest degradation in the Philippines include the fact that many of the secondary forests left behind after commercial logging in the 1970s were converted to grasslands and became barren

INFO

1) FAO (2020) Global Forest Resources Assessment 2020: Main report. Rome.

INFO

2) Global Forest Watch https://www.globalforestwatch.org/

INFO

Forestry Agency (2019) *[Report on the Collection of On-site Information in Producer Countries (Tropical Regions) under the FY2017 "Clean Wood" Utilization Promotion Project]* mountains due to frequent wildfires during the dry season. Furthermore, population growth has led to increased demand for fuelwood, and forest development for the purpose of expanding farmland has also contributed to forest degradation. In recent years, logging, natural disasters, illegal logging, and illegal mining have been analyzed as causes of forest degradation [4]. Mangroves have decreased from one-quarter to one-fifth of their area in 1900 by 1998 due to shrimp farming (Figure R05-1). Shrimp farms are abandoned after several years to a decade. The reasons for abandonment are the deterioration of mud quality and the spread of viral diseases, and the regeneration of mangroves after abandonment is difficult [5].

Figure R05-1 Mangroves in the Philippines

In 2013, the Philippines updated its Master Plan for Climate Resilient Forestry Development to include climate change measures. Forests are recognized not only as a source of timber and non-timber products, but also as providers of important ecosystem services such as agriculture, energy, domestic water sources, protection from disasters such as floods, and conservation of biodiversity to support tourism and fisheries. Furthermore, the Master Plan outlines sustainable forest management and watershed management to promote climate change resilience, strengthening community resilience to climate change disasters, and improving information management and monitoring and evaluation systems [6].

Characteristics of natural disasters in the Philippines

The Philippines is one of the countries most prone to natural disasters in Southeast Asia, with a wide variety of disasters, including floods, typhoons and tropical cyclones, landslides and mudslides, earthquakes, and volcanic disasters. Due to its geographical location and tectonic activity, it is susceptible to almost all types of natural disasters [7), 8), 9)]. The majority of deaths and missing persons are caused by disasters such as floods, landslides, and storm surges caused by typhoons, indicating that typhoons and tropical cyclones are the main cause of disaster damage (Figure R05-2) [10]. The number of natural disasters and the number of victims have both been increasing in recent years. In particular, disaster risks in metropolitan areas such as the Metro Manila are increasing, and poverty-stricken areas are especially vulnerable to disaster risks [11].

In the Philippines, since the 1990s, there has been a shift from policies that focused on “response and preparedness after disasters" to policies that emphasize “disaster risk management aimed at reducing disaster risks before they occur as

INFO

4) Shibuya, Y., & Mochida, H. (2004) [Study on forest restoration projects in degraded areas of the Philippines]. Bulletin of the University of Tsukuba Forests, 20, 1–58.

INFO

5) Tanaka, K. (1998) [Development and Environmental Issues in Mangrove Areas]. Chuo Suiken News 21.

INFO

6) The Department of Environment and Natural Resources (2016) Philippine Master Plan for Climate Resilient Forestry Development

INFO

7) JICA (2012) Country Disaster Management Profiles: (Basic Information Collection and Confirmation Survey on ASEAN Regional Disaster Management Cooperation)

INFO

8) JICA (2014) Disaster Risk Reduction and Management Capacity Enhancement Project

INFO

9)Office of Civil Defense - Department of National Defence(2018) The Philippine Disaster Risk Reduction and Management System

INFO

10) GLIDEnumber https://www.glidenumber.net/glide/public/search/search.jsp

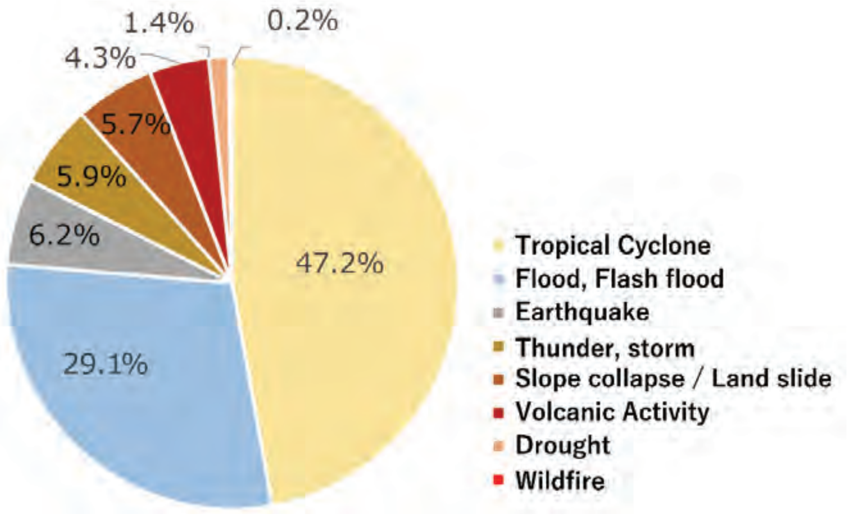

Figure R05-2 Percentage of disasters occurring in the Philippines (1990–2020) Created from 9)

INFO

11) JICA (2017) Data Collection Survey for Strategy Development of Disaster Risk Reduction and Management Sector in the Republic of the Philippines: Final Report

part of poverty reduction efforts." [11] In 2010, the Disaster Risk Reduction and Management (DRRM) Act was enacted. This shift has led to the establishment of a comprehensive disaster risk management framework based on the new DRRM approach, which includes disaster risk reduction, in addition to post-disaster recovery. This framework has been positioned as a cross-sectoral issue. Japan's cooperation covers a wide range of areas across all stages of the disaster cycle (disaster risk reduction, disaster preparedness, disaster response, and disaster recovery and reconstruction), forming a strong bilateral partnership. Japan has also taken a leadership role in discussions on disaster prevention at ASEAN and APEC meetings, contributing to the formation of regional frameworks such as the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) [11].

State functions on forest-based disaster risk reduction

In 2010, the DRRM Act reorganized the National Disaster Risk Reduction and Management Council (NDRRMC) as the highest decision-making body for disaster management at the national level [11]. In addition, a bill to establish a new government agency (Department of Disaster Resilience) to “lead, manage, and organize national efforts for disaster risk risk reduction, disaster preparedness and response, and post-disaster recovery, rehabilitation, and advancement" was approved by the House of Representatives in September 2020. It is expected to replace the NDRRMC as the main administrative agency [12].

INFO

12) Philippine News Agency (2020) Disaster resilience department bill gets final House nod.

The Department of Environment and Natural Resources (DENR), which implements policies for the conservation, management, development, and proper use of the country's environment and natural resources, has been implementing the following as the six-year goals of the Duterte administration since 2016: (1) social justice in land ownership, (2) good and effective governance in environmental protection, (3) restoration of forests and protected areas, (4) climate change adaptation and sustainable use of natural resources, and (5) conservation of coastal and marine resources [13]. In addition, the National Greening Program has been ongoing since 2011, and in 2020, 47,299 hectares were afforested nationwide, achieving 100% of the annual target of 46,907 hectares. Over the past 10 years since 2010, afforestation has been carried out on 23% of degraded forest areas.

INFO

13) The Department of Environment and Natural Resources (2020) Annual Report 2020

Key consideration for implementing forest-based disaster risk reduction activities

According to a 2017 survey by JICA [11], needs in the field of disaster risk reduction can be broadly categorized into (1) implementation of advanced disaster preparedness activities and risk mitigation measures, (2) disaster risk mitigation in the Metro Manila, where assets and population are concentrated, and in regions where development is lagging and vulnerability to disasters is high, and (3) further improvement of the accuracy and standardization of existing risk assessments.

When the Forestry Code of the Philippines was revised in 1975, land use restrictions based on slope were not intended for disaster prevention purposes, but as a result, the conversion of steep slopes into large-scale farmland was prevented. In the Philippines, approximately 1 million hectares of afforestation have been carried out since the 1900s, but the survival rate is low. This is attributed to insufficient post-planting maintenance and management. In addition, millions of people live in areas legally defined as forest land, so it is necessary to consider the needs of residents when conducting afforestation and land improvement activities.

When utilizing and implementing land improvement techniques, it is necessary to take into consideration the relevant guidelines and plans for slope collapse and landslide countermeasures. Furthermore, since there is no designated agency in charge of land improvement, it is necessary to approach the relevant agencies when considering activities in the field.

Recipe - R06

Initiatives in the Republic of India

For detail, refer to

F-DRR Country Report (2021) India (in Japanese only)

India is located in a monsoon region and experiences a high number of disasters caused by floods and tropical cyclones, but it also experiences various other disasters such as earthquakes, landslides, cold waves, heat waves, and droughts. In response to such natural disasters, India has established a legal and institutional framework for effective disaster management through the Disaster Management Act. The National Disaster Management Authority issues guidelines for central government agencies and state governments to use when formulating their disaster prevention plans, categorized by disaster type and response agency. India's National Disaster Management Plan views the shift from post-disaster response to disaster prevention, mitigation, and preparedness as a paradigm shift, and is actively promoting disaster risk reduction measures.

Situation surrounding the country and forests

The Republic of India is located on the Indian subcontinent in South Asia. The northeastern part of the country is dominated by large mountain ranges such as the Karakoram and Himalayan ranges, while the central part is characterized by alluvial plains traversed by the Ganges and Indus rivers. The western part consists of desert areas composed of rock and sand, and the southern Indian subcontinent is a highland area known as the Deccan Plateau. In terms of climate, India belongs to the tropical monsoon climate zone.

As of 2016-2017, land use in India consists of 62.0% agricultural land (including fallow land and uncultivated land), 23.4% forest, and 14.5% other land. Since the formulation of the National Forest Policy (1988), India has set a national goal of achieving a forest and tree coverage rate of 33.3% (minimum of one-third of the total land area of the country) and has been engaged in afforestation and forest conservation activities. In particular, in hills and mountainous regions, two-thirds of the

Figure R06-1 Prevention of surface soil erosion using stone walls area is to be covered with forests and trees in order to prevent erosion and land degradation and to ensure the fragile eco-system (Figure R06-1) [1]. This target has been carried over into India's current national plan, "Strategy for New India @75 (1988)." [2]

India's forest coverage rate fell to 19.2% in 1997, but thanks to reforestation and other forest regeneration and conservation efforts, the forest coverage rate is now on the rise. As of 2021, the forest coverage rate is 21.7% [3], with planted forests accounting for about 20% of the total forest area [4]. In India, forest conservation became a priority under the National Forest Policy, leading to a gradual decline in timber production.

In the Strategy for New India @75, which sets national goals and strategies through 2022, forest management is listed as one of the main pillars for a "Sustainable Environment." [2] In addition, the draft revision of the National Forest Policy, the highest-level policy on forests submitted in 2018, includes additional references to the importance of utilizing the disaster prevention functions of forests [5].

The "Intended Nationally Determined Contribution (INDC)" submitted to the UNFCCC in 2015 indicates the involvement of the forest sector in both mitigation and adaptation [6]. In terms of adaptation measures, nine priority areas are listed, including disaster management, and forests are related to activities such as "agriculture," "water," "coastal regions & islands," and "protecting biodiversity & the Himalayan ecosystem."

Characteristics of natural disasters in India

There are many disasters caused by floods and tropical cyclones, but various other disasters such as earthquakes, landslides, cold waves, heat waves, and droughts also occur (Figure R06-2) [7]. Hills and mountainous regions, especially the Himalayan region, are at risk of landslides and avalanches. The plains are susceptible to flooding, with 12% of the country's land area prone to flooding and river erosion. Coastal regions are susceptible to cyclones and storms, with approximately 5,700 km of the 7,516 km coastline prone to erosion [8].

The National Policy for Disaster Management (NPDM) (2009) and the National Disaster Management Plan (NDMP) (2019), which outline India's comprehensive approach to disaster management, focus on mainstreaming disaster risk reduction into development plans in various sectors [9, 10]. In the progress report on the Hyogo Framework for Action 2015 prepared by India, the following three points were highlighted as challenges and prospects: (1) the more effective integration of disaster risk considerations into sustainable development policies, planning and programming at all levels, with a special emphasis on disaster prevention, mitigation, preparedness and vulnerability reduction, (2) the development and strengthening of institutions, mechanisms and capacities at all levels, in particular at the community level, that can systematically contribute to building resilience to hazards, and (3) the systematic incorporation of risk reduction approaches into the

INFO

1) Ministry of Environment and Forest (1988) National Forest Policy

INFO

2) National Institution for Transforming India (2018) Strategy for New India@75

INFO

3) Forest survey of India (2022) India State of Forest Report 2021

INFO

4) FAO (2020) Global Forest Resources Assessment 2020: Main report. Rome.

INFO

5) Ministry of Environment, Forest and Climate Change (2018) Draft National Forest Policy, 2018

INFO

6) Government ofIndia (2015) India's intended Nationally determined contribution

INFO

7) GLIDEnumber https://www.glidenumber.net/glide/public/search/search.jsp

INFO

8) Asian Disaster Reduction Center (2018) Country Report India

INFO

9) National Disaster Management Authority (2009) National Policy on Disaster Management 2009

INFO

10) National Disaster Management Authority (2019) National Disaster Management Plan

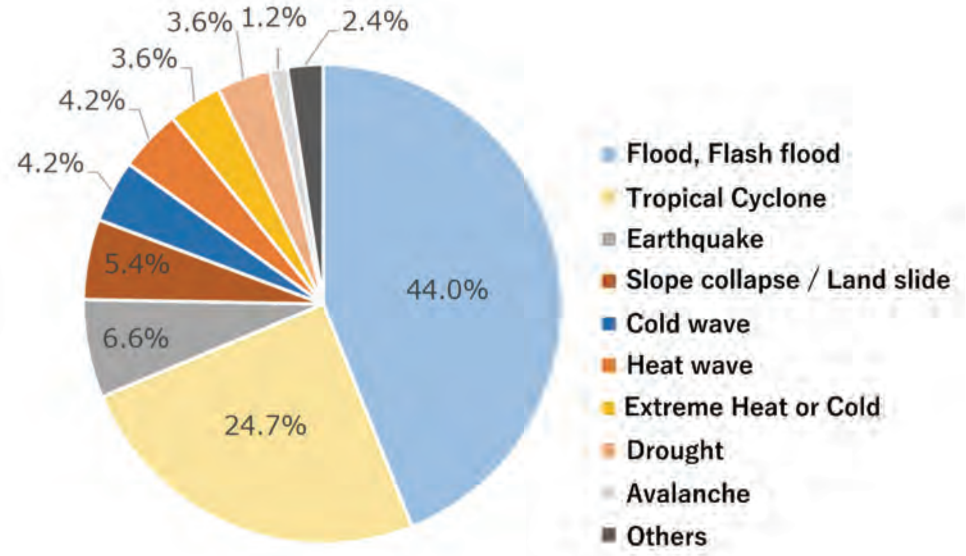

Figure R06-2 Percentage of disasters occurring in India (1991-2020) Created from 7)

INFO

11) Ministry of Home Affairs (2015)National progress report on the implementation of the Hyogo Framework for Action (2013-2015)

INFO

12) Government of India (2005) Disaster Management Act

design and implementation of emergency preparedness, response and recovery programmes in the reconstruction of affected communities [11].

Furthermore, the NDMP views the shift from post-disaster response to disaster prevention, mitigation, and preparedness as a paradigm shift and is proactive in promoting disaster risk reduction measures.

The National Disaster Management Committee has established guidelines for disaster prevention, mitigation, and recovery for each type of disaster, providing unified guidelines for the entire country. The National Disaster Management Act, enacted in 2005, established a legal and institutional framework for the effective management of disasters and related matters [12]. Based on this National Disaster Management Act, the NPDM was formulated in 2009, the NDMP was formulated in 2016 and was revised in 2019. Policies and plans are also being formulated at the state government level [8], [10].

State functions on forest-based disaster risk reduction

The National Disaster Management Act (2005), established disaster management systems and institutions at the national, state, and district levels. The central government has established the National Disaster Management Authority (NDMA), chaired by the prime minister; state governments have established the State Disaster Management Authority (SDMA), chaired by the state chief minister; and districts have established the District Disaster Management Authority (DDMA), chaired by the district head [8]. Notably, this law places a strong emphasis on disaster risk reduction, marking a shift away from India's previous disaster management policy, which had focused primarily on emergency response.

Since the formulation of the National Forest Policy in 1988, India has been working to regenerate and protect its forests. In particular, with regard to hills and mountainous regions, the policy stipulates that two-thirds of the land should be covered with forests and trees in order to prevent soil erosion and land degradation and to ensure the stability of fragile ecosystems. For this reason, forest protection policies in general are positioned as part of disaster risk reductionmeasures. The "Green India Mission," which began in 2014, is a program that is aimed to address climate change through focusing on forest-based ecosystem restoration. This program includes activities that contribute to disaster risk reductionthrough the use of forests for purposes such as watershed conservation and soil conservation.

Key consideration for implementing forest-based disaster risk reduction activities

India strongly asserts that technical and financial support from developed countries is essential for promoting climate change countermeasures, including disaster risk reduction measures. According to the "National Landslide Risk Management Strategy (2019)," [13] approximately 42 million hectares, or 12.6% of the land area, in northern and western India is prone to landslides. Over 65,000 villages are located in such regions.

The NDMP (2019) and the National Landslide Risk Management Strategy do not include forest-related agencies as the responsible agencies for structural measures against landslides. However, in the "Project for Natural Disaster Management in Forest Areas in Uttarakhand" implemented by Japan, the Uttarakhand Forest Department was designated as the counterpart agency, and capacity-building activities related to erosion control technology were conducted.

While forests, which are sites where slope failures and landslides occur, are under the jurisdiction of the Department of Forest, roads where sediment accumulates are managed by the Public Works Department, and rivers are managed by the National River Conservation Directorate, with multiple agencies involved. Since the implementation structure for slope stabilization measures varies by state, when considering the implementation of *Chisan* in India, it is necessary to contact the state's disaster management department to confirm the appropriate implementing agency.

INFO

13) National Disaster Management Authority (2019) National Landslide Risk Management Strategy

Appendix

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