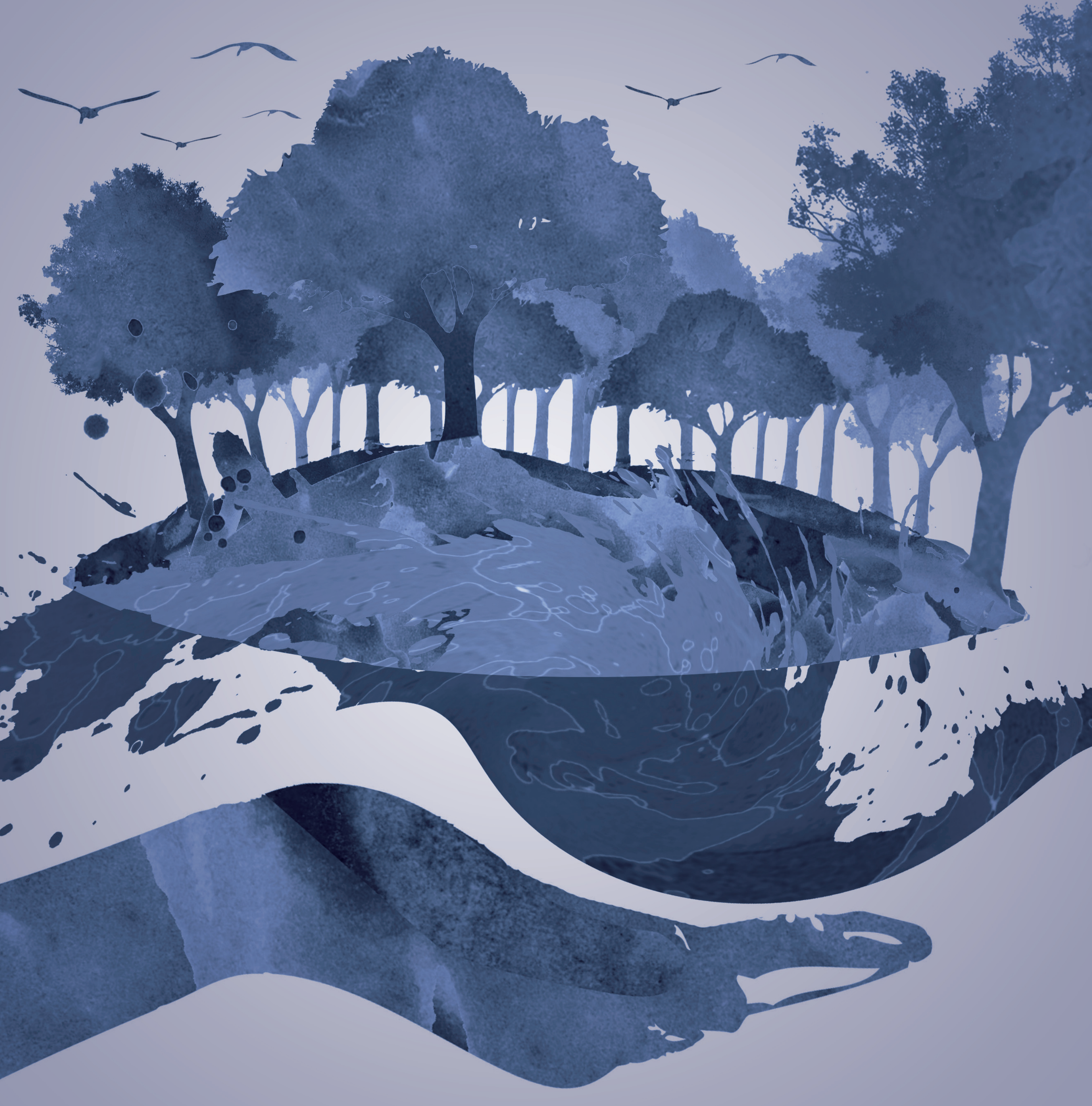

# The Ecosystem-based Disaster Risk Reduction

## Case Study and Exercise Source Book

PEDRR
Ecosystems for Adaptation and Disaster Risk Reduction

CNRD
Center for Natural Resources and Development

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CNRD
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PEDRR
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and Disaster Risk Reduction

# The Ecosystem-based Disaster Risk Reduction

## Case Study and Exercise Source Book

UNEP

exceed
EXCELLENCE CENTERS
FOR EXCHANGE AND DEVELOPMENT

Federal Ministry
for Economic Cooperation
and Development

DAAD Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

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# Introduction

## 1. Background

In 2013, the United Nations Environment Programme (UNEP) and Center for Natural Resources and Development (CNRD) based at the Cologne University of Applied Sciences (CUAS), Germany, jointly developed a master's module "Disasters, Ecosystems and Risk Reduction," which is currently being implemented in a number of universities around the world. The current format of the course is designed for masters students enrolled in a regular university and provides lecturers with the necessary teaching materials and a sophisticated didactic concept. The instructor' s manual (Figure 1) is available online and interested universities have open access to all materials (available online): *http://www.unep.org/disastersandconflicts/Introduction/DisasterRiskReduction/Eco-DRRMasterModule/tabid/106372/Default.aspx)*


**Figure 1. Instructor's manual: Disasters, Environment and Risk Reduction**

The course was designed to be modular and comprises 50 hours of materials for in-class teaching including PowerPoint slides with explanations for lecturers, plus further readings, case studies from different countries, and learning games. Fields surveys and assignments are the responsibility of the participating universities (see fig. 2). The course is structured in four main blocks:

1. Elements of Disaster Risk Reduction
2. Ecosystem-based Disaster Risk Reduction
3. Eco-DRR instruments and approaches
4. Mainstreaming Environment and DRR

A detailed description of the course content is included in the instructor's manual.

As a supplement to the course materials, the present case study document presents seven case studies with exercises for self-study compiled by researchers and practitioners. These case studies from different countries cover a range of topics in the Ecosystem-based Disaster Risk Reduction (Eco-DRR) context.

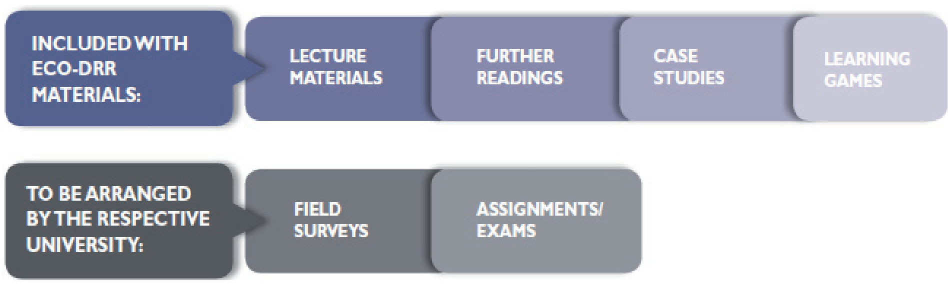


**Figure 2. Course materials**

## 2. Introduction to Ecosystem-based DRR

As recent policy documents have highlighted, environmental degradation is a leading cause of increased disaster risk (IPCC, 2012; UNISDR, 2011). The World Risk Report (2012) points out that "Environmental degradation is a significant factor that reduces the adaptive capacity of societies to deal with disaster risk in many countries," which means, in other words, that "not all storms and other natural hazards need to turn into disasters."

Environment and disasters interact with each other in a number of ways. Disasters cause massive damage to the environment, while degraded environments exacerbate disaster impacts. Responding to disasters often leads to additional environmental impacts, while investments in sound environmental management, especially in disaster prevention and post-disaster recovery stages, can reduce disaster risks and thus contribute to a more resilient and sustainable development. Climate change will likely exacerbate disaster impacts, while environmental management solutions are increasingly being applied for adaptation to climate change (Figure 3).

The close inter-linkages between sound environmental management, climate change impacts and disaster responses require a more systematic and comprehensive approach to disaster risk management, which in the past has mainly been reactive rather than preventive, engineering focused rather than based on planning and use of natural landscape features to prevent disaster risks. This is what we refer to as the "Eco-DRR" approach, wherein disaster risk management incorporates ecosystem management tools, which constitute the core of this module and introduces a more innovative and systems approach to sustainable disaster risk management.

Eco-DRR is the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable and resilient development (Estrella & Saalismaa, 2013). Well-managed ecosystems, such as wetlands, forests and coastal systems, act as **natural infrastructure, reducing physical exposure** to many hazards and **increasing socio-economic resilience of people** and communities by sustaining local livelihoods and providing essential natural resources such as food, water and building materials (Sudmeier-Rieux & Ash, 2009).

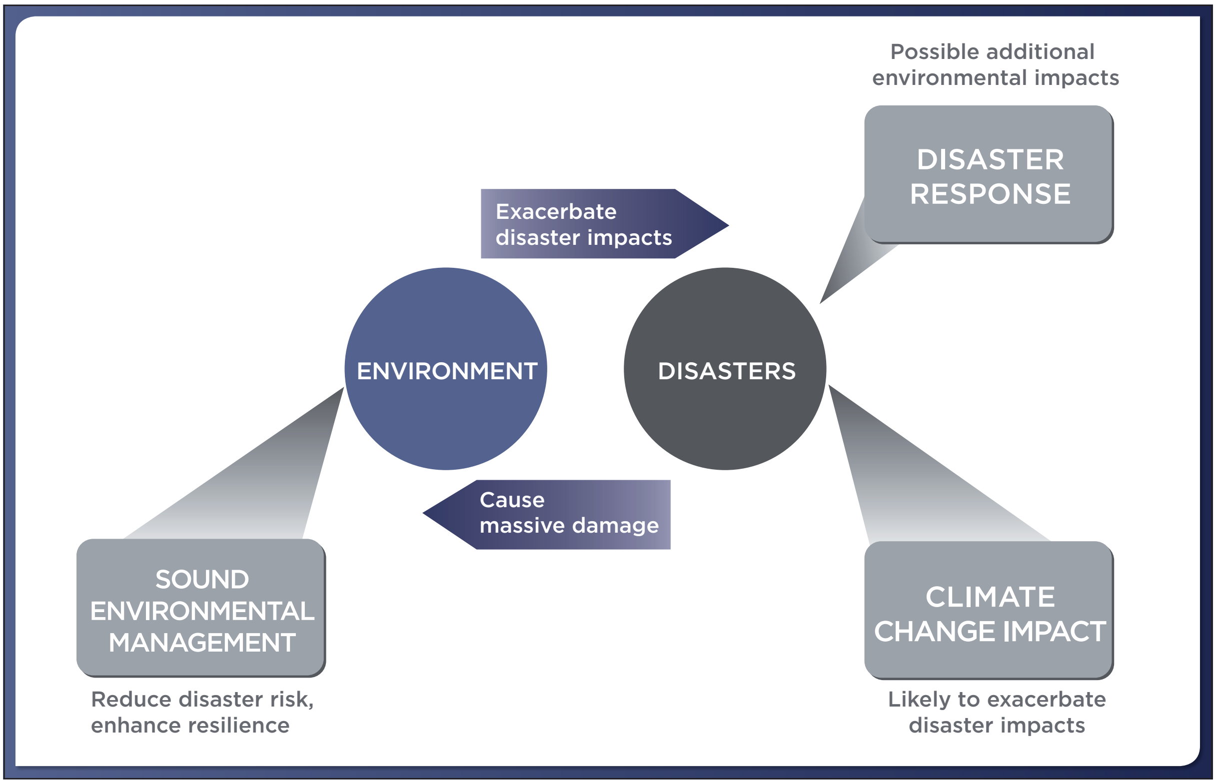


**Figure 3. Inter-linkages between environment and disasters** Source: Sandholz and Nehren, 2013

Ecosystem management not only offers an opportunity to strengthen natural infrastructure and human resilience against hazard impacts, but also generates a range of other social, economic and environmental benefits for multiple stakeholders, which in turn feed back into reduced risk outlines many hazard mitigation functions of ecosystems.

The physical risk reduction capacity of ecosystems depends on their health and structure, and the intensity of the hazard event. Healthy ecosystems reduce social-economic vulnerability by sustaining human livelihoods and providing essential goods such as food, fibre, medicines and construction materials (MEA, 2005). For example, in addition to providing coastal hazard protection, mangroves and seagrass beds support fishing and tourism activities and store high amounts of carbon (Wicaksono et al., 2011). Ecosystems can reduce physical exposure to common natural hazards, namely landslides, flooding, avalanches, storm surges, wildfires and droughts, by serving as natural infrastructure, protective barriers or buffers (Renaud et al., 2013). However, degraded ecosystems can still play a buffering role, although to a much lesser extent than fully functioning ecosystems.

The Millennium Ecosystem Assessment (2005, p. 2) comes to the conclusion that "over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel." On a global average, land conversion with an increasing use of provisioning ecosystem services has led to net gains in well-being and has contributed to economic development, but at the same time regulatory, maintenance and cultural services have been deteriorated in many places. As land and ecosystem degradation are accompanied by increasing costs, risks, and poverty for some population groups, sound land and ecosystem management is essential to sustain livelihoods for present and future generations. Against this background, the Eco-DRR approach comprises much more than just punctually preserving or restoring ecosystems, such as mangroves or dune systems, or implementing ecological infrastructure to reduce disaster risks. Rather, we consider the approach as an essential component of an integrated land management approach with the overall goal to create resilient landscapes.

Within the last years the ecosystem-based approach has received much attention in the disaster risk and climate change communities, but there are still many needs in research, education, and practice. With the Eco-DRR master's course we would like to fill some of these gaps by providing students with theoretical concepts and practical tools in understanding environment and disaster linkages and applications of ecosystem-based disaster risk management. The seven case studies presented in this booklet cover a range of geographical regions, ecosystems, hazard types, and DRR measures. We hope to encourage students to become familiar with the topic and become future members of a global Eco-DRR community.

## 3. Case studies

This case study booklet can be used as either a free standing publication or as supplemental material to the master's course, in addition to the case studies that were originally designed for the course. Student evaluations of this course consistently point to the importance of providing good case study examples first and explainining theory later, providing much better anchoring of theoretical knowledge. Case studies were selected to cover a range of ecozones, hazards and to address a number of different Eco-DRR topics.

1) **Landslide hazard regulation and mitigation: Creating Resilient Landscapes in the Serrana region of Rio de Janeiro State, Brazil:** This case study gives an overview of natural hazards and implemented measures to reduce disaster risk in the Serrana region of Rio de Janeiro State in Brazil, where in 2011 more than 900 people were killed by mudslides, landslides and floods. Special focus is placed on the concepts of resilient landscapes and ecosystem services to reduce disaster risk.

2) **Integrated Coastal Zone Management in Semarang (ICZM), Central Java, Indonesia:** ICZM is a multi-disciplinary approach to managing coastal areas, which are often highly populated and exposed to multiple hazards. In order to present this approach, Semarang in Central Java, Indonesia was chosen as case study area. Semarang is facing several disaster risks, in particular related to coastal flooding, salinization and land subsidence. Different structural, non-structural and ecosystem-based measures have been implemented to reduce the flood risk.

3) **Room for the River - Flood Risk Management, The Netherlands:** This case study features the Room for the River programme, the Dutch government's modern approach to flood management, including the steps and measures taken to achieve increased protection against high water levels and improved spatial quality in the riverine region.

4) **Integrated Water Resources Management – Tacaná Watersheds, Guatemala- Mexico:** This case study features the IUCN Tacaná Project, an integrated water resources management initiative that focused on the watersheds on the border between Guatemala and Mexico. It begins with a background of the project and the problem statement, followed by a presentation of the different pilot projects and a discussion of the outcomes.

5) **Linkages between Disaster Risk Reduction and Climate Change Adaptation – Burkina Faso/ Niger:** This case study on sustainable dryland management showcases innovations on traditional soil and water conservation and agroforestry techniques to increase food production and rehabilitate degraded lands in the Central Plateau of Burkina Faso and the Marandi and Zinder regions of southern Niger.

6) **Coastal ecological engineering and Cost-Benefit Analysis – City of Stamford, Connecticut, USA:** This case study features vegetated sand dunes enhanced with geotextile tubes, a soft engineering flood and storm surge prevention measure, as well as the methods used to identify it as the most suitable and sustainable short-term measure to increase beach resilience against coastal hazards in a town on the north-eastern coast of the United States.

7) **Eco-DRR and Mountain Ecosystems: Protection Forests of Switzerland and other Alpine countries:** This case study features protection forests in Switzerland and other Alpine countries, which are regarded to be a highly effective and efficient measure against natural hazards in the Alps, playing a key role in integrated disaster risk management strategies in the region. Modern management of protection forests is mainly based on harnessing the protection potential of natural ecosystems (structures and processes), aiming to maximize both effectiveness and efficiency.

## 4. How to use the case studies

The Eco-DRR/CCA case study booklet is designed as a guided learning resource and supports a problem-based learning approach. The basic idea is that master's students of the Eco-DRR course can work independently on the provided case studies and exercises, but the booklet can also be used as a free standing publication. Therefore the case studies are self-explanatory and no further documents are needed. However, where necessary the lecturer can support the students with introductory explanations and also prepare for a final in-class discussion of each case study. The case study exercises are recommended to make the students apply the knowledge gained throughout lectures and to get to know ecosystem-based adaptation in different geographical regions and ecozones. We also recommended to include the case studies and respective exercises throughout teaching the Eco-DRR module, preferably after having taught the first block or more to equip the students with some applied knowledge on the topic.

Each case study starts with a short outline on the case and the learning objectives. A list of recommended readings is provided as well. The text itself starts with geographical and socio-economical background information on the study region, followed by a problem statement and a critical review of proposed or already implemented measures. In this context the different types of measures (structural or non-structural; engineering, ecosystem-based, hybrid solutions) and their effectiveness are critically discussed. After a section with lessons learnt and/or conclusions an exercise for each case study is given.

The exercise section includes an answer key to support the students and lecturers. However, students might come up with solutions going beyond the model answers. Case study exercises can be worked on individually, as group work or group discussions. Teaching notes and answers are given at the end of each case study.

The case studies can be considered as supplementary materials for the following sessions:

**1.3 Linking Climate Change Adaptation and DRR:** Linkages between Disaster Risk Reduction and Climate Change Adaptation – Burkina Faso/ Niger

**1.9 From theory to practice. Data and tools for risk assessments:** Landslide hazard regulation and mitigation: Creating Resilient Landscapes in the Serrana region of Rio de Janeiro State, Brazil

**2.5 Ecosystem services for vulnerability reduction:** Eco-DRR and Mountain Ecosystems: Protection Forests of Switzerland and other Alpine countries

**2.6 Ecological engineering for DRR:** Coastal ecological engineering and Cost-Benefit Analysis - City of Stamford, Connecticut – USA **or**

**2.7 Theory. Valuing ecosystem services**

**3.2 Spatial planning tools and approaches for DRR:** Room for the River - Flood Risk Management, The Netherlands

**3.3 Integrated Water Resources Management / River basin management:** Integrated Water Resources Management - Tacaná Watersheds, Guatemala- Mexico

**3.4 Integrated Coastal Zone Management:** Integrated Coastal Zone Management in Semarang, Central Java, Indonesia (this one already has a case study in the end)

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# Case Study 1

## Landslide hazard regulation and mitigation: Creating resilient landscapes in the Serrana region of Rio de Janeiro State, Brazil

### 1. Overview

| | |
|---|---|
| **Outline** | This case study gives an overview of natural hazards and corresponding measures that can reduce disaster risk. It focuses on the Serrana region of Rio de Janeiro State in Brazil, a region where in 2011 more than 900 people were killed by mudslides, landslides and floods. Special focus is placed on the concepts of resilient landscapes and ecosystem services to reduce disaster risk. |
| **Learning objectives** | • Learn how sound ecosystem management can reduce disaster risk and what is needed to improve land management at regional scale;<br>• Identify which ecosystem-based measures are suitable for risk reduction in a mountain region of the (sub)humid tropics;<br>• Understand how satellite images are used to identify risk areas;<br>• Learn to use web-based literature reviews to define risk factors;<br>• Develop and discuss ecosystem-based measures to reduce disaster risk based on the obtained knowledge. |
| **Guidance** | The Rio de Janeiro State case study gives an overview of the geographical and climatic conditions of the Serrana region which is affected by landslides, mudslides and flooding. The case study describes mitigation measures that have been already implemented or that are in the planning phase.<br>The case study is followed by an exercise to enable students to develop skills regarding landslide identification and land-use planning. |
| **Recommended reading** | For general information about landslides, ecosystems and disaster risk reduction, disaster risk management:<br>Fell, R. et al., 2008. Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. Engineering Geology, 102(3-4), pp. 85-98.<br>Papathoma-Koehle, M. & Glade, T., 2013. The role of vegetation cover change in landslide hazard and risk. In F. Renaud, K. Sudmeier-Rieux & M. Estrella, eds. The Role of Ecosystems in Disaster Risk Reduction. United Kingdom: United Nations University Press. pp. 293-320. |

### 2. Background

| | |
|---|---|
| **Case study area** | Serrana region, Rio de Janeiro State |
| **Country** | Brazil |
| **Ecosystems** | Tropical rainforests |
| **Hazards** | Landslides, mudslides and flooding |

With a total surface area of 8.5 million km$^2$, which is 47% of the South American continent, and a population of 194 million (IBGE, 2012), Brazil is the world´s fifth largest country in terms of both area and population. The Federal Republic of Brazil is composed of 26 states and one federal

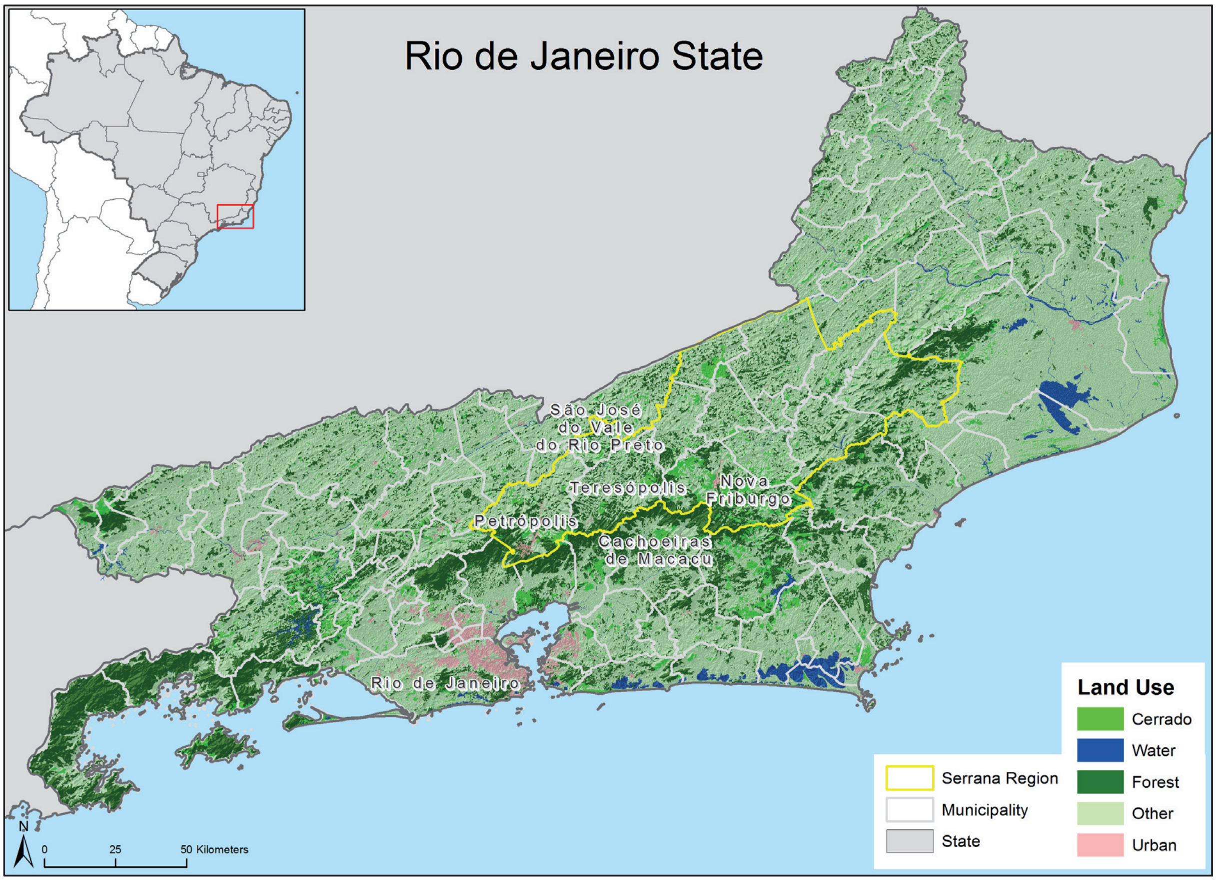



**Figure 1. Location of the Serrana Region in Rio de Janeiro State, Brazil**
Cartography: Wolfram Lange; Source data: INEA (2011)

district (IBGE, 2012). The estimate for the total gross domestic product in 2012 is 2.4 trillion USD (purchasing power parity adjusted), making the country the seventh largest economy worldwide. However, with an income of 11'875 USD per capita (2012) the country ranks number 77 in terms of per capita income (IMF, 2013). Rio de Janeiro, one of the 26 Brazilian states, is located between 20º45'49"S and 44º53'19"W, and covers an area of 43,653 km$^2$, which corresponds to 0.51% of the country's total area. The state comprises 6 mesoregions and 92 municipalities with a population of about 16 million people (2011), resulting in an average population density of 365 inhabitants/km$^2$ (CEPED-UFSC, 2011).

About 150 Brazilian municipalities are affected by landslides, mudflows and floods, among them the municipalities of Teresópolis, Petrópolis and Nova Friburgo in the Serrana region of Rio de Janeiro State that face some of the highest risks from natural hazards (www.cidades.gov.br). The high vulnerability results from natural risk factors, in particular torrential rainfalls, rugged topography, vulnerable geology and soils and, as well as human landscape degradation processes and high exposure of the population (Nehren, 2011; IDRL, 2012).

Rio de Janeiro State is located in the Mata Atlântica (Atlantic Forest) region (Figure 1), a biome extending from Northeast to Southeast Brazil and further inland to Paraguay and Northeast Argentina. Originally covering an area of 1.0-1.5 million km$^2$ (Galindo Leal & Gusmão-Câmara, 2003). The forest cover of the Mata Atlântica has been reduced to 11.4-16% of its original size (Ribeiro et al., 2009); other estimates are even lower with 5-9% (Ranta et al., 1998; Morellato & Haddad, 2000; Oliveira-Filho & Fontes, 2000), due to historical exploitation cycles and related deforestation processes. Since the 1940s deforestation and forest degradation are mainly driven by urban expansion, agricultural activities, and industrial development (Smyth & Royle, 2000). For example, some of the biggest Brazilian cities are located within areas originally covered by Mata Atlântica.

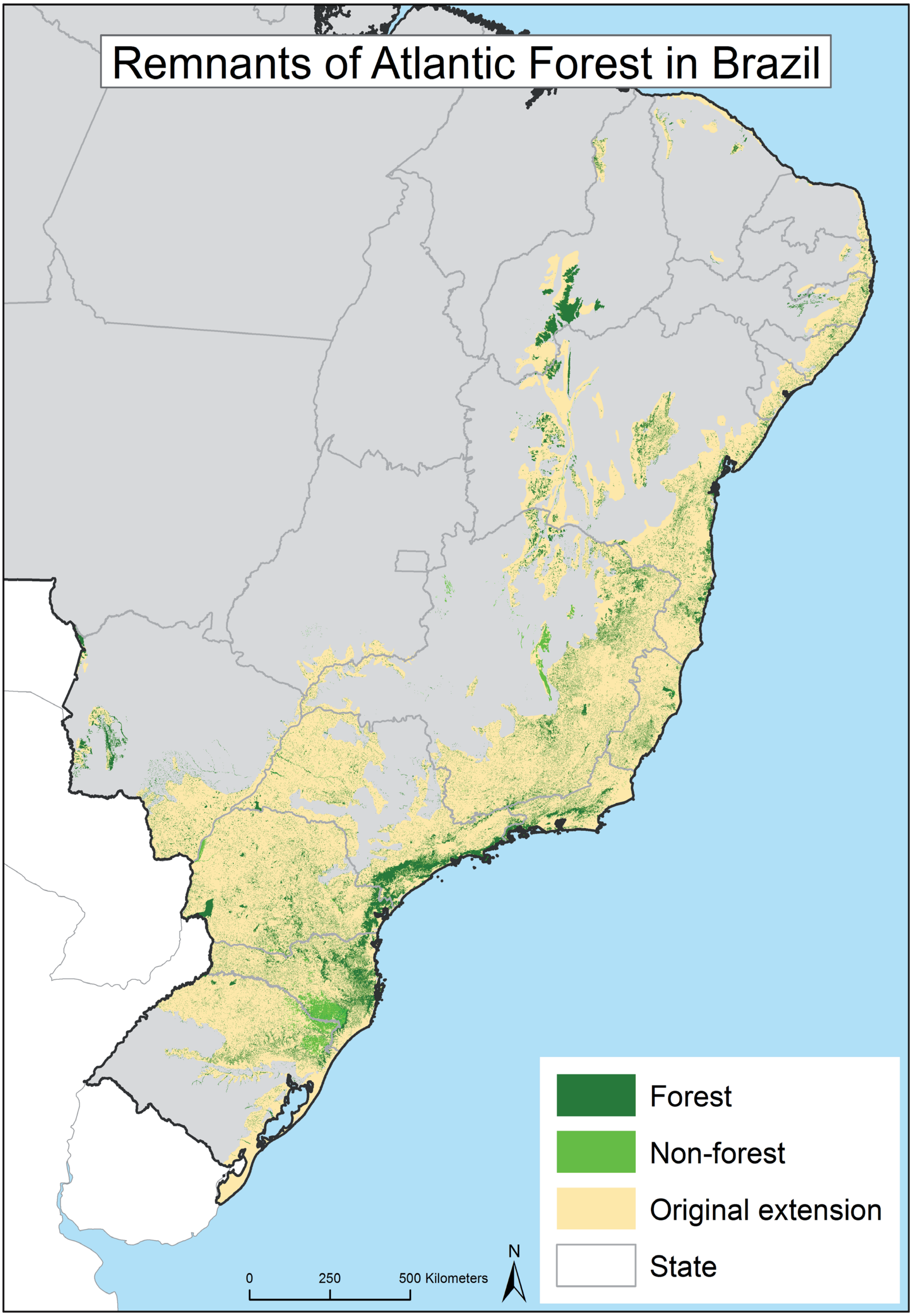



**Figure 2. Map of Forest Remnants of the Mata Atlântica region**
Cartography: Wolfram Lange; Source data: SOS Mata Atlântica (2013) & MMA (2013)

Despite the destruction, fragmentation and degradation of primeval forests, the remaining fragments of the Mata Atlântica are biologically highly diverse and home to many endemic plant and animal species (Galindo Leal & Gusmão-Câmara, 2003). Because of this richness and at the same time high threat due to land use intensification and urban and industrial development, the Mata Atlântica is designated as one of 25 hotspots of biodiversity worldwide with the highest conservation priority (Myers et al., 2000), and is the fifth most threatened biodiversity hotspot (www.conservation.org). Moreover, the remaining forest patches offer a variety of environmental services, including climate regulation, provisioning and regulation of water resources, provisioning of food and medicine, and recreation (SOS Mata Atlântica, 2013).

Even though Rio de Janeiro State is densely populated and urbanized, the forest cover is relatively high compared to other states within the Mata Atlântica region. This is due to the rugged topography of the Serra do Mar mountain range and the coastal ranges, which prevent intense agricultural and urban development (Nehren et al., 2009). This study focuses on the Serrana region of Rio de Janeiro State with the municipalities of Petrópolis, Teresópolis and Nova Friburgo. These municipalities are located in the Serra do Mar mountain range that reaches altitudes of almost 2,300 meters above sea level (m.a.s.l). The region is prone to landslides, mudslides and flooding, due to its steep topography, climatic conditions with frequently occurring heavy rainfall events, and geological and soil conditions with sliding surfaces on granitic basement rock and often silty weathering mantles.

## 3. Problem statement

### Floods, landslides and mudslides in the Serrana region

Floods, landslides and mudslides are the most common disasters in Brazil. Most of the events are sudden and violent, causing fatalities, economic losses and destruction of infrastructure, in both rural and urban areas (INPE, 2007; IFRC, 2012). The most affected areas are margins of watercourses and areas with very steep slopes (SBF, 2011).

One of the worst weather-related disasters in Brazilian history took place in January 2011 in the municipalities of Nova Friburgo, Teresópolis, Petrópolis and São Jose do Vale do Rio Preto in the State of Rio de Janeiro. After a 24 hours rainfall between 11th and 12th January, the Santo Antonio River level increased dramatically and many areas around the state reported land and mudslides. Houses were flooded or collapsed, missing persons were reported and people were trying to evacuate to safer areas. According to government data 916 fatalities were reported. The material damage was above 1.2 billion USD, more than 345 persons were missing, and in the end more than 35,000 people were left homeless.

Most of the areas affected by landslides were riverbanks showing some level of human intervention (e.g. for agricultural or residential purposes). Landslides that occurred in areas covered by natural ecosystems or with well-conserved native vegetation were of lower magnitude when compared with landslides that occurred in disturbed areas. Landslides in terrains covered with native vegetation were always located in the proximity of areas affected by human activities (SBF, 2011).

Main causes of the landslide:

- Irregular occupation of terrains (including occupation in Permanent Protected Areas – PPA's)
- Absence of housing policies
- Lack of a civil defense system (including lack of prevention plans, contingent plans, etc.)
- Lack of risk containment slopes program
- Lack of drainage programs at the macro and micro level (Asamblea Legislativa RJ, 2011)

Figure 3, on the next page, shows two images taken on January 13, 2011 of two areas affected by landslides and flooding in the State of Rio de Janeiro.

Figure 4 shows two images of the same place in different years. Image A shows that the margins of the river are occupied mostly by agricultural

**Figure 3. Areas affected by landslides and river overflow in Rio de Janeiro State**
Source: Schaffer W. B. et al. (2011)

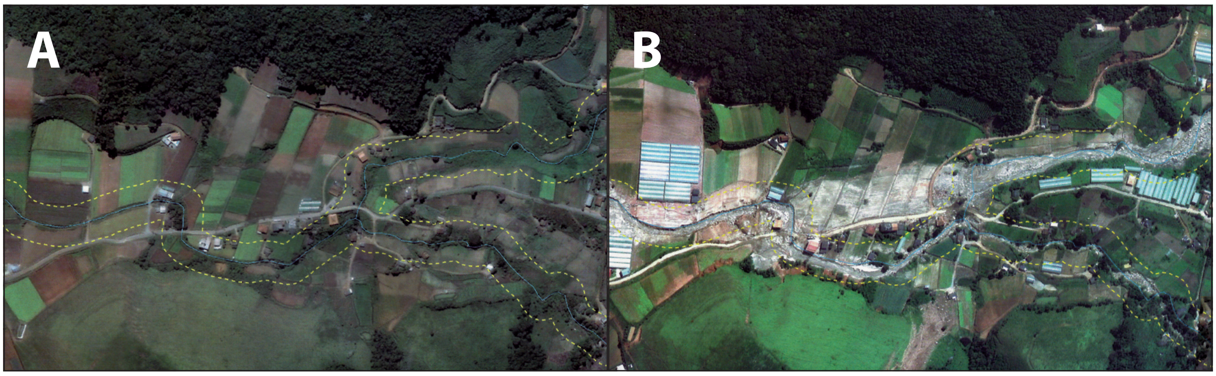



**Figure 4. Rural area in Bonsucesso, Teresópolis, Rio de Janeiro State**
Source: Schaffer W. B. et al. (2011)

activities without respecting permanent protected areas (PPA shown in yellow color) (Image taken on 13.03.2004). Image B shows the areas affected by flooding and erosion after heavy rainfall in January 2011 (Image taken on 20.01.2011).

## Disaster Risk and Disaster Risk Management

Apart from the natural risk factors mentioned before, the economic development of the region has led to a rapid increase of inhabitants in these municipalities despite the lack of adequate territories for housing purposes. Hillside terrains as well as those areas declared as permanent protection areas under Brazilian legislation have been occupied. As a result, exposure has increased in a region classified as having a high predominance of landslide and mudslide risk (CEPED-UFSC, 2011; DRM-RJ, 2012). Additionally, river banks facing high flood risk have also been occupied (Nehren et al., 2009).

In addition, the degradation of ecosystems by human activities has increased the risk of landslides, mudslides and floods during extreme events (Nehren et al., 2013). Intense summer rainfall is the main landslide-triggering factor (Fernandes et al., 2004; Smyth & Royle, 2000). The likelihood of landslides increases with the degradation of natural ecosystems due to uncontrolled land use, fires and land clearance. Efforts for ecosystems recovery cannot cope with the high level of degradation.

IFRC (2012) and INPE (2007) mention other human activities that are aggravating factors, such as the physical vulnerability, which is related to illegal settlements and the highly populated low-income settlement areas, deforestation, inadequate waste management, construction over unstable land-filled areas, among others; which together with torrential rain falls increase the risk of floods and landslides. The occurrence of landslides is also associated with road construction in hilly or unstable areas, due to natural and technical hazards. Landslides along roads are

**Box 1. Definitions**

**Landslide:** The movement of a mass of rock, debris, or earth (soil), down a slope (IUGS, 1997 in Fell et al., 2008).

**Landslide susceptibility:** A quantitative or qualitative assessment of the classification, volume (or area), and spatial distribution of landslides which exist or potentially may occur in an area. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding. Although it is expected that landsliding will occur more frequently in the most susceptible areas, in the susceptibility analysis, time frame is explicitly not taken into account (IUGS, 1997 in Fell et al., 2008).

**Flood:** An overflow of water onto normally dry land; the inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch; ponding of water at or near the point where the rain fell. Flooding is a longer term event than flash flooding; it may last days or weeks (NOAA, 2014).

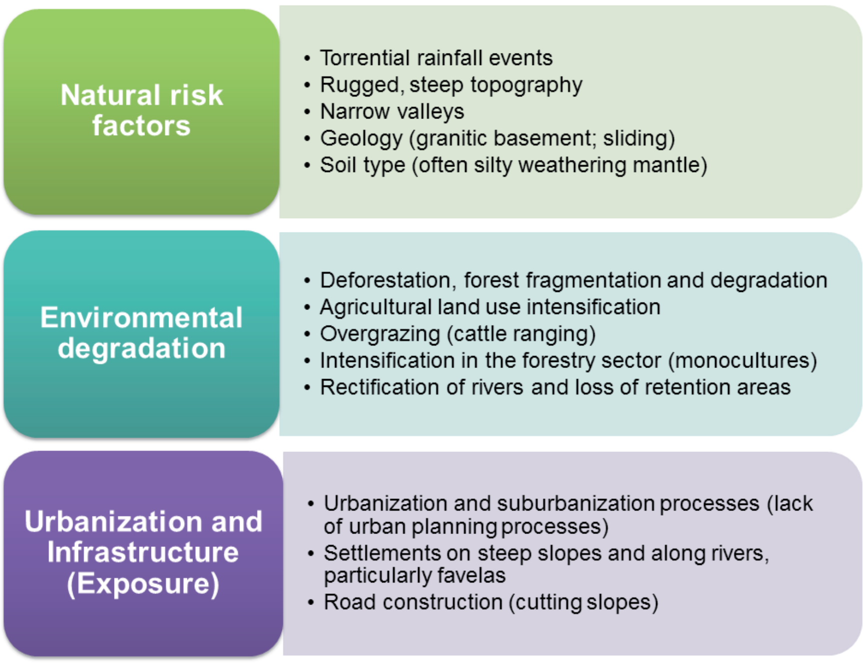



**Figure 5. Risk factors in the Serrana region of Rio de Janeiro State**

mentioned as part of the land degradation types in the region (Nehren et al., 2009) (Smyth & Royle, 2000).

After the 2011 event, serious political action was taken to improve land and ecosystem management to reduce disaster risk. The institutional framework related to risk management is coordinated by the National Secretariat of Civil Defense which is in charge of the coordination, planning and execution of programs, projects and activities related to civil defense and protection (IFRC, 2012). With respect to the legal framework related to protection of natural ecosystems located in hillside terrains in Brazil, the National Forest Code declares them as permanent protected areas (APP) due to their environmental functions and bans the felling of forests in areas with slopes between 25 and 45º (selective logging is allowed only under sustainable management) (SBF, 2011).

Regarding the perception of the population living in risk areas, a recent study shows that there is awareness about vulnerabilities, most drivers of landslides and about the importance of avoiding settlement in high-risk areas. However, people are lacking knowledge about the protection function of ecosystems and there is little involvement of the local population in ecosystem-based measures (Lange et al., 2013).

Figure 5 summarizes the main risk factors in the Serrana region of Rio de Janeiro State.

The implementation of disaster prevention activities could be optimized by improving long-term planning procedures. The Brazilian marginal settlements, better known as ***favelas*** are a reflection of insufficient urban planning structures in the country. The slums, often located in hilly areas, are regularly affected by landslides during the rainy season and were particularly hit in the 2011 event. According to Fernandes et al. (2004), the ***favelas*** themselves affect the stability of slopes through extensive usage of cuts, landfills, deforestation, changes in drainage conditions, accumulation of trash deposits on hillslopes, among others.

In recent years, the Brazilian government has intensified their efforts to restore degraded rural landscapes and make urban settlements less vulnerable with the overall goal to improve the resilience of landscapes and infrastructure. In this regard, ecosystem-based measures in the context of environmental planning and urban planning play a crucial role.

## 4. Measures implemented

Brazilian governmental authorities, such as the Brazilian Ministry for Environment (MMA) and the Government of Rio de Janeiro State are using the concept of resilient landscapes as the basis to reduce vulnerability and disaster risk and adapt to climate change. In order to reduce risks to landslides, mudslides and flooding, different measures were implemented by a number of actors: the government of the Rio de Janeiro State, the municipalities and also by the communities (CEPED-UFSC, 2011). These developments and the implementation of measures started before the 2011 event, but were accelerated after the catastrophe.

In order to restore the areas affected by the landslides and mudslides and to mitigate hazards, the Government of Rio de Janeiro State is mainly investing in structural engineered measures. However, to a certain extent ecosystem-based approaches are considered as well (SEA, 2013). In the following section, a few of these measures are briefly described.

### Structural measures in Rio de Janeiro State

Engineered structures to control flooding and landslides were implemented in many parts of the state. However, most of these measures have a limited effect, are relatively expensive, work only in the short-term, and do not address the main underlying risk factors. In order to address flooding, the Government of Rio de Janeiro State implemented structural measures such as dredging, dams and embankments restoration. To control rivers in periods of heavy rain, big channels and large water reservoirs were constructed (Asamblea Legislativa RJ, 2011). Besides riverways, engineered structures were also developed along roads and in settlements to modify sedimentation flow and control natural runoff patterns (Figure 6).

In particular, a large engineering project was implemented in the municipalities of Nova Friburgo, Teresópolis and Petrópolis, three areas greatly affected by the heavy rains in January 2011. The state invested approximately USD 250 million to advance this project (Asamblea Legislativa RJ, 2011).

Non-structural measures include river parks and reforestation of riparian areas, which have been implemented only partly so far (Asamblea Legislativa RJ, 2011). Dredging of rivers is also mentioned as a measure, but as the process is not well managed, sediments taken from riverbeds return to them during the rainy season (Ella, 2013).

The construction of natural channels for water infiltration is mentioned as an effective measure that was implemented. The channels help control flooding and drought, because they allow more water storage in the soil (Ella, 2013). Activities of reforestation and regeneration of riparian forests, such as those included in the Mutirão Reflorestamento Project, were also mentioned as being effective for flood control. However, government reports reference several barriers in implementing measures, some of which are related to institutional coordination, bureaucracy and even corruption (SEA, 2013).


**1. Hydraulic-engineering structures**

**Detension basins**: Flood damping is an effective measure to redistribute discharges over time. Increased volumes of runoff, which are resultant from urbanization, are not diminished, in fact, but flood peaks are reduced.

**Retention ponds:** A permanent pool with two main objectives, the first, and most important is water quality control; the second is water quantity control, although in a minor scale, when compared to the detention ponds.

**Polders and dikes:** The conception of a polder allows to protect a riverine area from the main river flooding, by constructing a dike along the channel. Inside the polder, temporary storage basins and an auxiliary channel to convey local waters to the reservoir are installed.

**2. Canalization and bank stabilization**

Canalization is the most traditional measure in drainage works. It is obtained by removing obstructions from the riverbed, straightening the river course and fixing the river banks, resulting in an increased conveyance.

**3. Slope stabilization**

Protective walls made of concrete or bricks have been built along roads and in settlements. Geotextile is often used to stabilize fresh landslides before planting protective vegetation.

**4. Terracing and drainage of embankments**

Terracing and drainage of embankments is a measure to protect roads from rockfall and reduce landslide and erosion risk. Compared to simple protective walls these measures require higher technical efforts and are therefore more expensive.

**5. Drain pipes in settlements and along roads**

Drain pipes made of plastic, concrete, or ceramics are often used in hillside settlements and along roads to reduce landslides risk.

**Figure 6. Example of technical measures implemented in the state of Rio de Janeiro State**[1]

## Non-structural measures

The Government of Rio de Janeiro State is also working on the improvement of disaster prevention systems through hydrological monitoring (better information and enlargement of a monitoring network), and preparation of contingency plans (Asamblea Legislativa RJ, 2011). A hillside monitoring system has been improved through the installation of meteorological radar and 117 pluviometers, as well as through the establishment of a high-tech operations center (Ella, 2013). CEPED-UFSC (2011) cites other non-structural measures related to risk management implemented by different organizations in the Serrana region:

**Table 1. Non-structural disaster risk reduction measures implemented by Rio de Janeiro State**

| Activity | Implementing institution and/or organization |
|---|---|
| Communication and awareness about risks | COMDEC, Secretaria de Educação[2] |
| Inventory of inhabitants living in risk areas | COMDEC, Federação de Associação de Moradores[3] |
| Community based training on risk perception | COMDEC |
| Prevention of disasters | COMDEC, Corpo de Bombeiros,[4] Associação de Moradores |

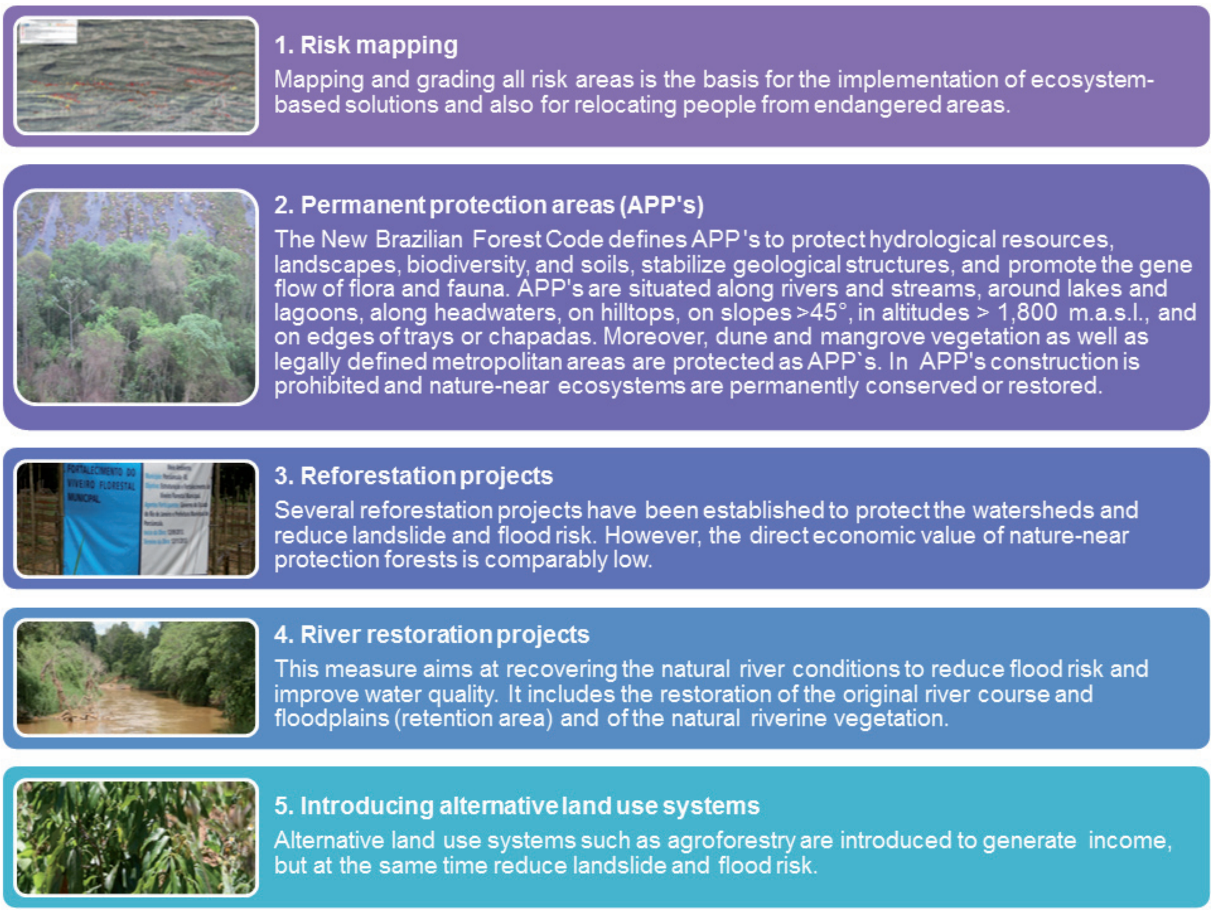



**Figure 7 Examples of ecosystem-based measures[5]**

**Box 2. Mutirão Reflorestamento Project**

One example of Eco-DRR measures implemented in Rio de Janeiro State is the *"Mutirão Reflorestamento"* project, founded in 1987 and since then executed by Rio de Janeiro's municipality. The reforestation actions are implemented in areas located close to *favelas*. Local inhabitants are hired and trained for planting and monitoring activities. The objectives of the project are to restore degraded natural environments through the improvement of the forest cover and to offer job to low-income inhabitants. The reforestation aims at mitigating landslide risks, reducing river and channeling sedimentation, minimizing the intensity of floods, and finally reducing the occupation of risk and protected areas for residential uses (Rio de Janeiro Prefeitura, 2007).

The project has been implemented in 107 communities, representing 1,600 ha which have been reforested with approximately 4 million trees from 150 different species. Some characteristics of the project include: coordination between municipalities and communities, ongoing maintenance, cost-efficient measures, as well as an environmental education component (Rio de Janeiro Prefeitura, 2007).

The *Mutirão Reflorestamento* Project has received awards as an innovative project. At the national level, it was awarded by the Ministry of Environment and at the international level it was selected as part of the UN project: Mega-Cities and as part of the data base of best practices and local leadership of the United Nations Human Settlements Programme (UNCHS), among others. The project is now part of the permanent activities executed by the Environmental Secretary of the Rio de Janeiro's Municipality.

The key challenges for project implementation have been fires and adverse climatic conditions, animal husbandry on slopes, community demobilization and undersized staff (Rio de Janeiro Prefeitura, 2007).

For more information visit:
*http://www0.rio.rj.gov.br/pcrj/destaques/especial/mutirao_reflorestamento2.htm*

## 5. Implications for Ecosystem-based DRR

Due to the limitations of technical solutions, ecosystem-based measures and hybrid solutions have been developed and partly implemented in Rio de Janeiro State (Figure 7). These solutions consider landscapes and ecosystem systems as a whole and aim at long-term effects to achieve resilience and support sustainable development. There is a wide range of actions from ecological urban planning to reforestation and river restoration in rural areas. Usually these measures need more time to show positive effects and often require continuous maintenance. However, due to this systematic approach to addressing disaster risks and participation of local authorities and communities in the planning and implementation process, the long-term results are often proven to be more effective than pure technical solutions. Moreover, costs are usually lower and there are co-benefits, such as climate, biodiversity, watershed, and soil protection. The examples provided in figure 7 are from the wider Rio de Janeiro State, not just from the Serrana region.

Besides the *Mutirão Reflorestamento* Project, there are also other initiatives that have been promoted recently, including those aimed at supporting the preparation of the Olympic Games to be held in 2016 in Rio de Janeiro. For example, between 2010 and 2012 around 2 million plantations were established in areas considered highly degraded and over 150 communities were involved in the process. The goal is to reforest 600 ha until 2016 (Cidade Olimpica, 2012).

After the catastrophic event in January 2011, ecosystem-based measures have been implemented to stabilize slopes and thereby reduce the future landslide risk. Box 3, on the next page, shows an example in the valley of Barracão dos Mendes in the municipality of Nova Friburgo.

### Payment for Ecosystem Services for improved ecosystem management

Payment for Ecosystem Services (PES) is a tool for paying land owners, such as farmers, for protecting critical ecosystems which provide

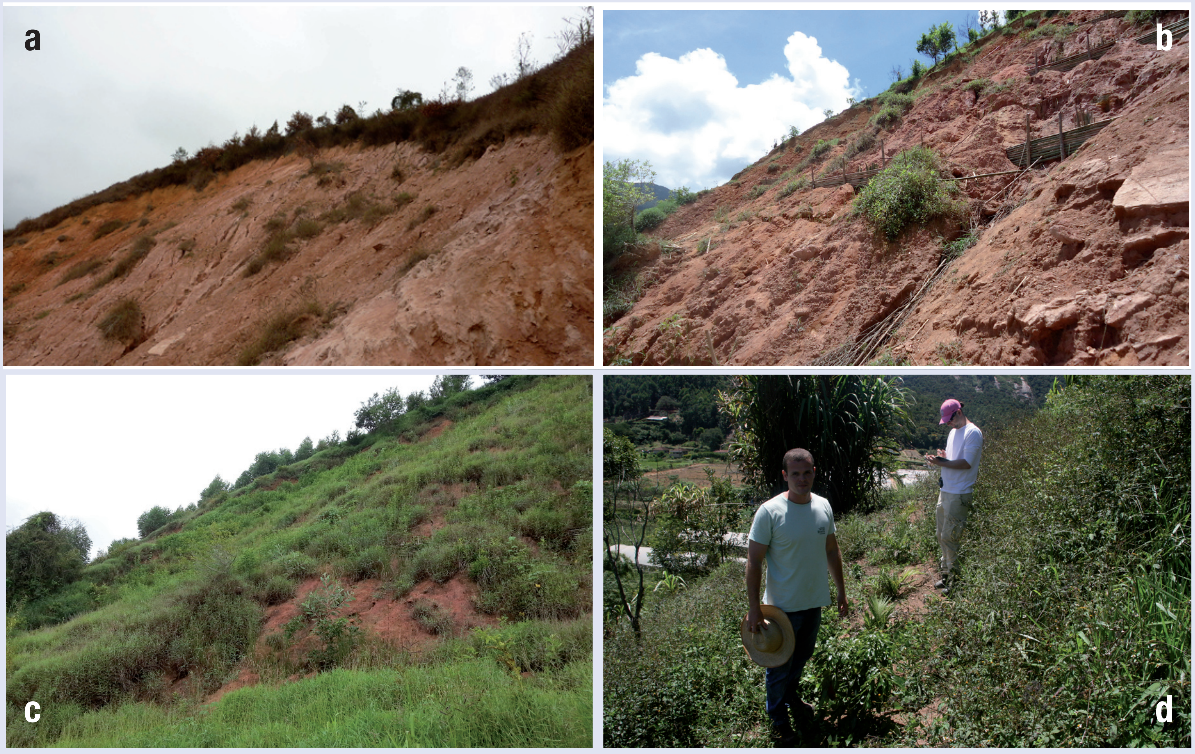
**Box 3. Ecological restoration of a slope that collapsed during the catastrophic event in 2011**

In January 2011, numerous landslides occurred in the valley of Barracão dos Mendes, a rural area close to the town of Nova Friburgo. Several of these landslides caused severe damage to infrastructure, such as roads and buildings. After the removal of the debris, many slopes along roads were stabilized using terraces, geotextile and protecting vegetation. However, due to the high costs of these measures exclusively ecosystem-based low-cost solutions were used in particular along minor roads and access roads.

Photo a shows the collapsed slope that damaged a road and agricultural infrastructure six months after the catastrophic event in January 2011. After removing the debris, the slope was stabilized by creating small sediment barriers made of Eucalyptus stakes and horizontal Bamboo sticks as well as using geotextile (photo b taken 23/01/2012). Afterwards vetiver grass (*Vetiveria zizanioides*) and different leguminous species (*Canavalia ensiformi, Crotalária juncea, Mucuna aterrina, Cajanus cajan*) were planted to improve the soil conditions and quickly create dense vegetation cover. Single trees were later planted, including the neotropical species *Bauhinia forticata, Cordia superba, Centrolobium tomentosum, Gallesia integrifolia, Inga laurina, Inga marginata, Lithraea molleoides, Lonchocarpus guillemineanus, Machaerium stipitatum, Piptadenia gonoacantha, Senna multijuga and Solanum pseudocapsicum,* as well as the alien species *Acacia holosericea* and *Cassia grandis*.

Photo c was taken in February 2013, two years after the landslide and shows the mid- and lower slopes with leguminous and single tree species. On the upper slope, agroforestry systems were introduced parallel to the inclination to stabilize the slope, improve the soil conditions and reduce surface runoff and infiltration. The agroforestry systems consist of corn, beans, palm trees (*Roystonea oleracea*), lychees and others, which have the advantage of creating additional farm income. Photo d shows the upper slope with an agroforestry system taken in March 2014. The total costs of this measure were estimated at 6,000 BRL (approx. 2,500 USD). Some challenges include the lack of inoculation of legumes (i.e. the process whereby rhhizobacteria enable legumes to fix nitrogen in the soil), lack of adequate tree saplings of high quality for afforestation, high rate of sapling mortality and lack of labour.

*The restoration project was implemented by Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro (Pesagro-Rio) and the data of this measure were kindly provided by Mr. Aluísio Granato de Andrade (Agricultural Engineer, D. Sc., Researcher at Embrapa-Solos) and Mr. Tiago A. Chaves (Agricultural Engineer, Consultant of the Rio Rural/Pesagro-Rio programme). Photos credits: Tiago de Andrade (a-c), Udo Nehren (d).*



valuable goods and services. These economic incentives have been proposed as cost-effective mechanisms to protect ecosystem services (Porras et al., 2008; Engel et al., 2008). In the Mata Atlântica region, more than 100 PES projects have already been implemented; two of them in Rio de Janeiro State (Becker & Seehusen, 2012). The PES schemes in the Mata Atlântica region address four principal ecosystem services that are internationally commercialized: (a) biodiversity, (b) carbon storage and sequestration, (c) water services, and (d) landscape scenery (Becker & Seehusen, 2012). Even though disaster risk reduction is not included in the PES schemes, a proper management of forests aiming at one of the four services mentioned above often also contributes to disaster risk reduction. Box 2 gives a brief overview of a PES project that has been implemented in the municipality of Rio de Janeiro.

In the Serrana region no PES project has been implemented so far. However, a project in the Três Picos State Park in the municipality of Cachoeiras de Macacu is currently in the development phase (Becker & Seehusen, 2012). This State Park is located in the mountain region of the upper Guapi-Macacu watershed that supplies drinking water for almost 2.5 million inhabitants of five municipalities downstream (Pedreira et al., 2009). Various studies have shown the positive effects of sound forest management on watershed services, including the reduction of flood risk (Mark & Dickinson, 2008). According to Rodríguez Osuna et al. (2014), improved forest management and reforestation of degraded pasture lands in this Guapi-Macacu watershed will have positive effects on water quality and most likely also contribute to flood and landslide risk reduction.

## 6. Lessons learned and conclusions

Through this case study, the importance of ecosystem management for disaster risk reduction is emphasized. In the State of Rio de Janeiro ecosystem-based measures such as the designation of PPAs[6] or the establishment of riverine vegetation under the National Forest Code are critical for optimizing ecosystem services and creating resilient landscapes. After the catastrophe of January 2011 in Rio de Janeiro State, it was observed that, where the permanent protected areas were respected, the impacts of landslides, mudslides and floods were of less intensity (SBF, 2011). Compliance with legislation that provides protection to PPAs should therefore be strengthened, while at the same time law enforcement is needed.

Considering landslides, mudslides and floods as the major natural hazards in the mountain region, both structural and non-structural measures are required for reducing disaster risk in Rio de Janeiro State, including ecosystem-based and hybrid solutions. As population and economic growth in the state are accompanied by urban sprawl, land use intensification and ecosystem degradation, integrated solutions under the guiding principle of resilient landscapes are required. Those include improved regional and urban planning to reduce exposure and vulnerability of the population, sound environmental management practices in the agricultural and forestry sectors, and an ecosystem management that considers landscapes as a whole and not only linear or punctual structures as elements for risk reduction or biodiversity protection.

The national and state governments, various institutions and communities are already cooperating to some extent in order to mitigate the effects of landslides, mudslides and flooding in Brazil, but an improved coordination is essential for more effective disaster prevention and preparedness. The establishment of partnerships among stakeholders would enhance risk management processes at the different levels. Processes of environmental awareness and education at the local level are needed as well.

As Rio de Janeiro State is located in a disaster prone area and climate-related extreme events cannot be avoided, management practices and measures must focus on reducing the vulnerability and exposure of the population. In other words, this means risk reduction in the long term through landscape and ecosystem stabilization or relocation of people in hazardous areas where such stabilization is not possible. This is an important issue in Brazil as disaster prevention and preparation is mainly focused on short-term reactions to disasters rather than long-term prevention including a strategy with regards to climate change.

In order to change the behavior at the local level with respect to risk perception and mitigation, processes of environmental awareness and education, reinforcement of laws and recovery of forest covers as part of the long-term planning process are needed. Also, monitoring, review and feedback during and after the implementation of mitigation and prevention measures are required to guarantee their sustainability. To change rural and urban land management towards more environmental sound practices, Payment for Ecosystem Services (PES) schemes are considered as an appropriate instrument.

## 7. Exercise and teaching notes[7]

Instructor's notes: through this exercise, students will identify areas susceptible to landslides using an image of an area in Rio de Janeiro State, illustrating conditions prior to the landslides (Image A) and (B) the aftermath of the heavy rainfall of January 2011. Image (B) presents the description of landslides and is intended to be used by instructors/teachers in order to give solutions to the exercise. The exercise can be solved individually or in groups of 2 or 3 persons. The estimated length of the exercise is between 30 to 40 minutes. After finishing the exercise, a small debate or discussion is proposed.

The students should imagine they are land-use planners and landslide risk managers:

1. Image **(A)** presents the previous conditions to the heavy rainfall of January 2011 in an area of Rio de Janeiro State. Using the yellow and green points, please **identify** areas which could be susceptible to landslides and mudslides and argue why this is the case. Do you think that those areas have already been affected by landslides?
   - For the identification the answer is given in Image (B)
   - The image shows some areas that could have been already affected by landslides, for example point 4 in Image (B)

2. After identifying vulnerable areas, please **describe** the reasons why you think each area could be affected by landslides and mudslides considering natural risk factors and land use conditions. Please conduct a web-based literature review to strengthen your assumption.

**Box 4 Teacher notes for Image (B)**

**Point 1** – represents a landslide which occurred in an area with well-preserved native vegetation. No human activity had been observed in this area.

**Point 2** – represents a landslide which occurred in an area with well-preserved native vegetation, but in this case, there is a road and deforestation of the hill base near to the starting point of the landslide.

**Point 3** – represents a landslide which occurred in an area with well-preserved native vegetation, but in this case, there are two types of interventions: one at the beginning of the landslide where the hilltop presents degraded vegetation and the second where the original base of the hill is cut by a road.

**Point 4** – represents a landslide in an area without its original vegetation on the slope as well as at the top. There is also a hillside road and earthworks for buildings.

**Point 5** – represents a landslide which occurred on slopes with conserved native vegetation, but without vegetation at the top and on slope sides.

**Point 6** – represents a landslide which occurred on slopes with grassland and a road at the top of the hill.

**Point 7** – represents a landslide which occurred in a hillside area with degraded vegetation, with settlements, agricultural activity at the base of the hill and a highway next to the top of the hill.

- Description of areas susceptible to landslides (points in the Images) are given in Box 3

3. Now that you have identified areas which present an elevated landslide and mudslide risk, which measures would you propose to be implemented in order to avoid possible landslide damage? Please consider land-use and topography of the area.
   - Examples: Risk mapping, permanent protection areas (PPAs), reforestation, alternative land use systems

*After conducting the exercise, please* ***discuss*** *in class about the difference of the magnitude of the landslides considering the land uses.*

**(A) Image showing previous conditions to the heavy rainfall of January 2011 in Rio de Janeiro State (Image taken 26.05.2010);** Source: Schaffer W. B. et al. (2011)


**(B) Image showing the aftermath of heavy rainfall of January 2011 in Rio de Janeiro State (Image taken 20.01.2011);** Source: Schaffer W. B. et al. (2011)

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## Endnotes

1 Picture sources (1) S. Alfonso, (2-5): U. Nehren

2 Secretary of Education

3 Federation of Residents Associations

4 Residents Associations

5 Picture sources: (1) Risk map of Teresópolis (2011), source: Serviço Geológico do Estado do Rio de Janeiro, Departamento de Recursos Minerais; Photos (2) - (5) U. Nehren

6 Permanent Protected Areas (PPAs) were established by Federal Law No. 12651, which establishes the general normative for the protection of riparian vegetation, among others.

7 Information based on: SBF, 2011. *Áreas de Preservaçao Permanente e Unidades de Conservaçao x Áreas de Risco. O que uma coisa tem a ver com a outra?*, Brasilia: Ministério do Meio Ambiente.

# Case Study 2

## Integrated Coastal Zone Management (ICZM) in Semarang, Central Java, Indonesia

### 1. Overview

| | |
|---|---|
| **Outline** | ICZM is a multi-disciplinary approach to managing coastal areas, which are often highly populated and exposed to multiple hazards. In order to present this approach, Semarang in Central Java, Indonesia was chosen as a case study area. Semarang is facing several disaster risks, in particular related to coastal flooding, salinization and land subsidence. Different structural, non-structural and ecosystem-based measures have been implemented to reduce flood risk. |
| **Learning objectives** | • To explore coastal hazards and mitigation solutions;<br>• To classify different types of measures for disaster risk reduction;<br>• To evaluate advantages and disadvantages of the different types of measures;<br>• To present a multi-disciplinary approach for managing natural and human-induced hazards along coastal areas;<br>• To understand the need for stakeholder participation and define stakeholder groups that are important for DRM. |
| **Guidance** | The Semarang case study illustrates coastal flooding and land subsidence and proposed measures implemented.<br>After presenting the case study, an exercise is proposed to strengthen the abilities of students to consider ICZM solutions and trade-offs. |
| **Recommended reading** | For general information about floods and river management, coastal system components and human impact on coastal environment:<br>Christopherson, R., 2008. Geosystems: An introduction to Physical Geography. 7th ed. New Jersey: Pearson Prentice Hall.<br>Marsh, W. & Kaufman, M., 2013. Physical Geography: Great systems and global environments. New York: Cambridge University Press.<br>Marfai, M. & King, L., 2008. Potential vulnerability implications of coastal inundation due to sea level rise for the coastal zone of Semarang city, Indonesia. *Environmental Geology*, 6(54), pp. 1235-1245.<br>IPCC., 2012. Special Report « Managing the Risks of Extreme Events and Disasters to advance Climate Change Adaptation ». Cambridge University Press, 582p.<br>For information and exercises related to risk and vulnerability assessment, see:<br>Renaud, F., Sudmeier-Rieux, K. & Estrella, M., 2013. The Role of Ecosystems in Disaster Risk Reduction, United Nations University Press, 486 p.<br>Multi-hazard risk assessment (*http://www.ecapra.org/sites/default/files/documents/Book%20Multi%20Hazard%20Risk%20Assessment_0.pdf*)<br>Risk City Exercise book 2011 (*http://www.ecapra.org/sites/default/files/documents/Multi-hazard%20exercise%20book_0.pdf*) |

## 2. Background

| | |
|---|---|
| **Case study area** | Semarang, Central Java Province |
| **Country** | Indonesia |
| **Ecosystems** | Coastal ecosystems, including estuary, wetland and mangrove |
| **Hazards** | Flooding, sea-level rise, land subsidence, water scarcity, and salinization |

The Republic of Indonesia is located in South East Asia, between the Indian and Pacific oceans. The country has the world's largest archipelago, with more than 17,500 islands with a total coastline of about 80,000 km. The territory covers an area of approximately 1,900,000 km$^2$ with a population of 250 million, which makes it the world's fourth most populous country. About 51% of the population is located in urban areas (UNDP, 2013; CIA, 2013), a large share of them in the coastal lowlands, especially in Low Elevation Coastal Zones (Indonesia is ranked No. 4 worldwide in urban population in the LECZ, see figure 2).

It has been estimated that 52% of the country's land surface is covered by forests (UN, 2013). In larger islands, the topography changes from coastal lowlands to interior mountain regions. The climate varies from humid tropical to moderate in highland regions. Due to its geographical and climatic conditions, the country faces a high variety of natural hazards, such as floods, storm surges, droughts, tsunamis, earthquakes, volcanic eruptions and forest fires (CIA, 2013; UN, 2013).

About 140 million people - more than half of the country's population - live on the island of Java, which only represents 6.65% of the total land area of Indonesia. This makes the island one of the most densely populated places worldwide. The city of Semarang is located in the north of Central Java province at 6º58'S and 110º25'E (see Figure 1). Semarang is one of the most important harbors in Central Java, and with an area of 374 km$^2$ the city is the fourth largest in the country (Harwitasari & van Ast, 2011). Semarang has 1.57 million inhabitants and is currently growing 1,38% each year (World Urbanization Prospects, 2011).

The climate in Semarang is categorized as humid tropical with an average annual rainfall between 2,000 and 2,500 mm, which peaks in December and January. Average monthly temperatures range between 25.8 and 29.3ºC (Marfai & King, 2008a; ACCCRN, 2010). The urban landscape is


**Figure 1. Location of Semarang city** Source: Cartography: Arief Darmawan, 2014

a mosaic of forest patches, agro-forestry plots, settlements, and rice fields. Semarang features hilly terrain on the southern part of the city and lowlands in the north. The mean elevation of the hilly areas is more than 400 meters above sea level (m.a.s.l.), most of them can be classified as steep slopes of 15-40% (Marfai & King, 2008a). Lowland areas are classified as Low Elevation Coastal Zones (LECZ see box 1 and figure 2), defined as altitudes of less than 10 m.a.s.l. with the majority of commercial and industrial areas found in these lowland areas (Syahrani, 2011; Marfai & King, 2007).

The coastal areas of Semarang cover about 4,575 ha with 25 km of coastline. Semarang's coastal areas can be divided into four micro-regions: (1) beach areas with sand and clay soils; (2) combination of alluvial sediments and tidal mangrove forest; (3) alluvium and mud sediment; and (4) reclamation areas for harbor and tourism purposes (Kobayashi, 2003, cited in Marfai & King, 2008a). Almost half of Semarang's inhabitants live in the coastal areas where also fishponds and agricultural areas are situated (Asian Cities Climate Change Resilience Network (ACCCRN, 2010). At the same time, these areas suffer from tidal inundation and land subsidence, which are expected to worsen due to the regional sea level rise prediction (Marfai & King, 2008a, b), putting livelihoods of affected people under risk.

Due to their dependence on fishing industries and their reluctance to be relocated to other areas, residents of the lowland areas are considered vulnerable to coastal flooding. This is particularly the case for urban poor residents who cannot afford to move elsewhere or who depend on income options in the area. Migrant groups of families previously relocated by the government to the area are also highly vulnerable. According to Marfai & Hizbaron (2011), even when inhabitants of flood-prone areas are aware of their risk, they often decide against leaving their homes. This often happens when people lack economic alternatives and face the potential loss of their

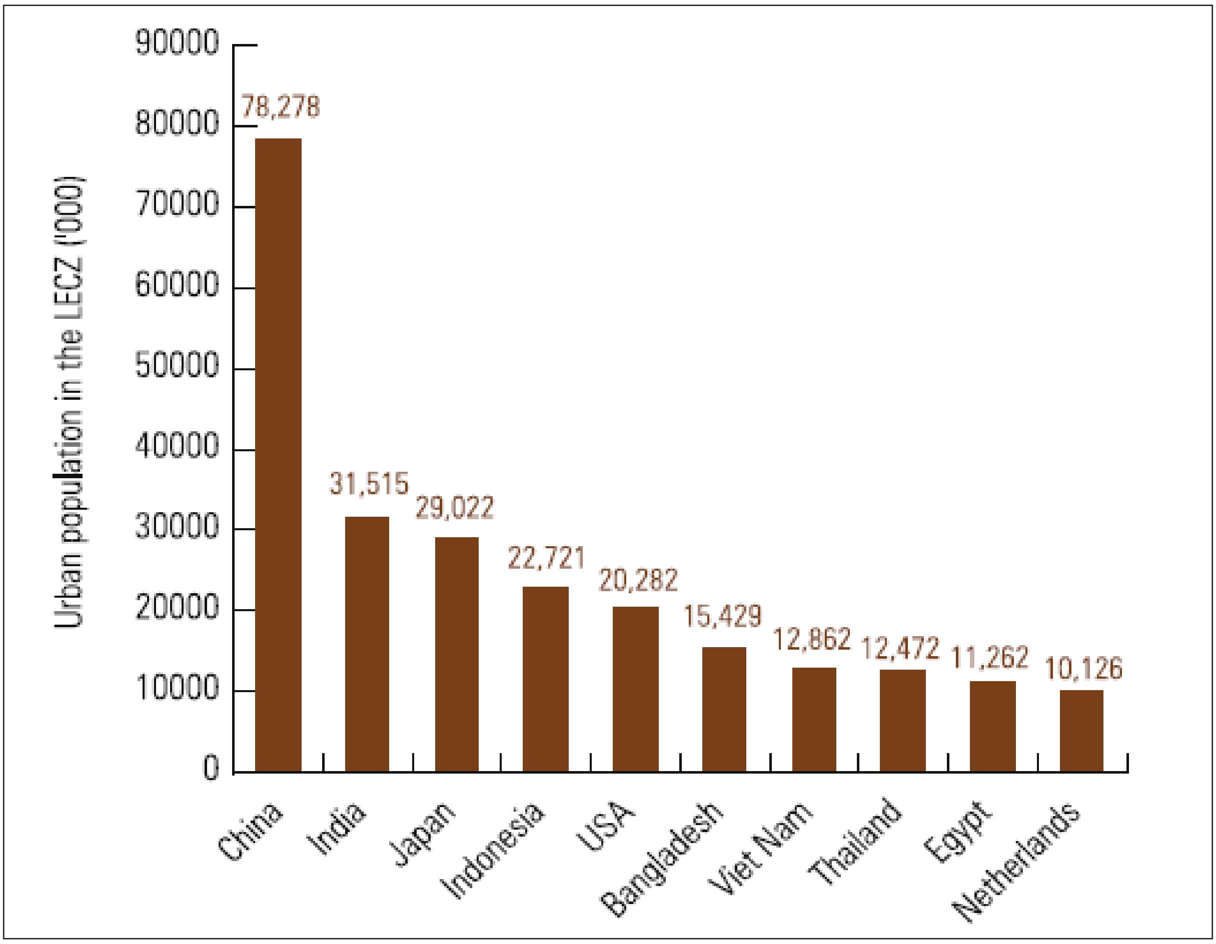


**Figure 2. Urban population in LECZ in selected countries** Source: State of the World Cities 2008/09, p. 144

**Table 1. Key Causes of Urban Floods (including in non-coastal cities)** Source (Mulyasari et al., 2011)

| Key Cause | Characteristics |
|---|---|
| Human Cause | Rapid Urbanization:<br>• Concentration of people and assets in flood prone areas<br>• Waste tends to clog drainage facilities, reducing drainage capacity and leading to increased surface runoff |
| Natural cause | Sea level rise:<br>• Higher sea levels and more severe storm surges<br>Rainfall intensity:<br>• Prolongation of heavier rainfall than in the past<br>Increased glacier melt:<br>• Changes that increase river flows |
| Governance cause | Inadequate urban planning:<br>• Uneven spatial distribution of urban population |

**Box 1. Definition of Low Elevation Coastal Zones (LECZ)**

The low elevation coastal zone is the continuous area along coastlines with altitudes less than 10 m.a.s.l. LECZ represent 2% of the world's land area but inhabit 10% of its total population and 13% of its urban population. 17% of the total urban population in Asia lives in LECZ, while in South-East Asia it is even more than one-third of the urban population.

Urbanization levels in low elevation coastal zones are higher than in other landscapes or land use systems. Globally, almost 60% of people in LECZs live in cities, compared with 44% in dryland ecosystems and 47% in cultivated areas (UN-HABITAT, 2008).

livelihoods and their social networks.

## 3. Problem statement

Semarang is facing two main natural hazards that are strongly inter-related: flooding and land subsidence. Both problems are directly linked to pressures on the available natural resources, in particular urbanization for residential, recreational and industrial purposes of the low-lying swamps and fields, and subsequent groundwater overexploitation (Marfai & King, 2008). Although these problems are well-known over the past twenty years, the "uncontrollable" urbanization in Semarang has led to highly unsustainable land use changes, (Marfai & King, 2007),

Marfai & King (2008b) estimated that by 2020 on average 2,227 ha of land will be lost per year due to land subsidence. There are three major causes for land subsidence: groundwater withdrawal, natural consolidation process, and subsidence induced by construction loading. Due to the climatic and geographical conditions and additional anthropogenic pressures, the coastal areas are affected by flooding, which is mentioned as the major hazard especially affecting the LECZ and the floodplains of the rivers of Semarang. Coastal flooding is aggravated by the effects of land subsidence and sea level rise, affecting different sectors and therefore representing a huge challenge to coastal managers and governments (Marfai & King, 2008).

Flooding damages local infrastructure as well as coastal settlements and agricultural lands, threatening the livelihoods of local people and resulting in socio-economic losses. Figure 3 shows the areas affected by sea water inundation in Semarang. According to flood projections, the area prone to flooding and tidal inundation is about 86 $km^2$ (23% of Semarang's area) with 60,000 households potentially at risk (Asian Cities Climate Change Resilience Network (ACCCRN, 2011).

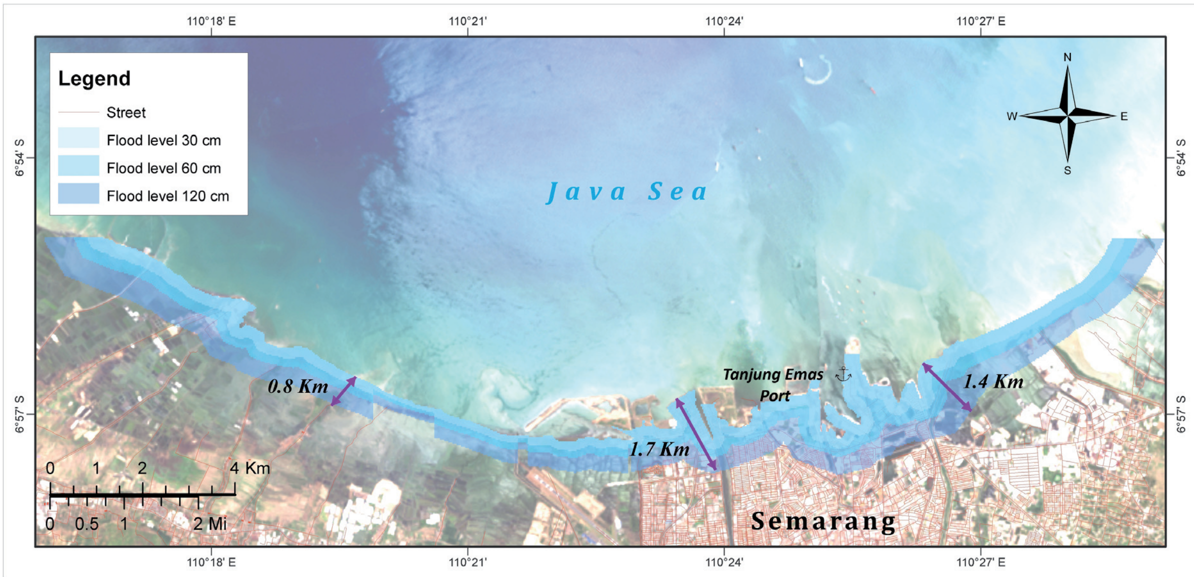


**Figure 3. Sea level rise projection and associated flooding scenarios for Semarang City**
Cartography: Arief Darmawan, 2014

The projected global rise in sea levels could result in increased flooding of coastal cities (UN-HABITAT, 2008) including the highly urbanized coasts of Java. Understanding community and people's response to flooding is essential to addressing issues of concrete action in coastal hazard management (Marfai & King, 2008a, b). Increasing coastal inundation may lead to substantial socio-economic losses in Semarang's coastal area. Predictions of the impact of sea level rise in the area have been made by Marfai & King (2008a, b) using different possible scenarios of water depths. Figure 3 shows different scenarios ranging from 30cm flood level (number used by IPCC in 1998, predicting an increase flood damages by 36–58%) to 120cm, as the sum of the depth of the tidal inundation in recent condition and the regional scenario of sea level rise (Marfai & King, 2008b). The model reveals that the coastal inundations will cause disturbances to the ecosystem. Beside this they will harm existing land uses and infrastructures and will thus lead to severe socio-economic losses. According to the worst case scenario, and assuming the continuity of the current land use patterns, a potential inundation of 180 cm, around 712.5 ha of agricultural and plantation areas, 930.8 ha of bare lands, 1716.6 ha of beach and yards, and 2235.0 ha of urbanized and fishpond areas would be lost (Marfai & King, 2007).

A severe flood event in Semarang in 1990 affected an area of 145 ha with up to 3 m depth inundation. During this event 47 people died, 126 houses were damaged, one school building and one dormitory collapsed (Marfai & King, 2008a). Presently 20 villages are located in the Semarang coastal area and are most vulnerable to coastal inundation (Marfai & King, 2008a). Most at risk from floods and other hazards are settlers and other poor populations living in informal settlements. Informal settlements very often occupy space that is not designated for residential use, such as riverbanks, green areas, wasteland along railway tracks, or space between built-up areas. Without secure land tenure, the inhabitants of informal settlements are reluctant to invest in improvements to their living conditions that would reduce their flood risk; thus, land tenure could be seen as the key to enabling informal settlers to reduce their risk (Tunas & Peresthu, 2010).

To control flooding in Semarang city, structural as well as non-structural measures have been implemented as discussed in section IV. Structural measures comprise dykes, drainage systems, pump stations, polder systems and coastal-land reclamations, etc., while non-structural measures include coastal planning and management, public education, and the establishment of an institutional framework for disaster management. However, these actions do not seem to be sufficient to significantly reduce flood risk in Semarang.

**Box 2. Measures classification**

**Structural measures:** Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems (UNISDR, 2007).

**Non-structural measures:** Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education (UNISDR, 2007).

According to Renaud et al. (2013), **ecosystem-based measures** can be subdivided in three main categories: (1) "Healthy and well-managed ecosystems that can serve as natural infrastructure to prevent hazards or buffer hazards impacts." Examples are protection forests in mountain areas that prevent from landslides, or mangroves, sand dunes and other types of coastal vegetation that reduce wave heights, protect from storm surges, and buffer against salt water intrusion; (II)"Healthy and well-managed ecosystems" (…) that "help reduce the exposure of people and their productive assets to hazards." Here a good example are floodplains in their natural state which absorb flood waters and allow rivers to meander and thereby reduce the flood peak; (III) Ecosystems which "sustain human livelihoods and provide for basic need, such as food, shelter and water - before, during and after hazard events". In this case, well-managed ecosystems can reduce vulnerabilities and provide services, such as seeds or nuts from fire resistant trees in regions with high risk of wild fires. Ecosystem-based DRR comprises tools such as ICZM, community-based natural resource and disaster management (CBNRDM) and integrated water resources management (IWRM). Ecosystem-based measures include both structural and non-structural measures: reforestation may be considered structural, while improved land use planning as part of IWRM or ICZM are non-structural measures.

**Table 2. Measures implemented to face flood hazards in Semarang** Source: (Marfai & Hizbaron, 2011)

| Subject | Plan and measures | Agencies in charge |
|---|---|---|
| Coastal land use | Detailed coastal master plan<br>Monitoring land use change on the coastal area<br>Law enforcement and implementation of the regulation system | Regional Development Board<br>Public Works Department |
| Garbage disposal | Improved garbage disposal system<br>Involving local community via public awareness | Public Works Department<br>Municipality Health Office<br>Community |
| Tidal flood prevention | Improving the polder system<br>Improving the number of pump stations | Regional Development Board<br>Public Works Department |
| Land subsidence | Monitoring land subsidence<br>Monitoring groundwater extraction | Public Works Department<br>Mining and Geology Department |
| River and drainage system | Detailed drainage master plan<br>Improving drainage capacity and reducing sedimentation of the drainage system | Regional Development Board<br>Public Works Department<br>Water Resources Department |

## 4. Measures implemented

The municipality of Semarang and the Government of Indonesia have undertaken both structural and non-structural measures to mitigate the flooding problem.

Main *structural measures* include floodways, dikes and drainage systems, coastal-land reclamation, pump stations, and polder systems in the low-lying areas. These structural measures have been implemented mainly by the local and national governments. ***Non-structural measures*** emphasize strengthening organizational frameworks for disaster management, coastal planning and management, and public education. These measures have been implemented mainly by local community groups and NGOs (Marfai & King, 2008a).

Table 2, on the previous page, gives examples of measures that have been undertaken at the governmental level in order to mitigate tidal flood hazards.

The work related to coastal management in Indonesia has been initiated and supported by international and bilateral donor agencies, who are keen supporters of decentralized coastal management and community based approaches (Siry, 2006).

Since 2010, Semarang has a "City Resilience Strategy" (CRS) which tackles coastal hazards using the Integrated Coastal Zone Management (ICZM) approach. The ICZM approach in Semarang allows for integrating disaster risk reduction into the medium-term development and spatial planning processes in the coastal zone, the enhancement of institutions in order to reduce disaster risk, the engagement of multiple stakeholders, management of water resources, drainage, waste management, housing and settlements, among other (Asian Cities Climate Change Resilience Network (ACCCRN, 2010). Some of the measures integrated in the CRS are also part of the National Adaptation Plan of Indonesia, where coastal zones are mentioned as priority areas (Syahrani, 2011). ICZM provides an institutional framework that brings together all relevant stakeholders in order to take into account policies, decisions and development actions that affect the coastal areas. In Indonesia, the Law 27/2007 on "Integrated Coastal and Small Island Management" is mentioned as the basis for ICZM and also allows the inclusion of Disaster Risk Reduction (DRR) in coastal zone management (Nicholls et al., 2007). In Semarang, the institutions that focus on coastal areas and flooding are the Planning and Development Board and the Water Resources Management Agency (Harwitasari, 2009).

Three specific measures in the context of ICZM were implemented in Semarang are described in detail in the following paragraphs.

### Polder system in Banger

Polders, developed first in the Netherlands, have been used for centuries to create arable land by draining delta swamps into nearby rivers. In Semarang, they create protected or reclaimed land from the sea (van Schoubroeck, 2010). Together with drainage systems and dikes, polders can be considered protective structures in

**Figures 4. and 5. Early construction phase of the Banger Polder Pilot System (2011)** Photo credits: Dana Adisukma

order to prevent floods (Marfai & King, 2008a).

According to Mondeel & Budinetro (2010), a polder is "an area, surrounded by a closed ring of flood protection elements (dikes and dams) to separate water regime inside the polder area from the water regime outside". It includes tidal gates and/or pumping stations which regulate the water table inside the polder.

Effective implementation of polder systems requires an integrated approach which considers all structural elements that constitute a polder (pumping station, dikes, retention basin, channels), the essential technical aspects (safety level, water level to be controlled, etc.), and the inclusion of all stakeholders (Mondeel & Budinetro, 2010).

In order to prevent tidal floods in the Northern and Eastern region of Semarang, a pilot polder system in the community of Banger was established (See Figures 1 and 2). The Banger area is named after the Kali Banger channel, the main channel in the area. The area experiences tidal flooding and is also affected by land subsidence, with a rate of 9 cm/year (Mondeel & Budinetro, 2010).

The pilot project is expected to be in operation in 2014. It is foreseen to protect about 70 ha of land from tidal inundation through the improvement of the retention capacity and improved drainage system and pumping capacity (Marfai & King, 2008a; ACCCRN, 2010; ACCCRN, 2011). The construction and operation costs of the pilot systems were approximately USD 6 million (Asian Cities Climate Change Resilience Network (ACCCRN, 2011). Construction of the polder has been financed by the Government of Indonesia, the Government of The Netherlands and the municipality of Semarang (Witteveen & Bos, 2013).

The local community is being included actively through its participation in the polder management board. This board also comprises municipal government representatives, which is in charge of the operation and maintenance of the system (Witteveen & Bos, 2013; Banger Sima, 2013), and is an extremely important component towards ensuring project sustainability. The construction of the pumping station as well as the excavation and dredging for the construction of the dam started in 2010, with the transfer of the dike management to the management board expected by 2013 (Helmer, 2011). To ensure the operation and maintenance of the system, the project includes the establishment of a fee of approximately USD 0.7 per month per household and a small fee levied on tourism activities such as the Kali Banger Festival (Irawati, 2012). In Banger, due to inadequate waste management, additional components are required, namely: dredging of rivers, revitalization of the drainage system and better control of solid waste (Witteveen & Bos, 2013).

Expected benefits of the polder system include reduced flood damage to houses and infrastructure, while making the area more attractive for tourist activities (Witteveen & Bos, 2013). Although the polder system will contribute to flood mitigation, Marfai & King, 2008,a argue that it will not solve all the inundation problems in Banger. Therefore, a holistic approach that includes other complementary structural, non-structural and ecosystem-based measures is needed.

### Sea embankment construction (dike) and other structural measures

Other structural measures proposed to address flood risk in Semarang include the construction of dike systems as well as of floodwalls along the rivers (in densely populated urban areas) and the use of vegetation in order to trap and stabilize fine sediments (Marfai & King, 2008a).

Another initiative is to construct a sea embankment in the northern part of the city, promoted by Semarang's local government. This embankment would be the first of its kind in the area. Proponents assert it would serve to prevent flooding in the city, reduce economic losses due to floods and increased accessibility to the city (ACCCRN, 2010; ACCCRN, 2011).

Disadvantages include high investment costs, potential conflicts due to land acquisition (including loss of some people's livelihoods), degradation of coastal ecosystems, and threats to public safety if there are failures in the design and construction phases (Asian Cities Climate Change Resilience Network (ACCCRN, 2010).


**Figures 6. and 7. Mangrove nursery area and rehabilitation of mangroves in coastal areas in Bedono, Demak Regency (surrounding area of Semarang)** Photo credits: Annisa Triyanti

Other measures include plans by the local government to develop 51 reservoirs, among them the Jatibarang reservoir and dam (expected to be in operation in 2014), which would also improve access to drinking water and electricity in the area (Asian Cities Climate Change Resilience Network (ACCCRN, 2011).

## 5. Implications for Ecosystem-based DRR

### Mangrove rehabilitation and conservation

Healthy mangrove ecosystems can protect coastal areas from erosion and coastal flooding and increase the resilience of communities in coping with climate change impacts.

In Semarang, the remaining mangrove ecosystems are under pressure due to intense agricultural land-use, industrial and residential demands. The economic loss of mangrove ecosystem degradation is estimated at about USD 61,000 per hectare and year, which underlines the great importance of this environmental problem (DKP, 2008 cited in ACCCRN, 2010).

Ecosystem-based measures in Semarang have focused on both protecting the remaining mangrove areas and replanting mangroves. These measures not only serve to protect or restore the ecosystem itself but have also a direct economic value, as fish ponds are protected as well. Local mangrove rehabilitation and conservation programmes have also been established to increase the adaptive capacity of coastal communities. One example is the "Kampung Iklim" or Climate District program intending to disseminate adaptation strategies at the district level, including mangrove rehabilitation and conservation in the Kampong areas to reduce erosion and increase soil surface. Additionally this approach can serve to generate income options for the local community (Syahrani, 2011).

Many community-based mangrove protection initiatives started with financial support from external organizations. Now several communities are initiating mangrove conservation, undertaking nursery planting and replanting mangroves in the shoreline area (Prihantoro, 2010).

Other ecosystem-based measures include vetiver grass and bamboo plantations for vegetative treatment of settlement areas which are prone to landslides. This method is less costly for communities and more eco-friendly in comparison with other structural approaches (Asian Cities Climate Change Resilience Network (ACCCRN, 2010).

For the coordination of mangrove conservation projects and other environmental initiatives undertaken in the context of ICZM, a mangrove working group was established in Semarang. It is a multi-stakeholder group, coordinated by the local government (Sutarto & Jarvie, 2012).

### Strengthening the organizational framework for disaster management

As part of the non-structural measures implemented in Semarang, the process of strengthening organizations and the organizational framework for disaster management is of particular importance. Coordination between the local government, the national board for natural disaster management and local representatives on district level has been initiated. Risk governance is decentralized, as districts and local governments are now made responsible for disaster management, and legislation related to coastal area management has been enhanced (Marfai & King, 2008a). This decentralization process has been pushed forward throughout Indonesia in previous years (UN-HABITAT - Regional Office for Asia and the Pacifics, 2008).

As a way to monitor the coastal areas, the local government of Semarang has established a land use plan, which is very important for long-term planning and risk reduction in flood prone areas. Nevertheless, further improvement on coastal land use planning is needed, greater inclusion of NGOs and communities and more detailed planning and mapping (Marfai & King, 2008a).

### Community-based approaches

Community-based approaches are an essential component of non-structural DRR measures, as local commitment is needed to make any approach sustainable (Marfai & King, 2008a). In 2004, the Government of Indonesia in its Law 32 - Local Administration – highlighted the importance of regional autonomy and fiscal decentralization, a paradigm shift from centralized to decentralized governance. The plan for 2004-2009 prioritized (among others) the preparation of local people to face disasters, aiming at developing policies and institutions for disaster management, empowering and preparing local communities to cope with disasters, facilitating community-based housing and human settlements reconstruction, and building local capacity in disaster management (UN-HABITAT - Regional Office for Asia and the Pacifics, 2008 ). However, while community-based approaches are emphasized at the national level, implementing such approaches remain a challenging issue at the local level (discussed further in the next section).

## 6. Lessons learned and conclusions

This case study in Semarang demonstrates how ICZM could serve as a planning instrument which integrates ecosystem-based disaster risk reduction. The measures implemented in Semarang can be framed as part of an ICZM strategy that promotes sustainable development, and at the same time, reduces the vulnerability of coastal area inhabitants from natural hazards and climate change impacts. Implementing Eco-DRR measures need to be undertaken as part of a holistic approach that also seeks to improve institutional arrangements and legislation (decentralization, e.g. polder system), while improving environmental management, raising public awareness of disaster risk and involving all relevant stakeholders during the implementation of measures.

In Semarang, the measures described were implemented by different stakeholders at various scales, whether by local communities themselves (usually autonomously) or by government institutions. Governments (at various levels) together with the private sector are more focused on the development of infrastructure, while local governments, communities and NGOs are working more on ecosystem-based measures. Even during the implementation phase, these measures can present various trade-offs (e.g. environmental and socio-economic trade-offs), which are important to consider in advance. Stakeholders involved or located in the intervention area have to be consulted and involved in planning as well as monitoring.

As described in Marfai et al. (2008), a variety of disaster management and risk reduction measures have been undertaken throughout the Central Java province, including: land use management, integrated water resources management, urban infrastructure planning, provision of low-priced housing to resettle people living in vulnerable areas, and enhancement of community organizations by building awareness or encouraging local organizations to address hazards. In order to ensure that successful implementation of land use planning instruments related to coastal zone management, the definition of governance mechanisms, legislation, enforcement and clear government mandates are imperative. Any land use plan also requires proper implementation and monitoring, involving different stakeholder groups. This is a huge challenge, especially for a growing and expanding city like Semarang, which is also facing increasing disaster risk.

Among the main challenges to establish adequate measures to reduce flooding impacts in coastal areas of Semarang are the limited financial resources and the need to relocate individuals or communities away from flood prone areas. These issues have resulted in some local resistance and loss of public support. Addressing community participation in decision-making more effectively is central. For instance, the Government did not seek public participation in implementing structural measures or only did so after implementation. In other cases, particularly in relation to implementation of non-structural measures, there was greater involvement of communities.

The Semarang case study confirms that the management of coastal areas requires multi-disciplinary integrated approaches and institutional arrangements in order to face human-induced challenges faced by increasing hazard events, greatly aggravated by unplanned land use and pressures on natural resources.

## 7. Exercise and teaching notes

1. **Classify the measures taken in Semarang, and group them according to two criteria:**
   - Structural or non-structural measures
   - Community-based approach or measures not involving community participation

| | Structural measure | Non-structural measure |
|---|---|---|
| **Community-based approach** | | |
| **Measure not involving community participation** | | |

2. **After completing the table above, discuss your findings in your subgroup or in class using the following guiding questions:**
   - Is it easy to classify the measures? If not, which criteria or measure is more complex?
   - Do you have any doubts on the classification? If yes, where and why?
   - Was there a greater emphasis on structural or non-structural measures and if you were a decision-maker, which measures would you emphasize?

3. **Please describe the advantages and disadvantages of the different types of measures:**

| | Advantages | Disadvantages |
|---|---|---|
| **Structural measures** | | |
| **Non-structural measures** | | |

4. **After having a general description of measures implemented in Semarang, identify the stakeholders which are already or should be involved in the decision-making and implementation of the different measures. In your analysis, also consider the stakeholders who could be impacted by the implementation of the measures.**

| Measure | Stakeholder groups that are or should be involved |
|---|---|
| **Polder system** | |
| **Sea embankment construction** | |
| **Mangrove rehabilitation and conservation** | |
| **Strengthening of organizational framework** | |

   - In your opinion, what could be potential difficulties when convening a multi-stakeholder discussion? Can you make suggestions how to establish a participatory approach?

5. **Please discuss with your classmates which measures seem to be most suitable from your point of view and why this is the case? What is needed to make the measures sustainable?**

*Instructor's notes: students will analyze the measures presented in the case study. The exercise can be developed by groups of 2 or 3 persons and may last 50 to 60 min. After finishing the exercise, the students can share and discuss their answers with their classmates. The students will need to have the case study documents.*

## Teaching notes

Note: the "suggested answers" given below should be treated only as guidelines for the instructor. Students are encouraged to find their own solutions which could be added.

1. **Try to classify the measures taken in Semarang, and group them according to two criteria**

| | **Structural measure** | **Non-structural measure** |
|---|---|---|
| **Community-based approach** | Polder systems<br>Mangrove rehabilitation and conservation | Strengthening organizational frameworks for disaster management<br>Coastal planning and management<br>Public education |
| **Measure not (necessarily) involving community participation** | Floodways<br>Dikes<br>Drainage systems<br>Coastal-land reclamation | |

2. **After completing the table above, discuss your findings in your subgroup or in class using the following guiding questions:**
   - Is it easy to classify the measures? If not, which criteria or measure is more complex?
   - Do you have any doubts on the classification? If yes, where and why?

Normally, structural measures represent huge investments which are implemented by governmental agencies. Furthermore, implementation of such measures does not necessarily or automatically include the participation of local communities. But, there are some examples, such as the polder system, which facilitates community participation in order to guarantee the implementation and maintenance of the project. Non-structural measures are characterized by promoting the participation of the communities.

In general, one can say that non-structural measures usually include participation of stakeholder groups whereas this is less often the case for structural measures. However, one has to know more details about the respective project/approach to draw conclusions. Therefore, the classification above is more an approximation than an exact one.

   - Was there a greater emphasis on structural or non-structural measures and if you were a decision-maker, which measures would you emphasize?

In Semarang, the focus on structural measures so far is strong. Often such kind of measures is more costly than non-structural ones as they require significant capital investments and technical expertise which local communities on their own may not be able to provide. Structural measures are constructed for a span of 20-100 years of functioning; if not properly constructed investments may be lost. Nonetheless, such approaches might be suitable solutions especially for highly populated areas like Semarang. If not properly constructed, they might put many people at risk as they may provide false security if not constructed properly or if assuming wrong parameters (e.g. not accounting for climate change impact on flooding).

Ecosystem-based measures were only put on the agenda in Semarang recently (e.g. by setting up programs for mangrove area restoration). Such non-structural approaches may be politically and socio-culturally more time-consuming to negotiate among all the stakeholder groups, but they are often more cost-effective.

Addressing the complex management issues in the coastal area of Semarang requires an integrative, holistic approach and an interactive planning process. To do so, the most crucial issue is proper land management of the coastal and surrounding areas. This includes interdisciplinary and inter-organizational processes toward an effective general framework for dealing with conflicts arising from interactions of the various uses and users of coastal areas. And it requires close coordination and cooperation among the various stakeholders involving the government line agencies, research institutes, NGOs and the local communities.

**3. Please describe the advantages and disadvantages of the different types of measures:**[1]

| | Advantages | Disadvantages |
|---|---|---|
| **Structural measures** | Flood attenuation<br>Downstream discharge control<br>Groundwater control<br>Run-off delay and increase of infiltration | High level of investment<br>Reduction of floodplain fertility<br>High potential for ecological impacts<br>Morphological changes<br>Land subsidence<br>Conflicts due to land acquisition<br>Threats to public safety if there are failures in the design and construction phases |
| **Non-structural measures** | Allow more participation of communities at the local level<br>Strengthening of organizational frameworks for disaster management can support long-time sustainability<br>No significant environmental changes<br>Effective in dealing with flood impacts and damages | Communities need to be defined and different subgroups do not always agree with each other. Negotiation processes between stakeholder groups can be time-consuming<br>Strong commitment from local communities required<br>High level of bureaucracy, different levels involved, from state to local, thus time-consuming<br>Rise of property value |

**4. After having a general description of measures implemented in Semarang, identify the stakeholders which are already or should be involved in the decision-making and implementation of the different measures. In your analysis, also consider the stakeholders who could be impacted by the implementation of the measures.**

| Measure | Stakeholder groups that are or should be involved |
|---|---|
| **Polder system** | Government of Indonesia<br>Government of Semarang<br>Local communities<br>Practitioners / experts |
| **Sea embankment construction** | Government of Semarang<br>Local communities<br>experts |

| Measure | Stakeholder groups that are or should be involved |
|---|---|
| **Mangrove rehabilitation and conservation** | Government of Indonesia<br>Government of Semarang<br>Coastal communities<br>Local fishermen and other locals that generate income from mangrove areas (including marginalized groups)<br>Practitioners/NGO experts |
| **Strengthening of organizational framework** | Government of Indonesia<br>Government of Semarang<br>Local communities/head of communities<br>Practitioners/NGO experts |

5. **Please discuss with your classmates which measures seem to be most suitable from your point of view and why this is the case? What is needed to make the measures sustainable?**

According to the information presented, the instructor should guide students to identify the complementarity between the two types of measures (structural and non-structural). The following table provides some examples for both types of measures, as presented in question 3. A long-term sustainability strategy requires, in particular, the commitment of the involved governmental bodies and community as well as a budget plan including maintenance costs.

| Structural measures | Non-structural measures |
|---|---|
| Reforestation<br>Erosion control<br>Soil conservation<br>Retention ponds<br>Impact mitigation of reservoirs<br>Construction of platforms and polders in floodplains | Institutional and legal frameworks<br>Implementation of insurance systems and coverages<br>Forecasting / warning systems |

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## Endnotes

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# Case Study 3

## Room for the river: Flood risk management, The Netherlands

## 1. Overview

| | |
|---|---|
| **Outline** | This case study features the "Room for the River programme", the Dutch government's modern approach to flood management. It includes the steps and measures taken to achieve increased protection against high water levels and improved spatial quality in the riverine region. |
| **Learning objectives** | • Learn the different ecosystem-based measures available to reduce river flood risk, in a country with highly modified waterways<br>• Gain insight into the project management process, from consultations to implementation<br>• Learn the challenges flood managers face in a flood-risk prone, highly urbanized area. |
| **Guidance** | This case study showcases how the Dutch government utilized ecosystem-based measures and ensured an integrated approach in addressing flood risk. |
| **Recommended reading** | Dutch Ministry of Transport, Public Works and Water Management, 2008. *Flood Risk: Understanding concepts*.<br>Wiering M.A. & B.J.M. Arts, 2006. *Discursive shifts in Dutch river management: 'deep' institutional change or adaptation strategy?*.<br>Van Eijk et al., 2013. Good flood, bad flood: Maintaining dynamic river basins for community resilience, in: The Role of Ecosystems in Disaster Risk Reduction, eds. Renaud G., Sudmeier-Rieux K., Estrella M.<br>For the case study exercise:<br>Dutch Ministry of Water Management, Transport and Public Works, 2006b. *Spatial Planning Key Decision Room for the River: Explanatory memorandum* (PKB Part 4) pp. 39-72. |

## 2. Background

The Netherlands, one of four constituent countries of the Kingdom of the Netherlands, is divided into twelve provinces. Located in north-western Europe, it shares borders with Belgium to the West and South and Germany to the East (see Figure 1). Approximately 40% of the country's 16.7 million people (as of 2012) live within the *Randstad*, a metropolitan area composed mainly of the cities of Amsterdam, Rotterdam, The Hague and Utrecht. The Netherlands has the highest population density in the European Union and is one of the most densely populated countries in the world with 496 inhabitants per square kilometre (Statistics Netherlands, 2013).

The country's total surface area of 41'528 km$^2$ is mainly composed of coastal lowland and reclaimed land, the lowest point being at 7 meters below sea level (Zuidplaspolder), while the highest point is at only 322 meters above sea level (Vaalserberg) (CIA Factbook, 2013). Due to its maritime climate, the Netherlands experience cool summers and


**Figure 1. The Netherlands, bordered by Germany, Belgium and the North Sea**
(CIA Factbook, 2013)

mild winters. Mean annual rainfall is between 700 and 900 mm (Royal Netherlands Meteorological Institute, 2010; Encyclopedia Britannica, 2013). Water is a predominant feature of the Dutch landscape. In fact, 18.41% of its land area is made up of different water bodies (Netherlands Board of Tourism and Conventions, 2013). Three major European rivers - Rhine, Maas (Meuse) and Scheldt - flow through the Netherlands and drain into the North Sea. The estuaries of these rivers along with their numerous distributaries form most of the country (Faculty of Geosciences, Utrecht University, 2005).

With 60% of the total land area being prone to flooding, high water levels constantly pose a threat to areas along the coast and rivers and have been an ever present issue in the Netherlands. The Dutch have been addressing flooding issues since the 9$^{th}$ century, mainly by building dikes, levees, sluice gates, and storm surge barriers (Dutch Ministry of Water Management, Transport and Public Works, 2011a). Eventually, they started reclaiming land from the rivers through the drainage of wetlands, river floodplains, and lakes using windmills, thus creating dry and fertile lands called polders. The Dutch riverine area is of high economic, ecologic, and scenic importance. The rivers are essential for transporting people and economic goods internally as well as internationally and the surrounding wetlands are home to a number of wildlife species (Dutch Delta Programme, 2006b). The scenic and cultural value of river waterfronts is also widely appreciated in the Netherlands.

## 3. Problem statement

Centuries of traditional flood control measures have led to rivers becoming further confined between dikes. Smaller floodplains mean that built infrastructures are more prone to overtopping and failure in case of high water levels. Entrained silt increases the height of the remaining floodplains in the riverside of the dikes which contributes to land subsidence especially downstream (Dutch Ministry of Water Management, Transport and Public Works, 2006b). River obstacles such as groynes, rigid hydraulic structures built from an ocean shore, and bridge columns impede river flow and increase water level (Dutch Ministry of Water Management, Transport and Public Works, 2006b). Population growth behind the dikes means that the safety of 4 million people is at risk when flooding occurs (Dutch Delta Programme, 2006a).

The growing flood risk has been largely attributed to a combination of unusually heavy rains and human altered landscapes throughout the river basin. The increase in precipitation quantity and frequency has been putting pressure on rivers to discharge larger amounts of water. Following the near-flooding events in 1993 and 1995, which led to the evacuation of 250'000 people and one million cattle (Dutch Ministry of Water Management, Transport and Public Works, 2006b), flood safety standards had to be raised in order to cope with extreme flood events with a return period of 1'250 years. This means increasing river discharge thresholds from 15'000 $m^3/s$ to 16'000 $m^3/s$ for tributaries of the Rhine River and from 3'650 $m^3/s$ to 3'850 $m^3/s$ for branches of the River Waal (Roth & Winnubst, 2009; Biesboer, 2012). Interventions on the rivers need to be able to withstand any flow rate up to these defined maximum levels without causing flooding. In addition, sea level is predicted to be 0.6 to 1.5 meters higher by 2100 than today (Dutch Delta Committee, 2008), which, if compounded by stronger, more intense storms in the future, could lead to higher storm surges. This impacts river water levels, especially those of the Rhine and Meuse distributaries near the North Sea coast.

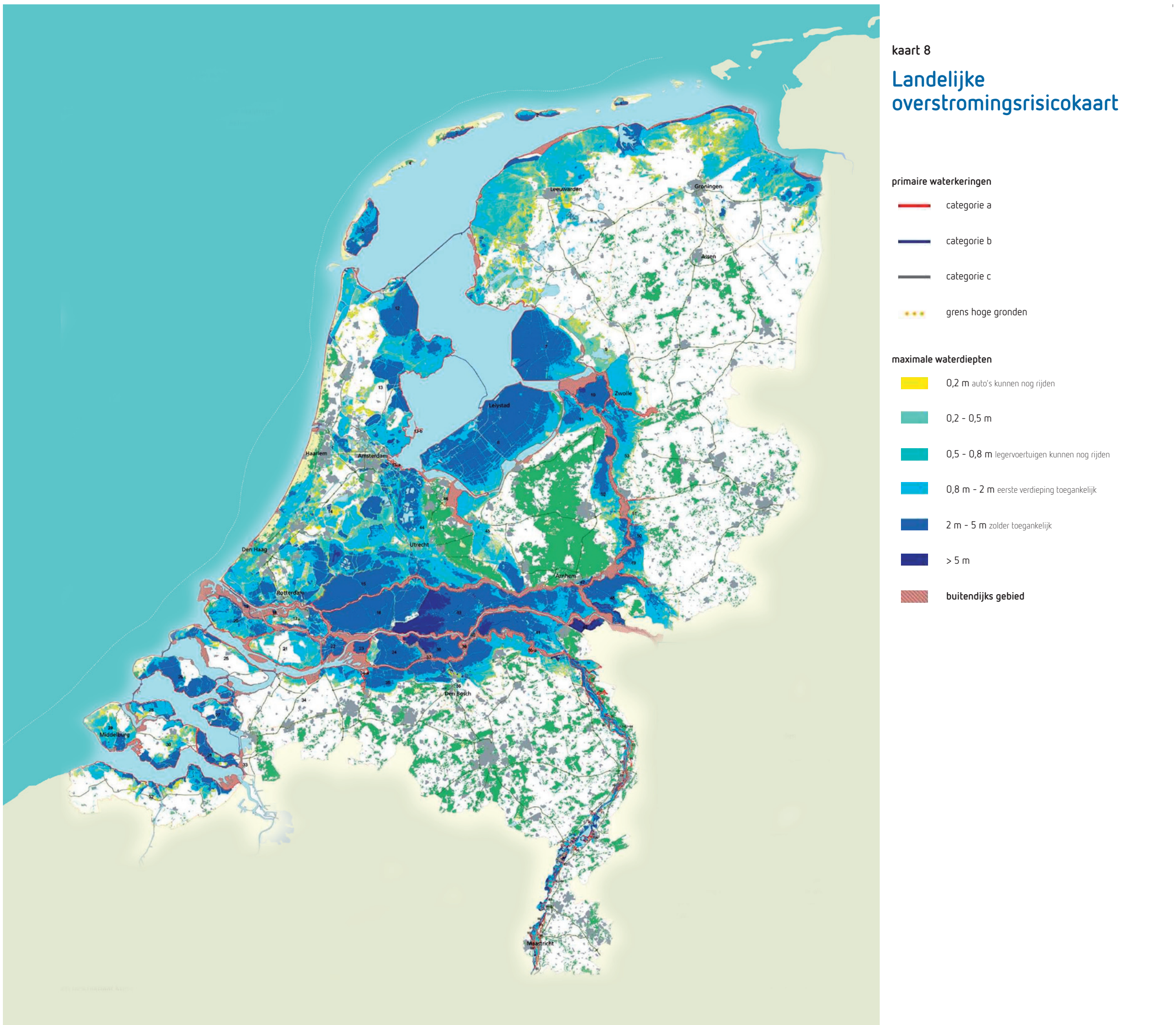



**Figure 2. Netherlands National Water Plan**
Source: Dutch Ministry of Transport, Public Works and Water Management, 2009.

## 4. Measures implemented

### Rationale

While further reinforcement of the dikes remains an option for reducing flood risk, a study has shown that it is not the most sustainable solution. The 1'000 $m^3$/s increase in river discharge values of distributaries of the Rhine needed to meet future safety levels could be solved by adding 30 cm to the current dike height, but higher and heavier structures would also mean greater risk in case of breach (Biesboer, 2012). It was calculated that an added 1.5 meters to all dike rings will lead to an increase in potential material damage of 60% in the case of a breach (Dutch Ministry of Water Management, Transport and Public Works, 2006b). The alternative would be to provide extra space for the river so that increases in river discharge would be countered by lateral outflow of excess water, thus maintaining the water levels (Biesboer, 2012).

In the position paper entitled "Room for Rivers" released in 2000, the Government of the Netherlands expressed the political will to decrease river discharge levels primarily through spatial measures rather than through dike reinforcement. Providing more space for the rivers to flow will be the main approach to reducing water levels in the event of flooding (Dutch Delta Programme, 2006b). As Frans Klijn, senior specialist in Water Management and Spatial Planning at the Deltares Research Institute, aptly puts it, "since 1850, the room for the river has been halved, we're now giving some of it back" (Biesboer, 2012).

### Main components of the measure(s)

The nationwide Room for the River programme focuses on 39 locations along the distributaries of the rivers Rhine, Meuse (Maas), and Scheldt and surrounding areas. The plan was approved in 2007 and is scheduled for completion by 2015. The 2.3 billion Euro programme aims to achieve flood protection objectives by creating more space for the rivers while improving the overall spatial quality (see Box 1) of the riverine region. The extra space for the rivers generated to cope with increasing flood risk will also need to remain permanently available for this purpose and for other recreational and ecological functions (Dutch Delta Programme, 2006a).

**Box 1. What is spatial quality?**

Spatial quality is a combination of three elements: utilisation value, perception value and future value. Utilisation value pertains to the number of possible public, non-excluding, and multiple usages an area can offer. Perception value has to do with people's living environment, its characteristic features, heritage elements and beauty (Explanatory Memorandum, 2006). Finally, an area is of high future value when its usage can be qualified as sustainable and is adaptable to changing needs (Tisma, 2004).

The Room for the River programme is a collaborative project between the national, provincial, municipal authorities, and the water boards. The Minister of Infrastructure and the Environment bears responsibility for the programme. Local authorities are in charge of the design and implementation of measures and the national government provides the funding if the project is accepted. In terms of monitoring, each target area has a river branch manager who regularly updates the Room for the River Programme Office with the project's current status. This continuous communication not only simplifies the assessment of the project, but also enables the Programme Office to intervene in time if a project is not on track. In parallel, the Programme Office submits an annual progress report to the Dutch Parliament for approval (Rijke et al., 2012).

### Methodology and guidelines

#### 1) Participatory decision-making process

An integrated approach to flood defence in the riverine area is one of the key aspects of the Room for the River programme. The government routinely consulted the public, members of the Programme's administrative body as well as other relevant institutions before issuing its final decisions (see Box 2).

**Box 2. Room for the River Negotiation Process Timeline**

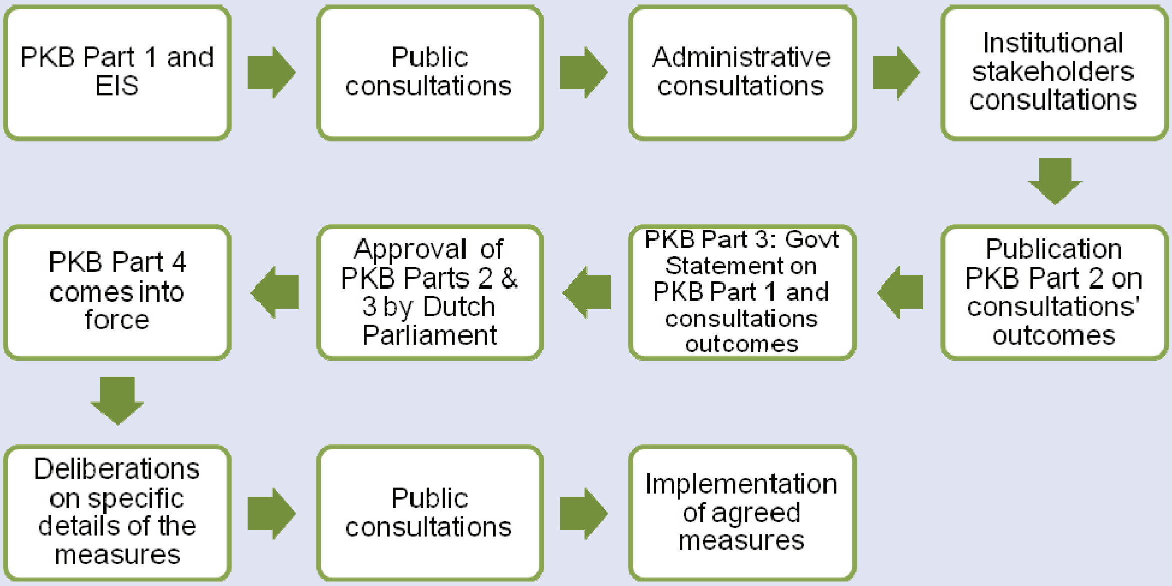



**Figure 3. Steps taken during the decision process of the Room for the River programme**
Adapted from Dutch Ministry of Water Management, Transport and Public Works, 2006b

The Government published the Draft Key Planning Decision "Room for Rivers" (PKB Part 1) on 15 April 2005. An Environmental Impact Statement (EIS), a Cost-Benefit Analysis, the Strategic Framework for the Birds and Habitats Directives[1], and the Regional Advisory Report were released simultaneously. The public was then asked to inspect these documents and voice its opinions between 1 June and 23 August 2005. A total of 2'843 responses were gathered. Administrative consultations regarding PKB Part 1 soon followed between 30 August and 15 September 2005. The EIS Committee, the Netherlands Council on Housing, Spatial Development and the Environment issued their recommendations between 14 and 27 October 2005. The responses, recommendations and meeting reports during the consultations were included in PKB Part 2.

In PKB Part 3, the Government issued its position with regards to PKB Part 1 and the outcome of the consultations. Afterwards, PKB 2 and 3 were submitted to the Dutch Parliament. The plan was finally approved by the end of 2006.

The decisions and final results of the whole procedure were then written in PKB Part 4. Once this PKB came into force, it was no longer open for appeals and the details on the individual measures of the basic package could finally be defined. Once again, these became the subject of public deliberations. It is only when this procedure had taken place that the agreed upon implementation measures began (Dutch Ministry of Water Management, Transport and Public Works, 2006b) (Fig. 4). By the end of this process, only 39 areas out of the 600 considered remained and were selected for construction (Scientific American, 2012).

## 2) Strategic Policy Decisions

Several strategic policy decisions were taken which influenced the choice of measures. The government has an ***efficient and long-term perspective*** for the Room for the River programme. Interventions were designed to contribute to achieving flood protection levels beyond current standards and anticipate future developments to avoid taking action more than once at the same location. The plan also provides clauses on areas on the landward side of the dikes to be reserved for implementation of measures in the longer term. Moreover, the measures considered in this programme are based on the desired long-term measures (Dutch Ministry of Water Management, Transport and Public Works, 2006b).

The government also intends to implement measures that could support *both objectives of flood safety and spatial quality improvement.* In terms of nature conservation, the EU Birds and Habitats Directives influenced the choice of measures to a certain extent (see Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild flora and fauna) (Dutch Ministry of Water Management, Transport and Public Works, 2006b).

Certain *technical considerations* also helped to influence the type of measures that would be implemented. Building new retention reservoirs are regarded as a last resort if discharge levels were to rise to 18'000 m$^3$/s in the future. Creation of high-water channels through enclosed polders was also avoided since it would entail splitting the polders into smaller dike rings which are easier to flood in case of high water levels. Among the concerns cited above, the authorities are also bound by their *budget and specified deadlines*. Whenever possible, the most cost-effective spatial measures that could be completed by 2015 were selected.

The interventions were categorized into Basic Packages of Measures according to the distributaries concerned: (1) Upper Rhine/Waal; (2) Merwedes, Bergsche Maas, Amer, Rhine-Maas estuary area; (3) Pannerdensch Canal, Lower Rhine and Lek; and (4) Ijssel (see Figure 4). If the original measures are unable to achieve the objectives by 2015, alternative and supplemental measures will be considered only if they reduce flood levels within the designated time frame and can be delivered within budget (Dutch Ministry of Water Management, Transport and Public Works, 2006a).

### 3) Technical aspects

The objectives are to be achieved by creating additional flooding space through river widening or by introducing other measures on the river side of the dikes (see Figure 5). Nine different strategies are to be implemented in 39 locations along the Dutch riverine area. These measures were selected based on the amount of impact, quality and costs. The total budget and appropriate implementation measures were determined by the amount of water reduction needed.

Measures that create more room for the river by restoring former floodplains are implemented whenever possible (e.g. dike relocation, lowering of floodplains, depoldering). Interventions on the river side of the dikes (e.g. deepening summer bed, lowering of groynes, removing obstacles on the river bed) as well as the creation of alternate areas for water to flow or be stored (e.g. water storage, high water channel) are also viable measures. Dike reinforcement is only considered when measures to create more room for the river are not feasible.

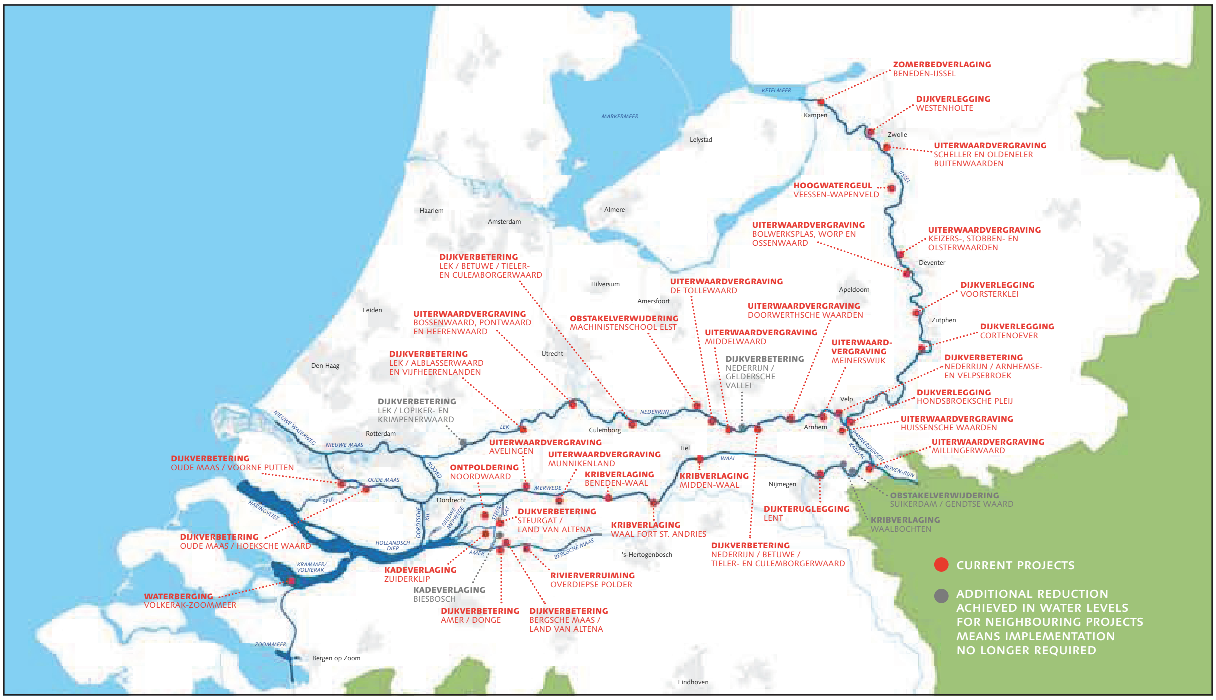
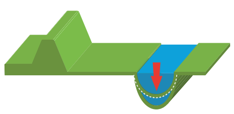
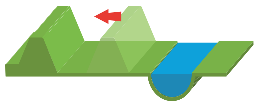



**Figure 4. Intervention map of Room for the River Programme with the corresponding measures. Measures in 4 out of the 39 selected areas have been deemed unnecessary after reduction of water levels have been achieved in nearby areas.** Adapted from Dutch Ministry of Water Management, Transport and Public Works, 2012

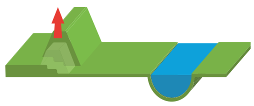


**Deepening summer bed**
The river bed is deepened by excavating the surface layer of the river bed. The deepened river bed provides more room for the river

**Water storage**
The Volkerak-Zoommeer lake provides for temporary water storage when exceptional conditions result in the combination of a closed storm surge barrier and high river discharges to the sea.

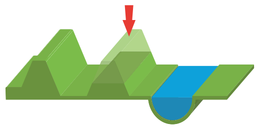


**Dike relocation**
Relocating a dike land inwards increases the width of the floodplains and provides more room for the river.

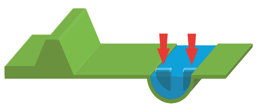


**Strengthening dikes**
Dikes are strengthened in areas in which creating more room for the river is not an option

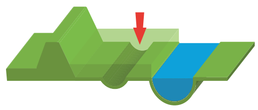
**High-water channel**
A high-water channel is a diked area that branches off from the main river to discharge some of the water via a separate route.



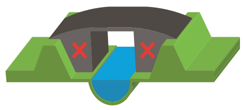
**Lowering of floodplains**
Lowering (excavating) an area of the floodplain increases the room for the river during high water levels.



**Lowering groynes**
Groynes stabilise the location of the river and ensure that the river remains at the correct depth. However, at high water levels groynes can form an obstruction to the flow of water in the river. Lowering groynes increases the flow rate of the water in the river.



**Depoldering**
The dike on the river side of a polder is relocated land inwards and water can flow into the polder at high water levels.



**Removing obstacles**
Removing or modifying obstacles in the river bed where possible, or modifying them, increases the flow rate of the water in the river.

**Figure 5. Measures being implemented in the Room for the River Programme**
Adapted from Dutch Ministry of Water Management, Transport and Public Works, 2006a

## Box 4. Room for the River Project Lent-Nijmegen Site

One project under the Room for the River Programme is located near the cities of Lent and Nijmegen. In this region, efforts are currently underway to build more efficient flood defenses whilst creating a more attractive and sustainable urban living space (Scientific American, 2012). The Waal River in this part of the city bends sharply forming a bottleneck that makes the surrounding areas susceptible to flooding. The €359 million-project (US$460 million) involves pushing a dike 350 meters inland to allow higher river discharge and reduce flood risk. Once this measure is executed, a high-water channel will be constructed in the freed-up flood plains, thus creating an island meant to be “a unique urban river park in the heart of Nijmegen with room for living, recreational activities, culture, water, and nature.” (Dutch Ministry of Water Management, Transport and Public Works, 2011b). All these construction works will inevitably change the waterfront, but developers took care to respect the existing cultural and heritage features by integrating them into the planning design (Scientific American, 2012).

In the densely populated riverine area, giving more space to the rivers often requires reclaiming land. The implementation of the programme meant removing around 50 houses, which required negotiations and compensation for the property owners (Dutch Ministry of Water Management, Transport and Public Works, 2006b). The demolitions had the surprising effect of getting people more involved in the decision-making process; many submitted their suggestions on how to make the waterfront more attractive. According to Mr. Meulepas, Room for the River project manager, “it was important for them to participate, and it became their own plan." (Scientific American, 2012).

**Box 4. Room for the River Project Lent-Nijmegen Site (continued)**

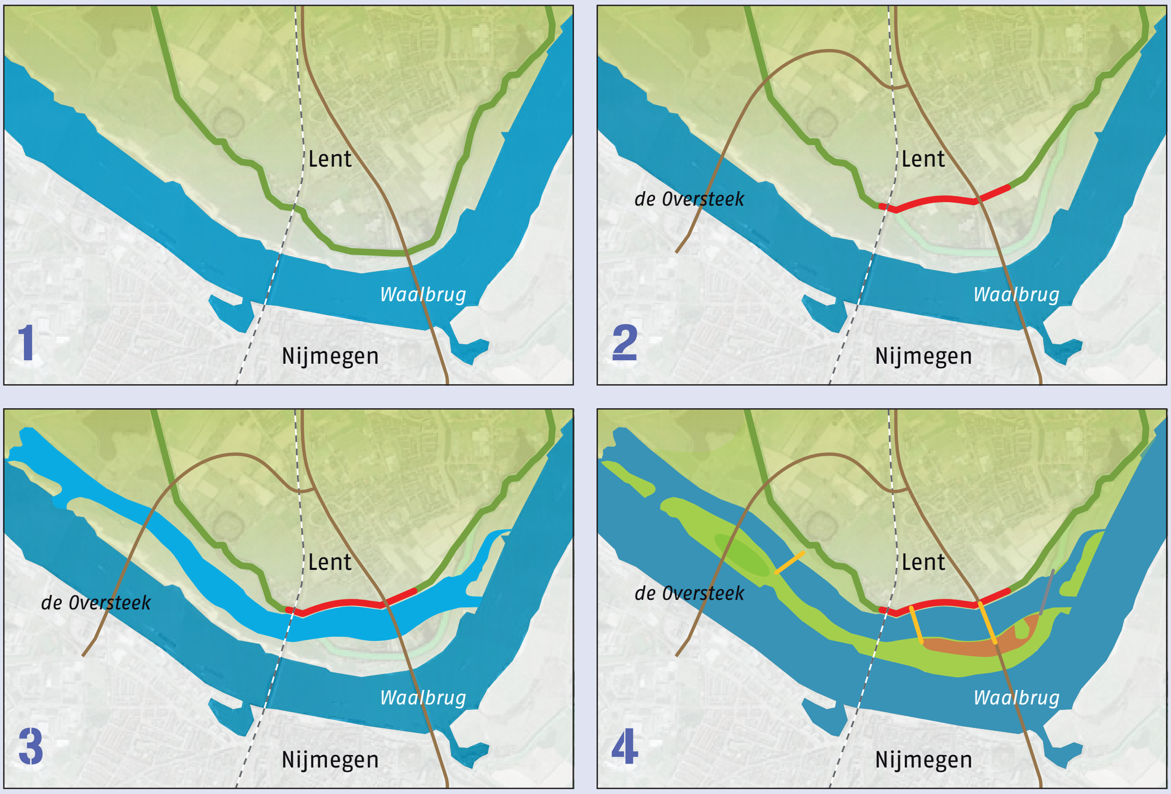



**Figure 6. The different stages of the Lent-Nijmegen project: (1) Initial situation showing the location of the dike before constructions began (green line); (2) The part of the dike closest to the river bend will be moved 350 m inland (red line); (3) A high-water channel (light blue) will be dug, thus creating an island in the middle of the Waal; (4) Bridges (yellow lines) will be constructed to connect Lent with the island- This new water feature will have beaches, recreation areas as well as floodplains**
(Dutch Ministry of Water Management, Transport and Public Works, 2011b)

**Figure 7. Computer rendering of the Lent-Nijmegen project site after implementation of the measures**
(Kingdom of the Netherlands, 2011)

## 5. Implications for Ecosystem-based DRR

The Room for the River Programme is providing local and international visibility to ecosystem-based DRR approaches (Biesboer, 2012). Once completed, it will demonstrate that ecosystem-based measures to flood risk reduction can go hand-in-hand with spatial and environmental development. Restored wetlands and floodplains will not only regulate the rivers' flow rates, but will also encourage wildlife habitats and breeding grounds along the rivers (Estrella & Saalismaa, 2013). This will attract nature enthusiasts, water sports aficionados, and businesses that will further invigorate the river waterfronts. The whole process also raised public awareness on alternatives to traditional dike improvement. Furthermore, Dutch agencies working on conserving nature and biodiversity are becoming more and more engaged in the water management arena (Wiering & Arts, 2006). The integrated approach taken by the governing bodies of the Programme assured the sustainability of the project. Negotiated solutions meant that the measures were accepted and adopted by the local inhabitants (Scientific American, 2012). Taking into account the recommendations and opinions of the local communities concerned is an example of making use of local knowledge in selecting the best measures to implement.

## Strengths and weaknesses

The Room for the River programme, despite being a good initiative that incorporates an ecological aspect to flood management, is not beyond criticism. For one, the project has a high cost. Opponents of the programme argued that traditional dike enhancement would have been less costly (in the short-term) than the 2.3 billion Euro project. According to the study conducted by the Dutch Central Planning Bureau, river widening costs would be 1.5 times more expensive than dike improvements (Biesboer, 2012). The other drawback of the programme is the demolition of houses and loss of some animal habitats. Providing more room for the rivers entails removal of 125 dwellings and the elimination of 12.8 $km^2$ of agricultural land, not to mention the tons of contaminated soil which will be moved. Increasing the height of the dikes would have also been an easier fit easier in infrastructure planning (Explanatory Memorandum, 2013). Moreover, some components of the basic packages negatively impact natural habitats. In one of the sites along the River IJssel, 20 $km^2$ of feeding area for herbivorous waterfowl will need to be transformed, although into a more dynamic riverfront area for more recreational activities.

However, the programme also has a number of corresponding strengths. For instance, the measures will allow a more sustainable alternative to river discharge level reduction than dike reinforcement. Project sites which will restore former floodplains or the construction of high-water channels will compensate for the loss of feeding and breeding grounds in other project sites where these areas will be affected. In addition, the spatial measures favour conditions of habitat types like water vegetation, species-rich marsh brushwood and hay meadows (Dutch Delta Programme, 2006b). The government will also compensate lost agricultural lands and private properties and help in the relocation of families and businesses (Dutch Delta Programme, 2006b).

Public engagement and close collaborations between political levels have been essential in achieving community support. Instead of imposing the measures, authorities in the national level tried to reach consensus through consultations. The recommendations of the local authorities and inhabitants, albeit not always accepted by the national government, were at least solicited at different stages and were subject to deliberations. Lastly, the programme is also based on science and applied research which makes for evidence-based decision and policy-making.

# 6. Lessons learned and conclusions

The Room for the River Programme demonstrates the contributions of wetlands to flood risk management as well as to the biodiversity, economic prosperity and overall environmental quality of the Dutch riverine region. However, while floodplain restoration and other interventions that create more room for the rivers are the preferred measures, pragmatism dictates a more hybrid approach where structural solutions still come as a last resort to lowering river discharge levels. Bas Jonkman, Professor of Engineering at TU Delft endorses the Room for the River Programme. For him, it is proof that "great solutions can be created by bringing together the spatial and technical/hydraulic engineering designs" (Biesboer, 2012). Consultations with the public are considered as one of the strong points of this programme (Rijke et al., 2012). They improve the quality of the decisions taken by "seeking legitimate, feasible, and context-specific solutions" (Huitema et al., 2009). Solutions reached through consensus are less likely to encounter resistance among the local population. As programme director, Ingwer de Boer, points out, participation in the determination of the measures made the different stakeholders "co-owners" of this plan (Biesboer, 2012).

The Room for the River programme is part of the gradual, but continuous transition being led by the Dutch government from traditional engineered structures to more ecosystem-based approaches. This strategy offers the opportunity for communities to accommodate and live with the water rather than to contain it in increasingly smaller spaces. However, such approaches remain in the margins as compared to traditional approaches for flood control (e.g. building dikes, polders, sluices, and storm surge barriers). As with any change, this shift in mentality takes time.

Sceptics and proponents of this programme, both in the Netherlands and abroad are following its progress closely. If successful in terms of flood risk reduction, similar approaches to the Room for the River programme could be scaled-up and re-applied to other areas of the world, such as New York (Better Cities Now, 2013).

## 7. Exercise and teaching notes

1. Among the measures mentioned in box 2, which ones truly provide more space for the rivers to flow in order to reduce flood risk?

2. What is the Dutch government's basis for opting for river widening solutions rather than dike reinforcement?

3. One of the measures being implemented in the Merwedes, Bergsche Maas, Amer, Rhine-Maas estuary region is the depoldering of the Noordwaard, a reclaimed agricultural area which used to be part of the Biesbosch National Park (see Figure 7, adapted from Dutch Ministry of Infrastructure and the Environment, 2012).

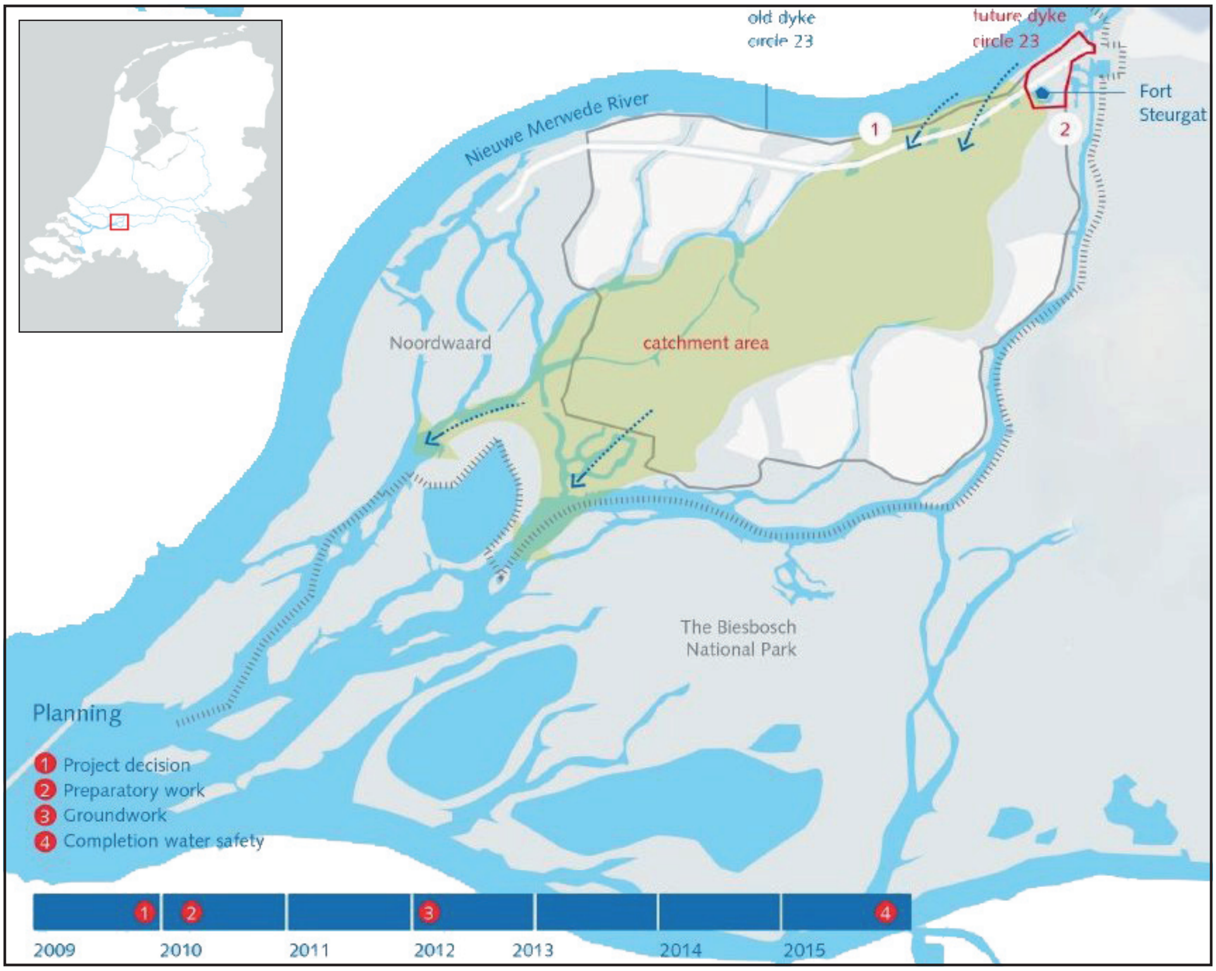



**Figure 8. Map of project area showing the Noordwaard polder (protected by a dyke circle represented by the grey outline) and the Biesbosch National Park (shaded area in grey). Areas in white are flood-free zones. Only the area shaded in yellow will be flooded in times of high discharges from the Nieuwe Merwede River** (source: adapted from Dutch Ministry of Infrastructure and the Environment, 2012)**.**
**This solution will effectively increase floodplain and reduce river flood risk in surrounding areas up to a certain extent, as sea level has a bigger influence than river discharge in flood levels in this part of the delta** (Dutch Ministry of Water Management, Transport and Public Works, 2006b)

This strategy will provide extra flood space and allow water to flow faster out to sea in times of high river discharge, thus reducing flood levels near the city of Dordrecht, part of dynamic conurbation of the *Randstad*, in the northwest of the national park (Dutch Ministry of Water Management, Transport and Public Works, 2006b). The catchment area (indicated in yellow in Figure 7) will only be inundated at certain times of the year and thus could be partly used for cattle grazing during periods of low water levels. Residents and farmers with properties outside of this floodplain may continue to live and work on existing or newly constructed mounds (Dutch Ministry of Infrastructure and the Environment, 2012).

a. During the decision-making stage of the programme, what has been essential to the acceptance of the measures by all actor and stakeholders involved?

b. Had you been a member of the Room for the River committee, which arguments would you have chosen to convince local residents and farmers that depolderisation is the most suitable option to manage flood risk in the Dordrecht area (*Enumerate the potential strengths and benefits of the measure*)? Consider the possible drawbacks and suggest ways to compensate for them.

*Teacher's notes: This exercise aims to make participants understand and apply the strategy used by Dutch authorities in the Room for the River programme by putting them in the role of a public official. Question 3, in particular, is meant to demonstrate the importance of negotiated solutions with all stakeholders. This exercise teaches them to think of concerns local people may have and the ways to promote the measure to be implemented in their municipality.*

## Answers

1. Among the measures mentioned in box 2, which ones truly provide more space for the rivers to flow in order to reduce flood risk?

Deepening the summer bed, dike relocation, depoldering, lowering of floodplains, removal of obstacles, lowering groynes, building high-water channels. Water retention ponds are meant for temporary storage and will not contribute to increase in floodplains ***per se***. Moreover, water storage, along with dike reinforcement, is considered as alternative measures where creating more space is not feasible.

2. What is the Dutch government's rationale for opting for river widening solutions rather than dike reinforcement?

   Dike strengthening and height increase will aggravate land subsidence and will potentially cause greater damage in case of breach. Moreover, as precipitation and river discharge increase, reinforcement will be too costly to become sustainable and will have adverse effects on the beauty of the landscape.

3a. During the decision-making stage of the programme, what has been essential to the acceptance of the measures by all actor and stakeholders involved?

   Public and administrative consultations.

3b. Had you been a member of the Room for the River committee, which arguments would you have chosen to convince local residents and farmers that depolderisation is the most suitable option to manage flood risk in the Dordrecht area (*Enumerate the potential strengths and benefits of the measure*)? Consider the possible drawbacks and suggest ways to compensate for them.

   Benefits:

   - A more sustainable and effective way to reduce water levels
   - Increased safety
   - Partial restoration of the Biesbosch national park
   - The remaining lands of the former polder on existing or new constructed mounds could still inhabited by local residents or exploited by farmers

   Drawbacks:

   - High costs; in the long term, it will be less costly than regularly reinforcing dikes as water level rises. River widening also decreases the risk of damage in case of flooding and dike failure.

- Loss of valuable agricultural lands and destruction of some private homes; compensation and relocation assistance are provided by the government. The catchment area can still be used for grazing when it is not flooded.

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## Endnotes

1 To know more on the EU's Habitats Directive, visit: *http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm*

# Case Study 4

## Integrated Water Resource Management (IWRM) Tacaná Watersheds, Guatemala – Mexico

## 1. Overview

| | |
|---|---|
| **Outline** | This case study features the IUCN Tacaná Project, an integrated water resources management initiative which focused on the watersheds on the border between Guatemala and Mexico. It begins with a background of the project and the problem statement followed by a presentation of the different pilot projects and a discussion of the outcomes. |
| **Learning objectives** | • Understand the concept of IWRM and how it can reduce disaster risk<br>• Learn about the Tacaná pilot projects and their implementation<br>• See how the Tacaná watersheds project influenced policy, from the local to the transnational level |
| **Guidance** | Although this is a transboundary project, more emphasis is placed on the projects conducted in Guatemala<br><br>Highlight the link between IWRM and Eco-DRR |
| **Recommended reading** | IUCN, International Union for the Conservation of Nature, 2013. *Guatemala-Mexico Tacaná Project*. Gland: International Union for the Conservation of Nature IUCN.<br><br>Roy, D., Barr, J., and Venema H.D., 2011. *Ecosystem approaches in Integrated Water Resources Management (IWRM): A review of transboundary river basins*, United Nations Environment Programme (UNEP) and the International Institute for Sustainable Development.<br><br>Dalton, J., Murti, R. & Chandra, A., 2013. Utilizing integrated water resources management approaches to support disaster risk reduction. : F. Renaud, K. Sudmeier-Rieux & M. Estrella, éds. *The role of ecosystems in disaster risk reduction*. Geneva: United Nations University, pp. 248-269.<br><br>Other IWRM Projects led by IUCN – Water & Nature Initiative (accessible online: *http://www.waterandnature.org/en/results/project-results*). |

## 2. Background

| | |
|---|---|
| **Case study area** | Catchment basins of the Suchiate, Coatán, Cosalapa, and Cahoacán Rivers |
| **Country** | Guatemala, Mexico |
| **Ecosystems** | Forest (mountainous in the upper catchments near the Tacaná Volcano) |
| **Hazards** | Flood, Tropical storms and hurricanes, water shortage |

Launched in 2001, the Water and Nature Initiative (WANI) is the International Union for the Conservation of Nature's (IUCN) response to a call for concrete actions following the global agenda on water and development in 2000. Through a learning-by-doing process, it aims to "mainstream an ecosystem approach into catchment policies, planning and management". During the first phase of WANI which ran between 2001 and 2008, 12 pilot projects were set up to test implementation of integrated water resource management (IWRM) at river basin levels and to promote learning, partnership building and stakeholder empowerment needed to catalyze change (Smith, 2010; IUCN, 2012). The main premise is to demonstrate practical IWRM solutions by combining ecosystem services and security, good governance and stakeholder participation, economic development and sustainable financing and leadership and learning.

Under WANI, the "Integrated Management of Watersheds Associated with the Tacaná Volcano Guatemala-Mexico Project" (or Tacaná Project, for short) began in 2003 for an expected 4 years (IUCN, 2009(a); IUCN, 2012). The project covers an area of 3'170 km2 on the border between the department of San Marcos, Guatemala and the State of Chiapas, Mexico (Mazariegos & Illescas, 2010) and encompasses the Tacaná watersheds comprising of the catchment basins of the Suchiate and Coatán rivers, which originate on the slopes of the Tacaná volcano and span along rivers towards Mexico, and the basins of the Cosalapa and Cahoacán rivers located

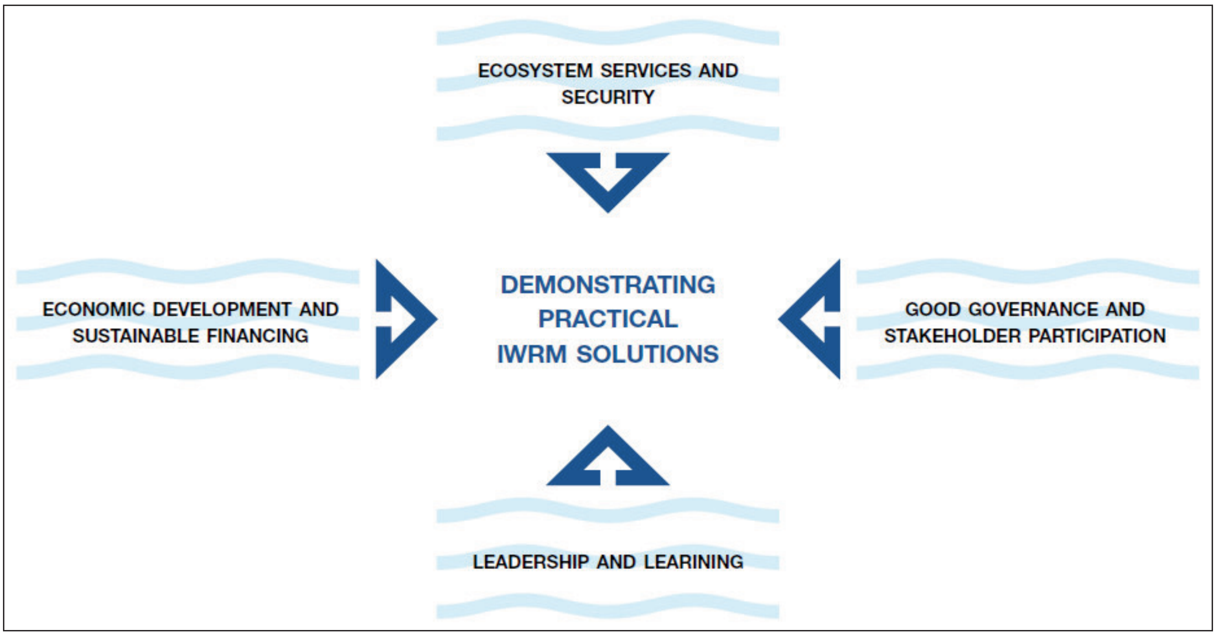


**Figure 1 Elements of the WANI Programme** Source: IUCN, 2012

**Box 1. IWRM and the ecosystem approach**

Integrated Water Resource Management (IWRM) is "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (Convention on Biological Diversity, 2000; Cap-Net/UNDP, Nile IWRM-Net, UNISDR & UNOCHA, 2009).

IWRM is a flexible strategy which adapts to the country or political level to which it is applied. Although there is no fixed framework to IWRM, its founding principles – efficiency, equity, and environmental sustainability – remain the same (Roy et al., 2011).

This approach provides multiple benefits for nature as well as for society (Smith, 2010). The environment becomes a part of decision making and its inclusion attracts more investment in its restoration and conservation. This approach supports social inclusion by inviting various stakeholders to take part in the decision process and better governance. It also encourages innovation and learning as it proceeds by learning by practice and the generated knowledge is shared and replicated. While its inclusiveness adds complexity to IWRM, success of an ecosystem approach will demonstrate that even complex situations are manageable. Finally, IWRM based on ecosystem management enhances resilience in a sustainable manner (Smith, 2010).

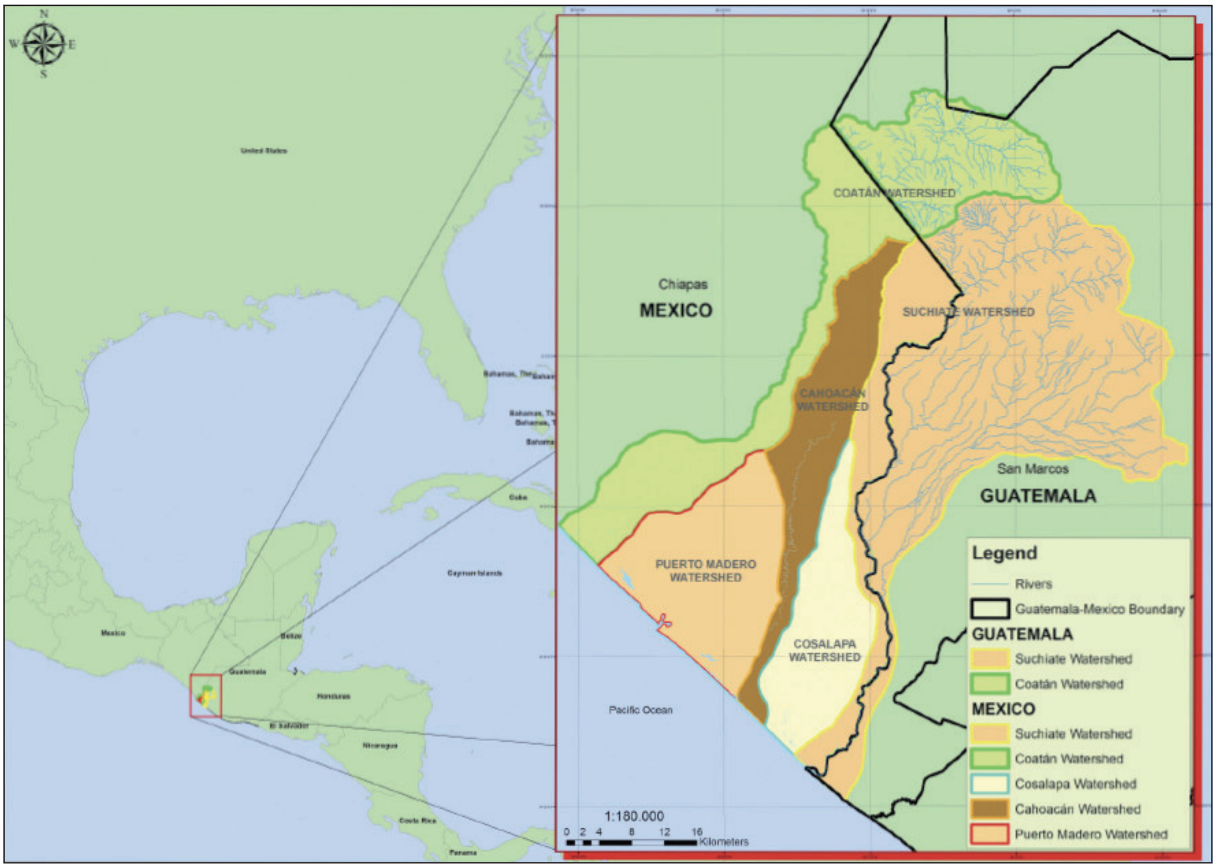


**Figure 2 Map of the Tacaná watersheds** Source: IUCN / Mario Rodriguez

entirely within Mexico (see Fig.1, (IUCN, 2012)). The watersheds are important for both domestic and livelihood purposes as they supply water to households and provide irrigation for agriculture. The region is major producer of coffee and is renowned for its biological produce (IUCN, 2009(a)). Livestock production and fishing are also important for local livelihoods (IUCN, 2009; IUCN, 2012).

## 3. Problem statement

Environmental degradation, deforestation and improper land use have weakened the soil structure and have reduced the ability of the watersheds to retain water. Large-scale farming for cash crops such as sugarcane, banana, and African palm has polluted the soil and water, while poor farmers have cleared forests in higher parts of the catchments to cultivate small farms (IUCN, 2012). As a result, this area of rugged landscape suffered from severe soil erosion, flooding and mudslides during strong tropical storms and hurricanes (IUCN, 2009; IUCN, 2012). Moreover, increased stress on water resources due to high population density and extreme climate events also has restraining effects on livelihoods. Water scarcity during the dry season severely affects agricultural activities in this area and contributes to worsening the economic situation of one of the poorest provinces in Guatemala (Mazariegos & Illescas, 2010).

Lack of coordination between the local authorities and the national government resulted in weak governmental presence, uncoordinated policies, inadequate water laws and regulations, complex land rights system, budget restrictions, low stakeholder participation, little or no community organization, and limited transparency (IUCN, 2012). Despite having shared watercourses, no transboundary water management body existed between Guatemala and Mexico and local Mexican water councils had restricted capacity to implement law and policies regarding water resources (IUCN, 2012).

## 4. Measures implemented

### Rationale

Started in 2003, the Tacaná Project's main objective was to restore degraded watersheds and in the process, secure water supply to local residents and farmers and reduce flood risk (IUCN, 2009).

The general objective of the Tacaná watersheds projects was to optimize the benefits provided by freshwater, soils and ecosystems associated with populations in the project's area of influence as their intrinsic values are conserved and restored (IUCN, 2009(a)). Specifically, it aims to:

1. "Consolidate mechanisms for coordination and management of water resources under the comprehensive approach;
2. Gather information for comprehensive catchment management plans;
3. Implement a strategy for raising awareness and information sharing;
4. Build strategic alliances for the implementation of management plans in the short, medium and long-term;
5. Initiate pilot activities to implement priorities of the management plans" (IUCN, 2009(a)).

## Main components of the project

The Tacaná Project made several interventions at the local, departmental, national and even transnational levels which worked on environmental conservation, education and advocacy, livelihood support and building capacity for improved water governance (IUCN, 2012).

## Project details

### Community pilot projects

WANI and partners helped design pilot projects which enhanced livelihood security while addressing water, soil and environmental conservation. 86 pilot projects in Guatemala and 21 in Mexico were led by community groups whose members are 90% women. Examples cited in IUCN (2012) include:

**Box 2 Pilot projects in the San Pablo - Suchiate River Midlands Micro-Watershed**

The village of Tojoj in the town in San Pablo, Guatemala, located in the mid-section of the Suchiate River watershed, suffers from a chronic lack of tap water. In order to get supply, hoses run from the nearest source of water to each individual home. In October 2005, Tropical Storm Stan washed away 3'800 meters of hoses in the village. The Tacaná project helped facilitate donation transfer from the Dutch Embassy in Guatemala and directed the reconstruction project. It also negotiated with suppliers and provided materials. In addition to building a proper water distribution system, water treatment tanks to filter contaminated effluent from coffee bean processing were also installed. A nursery expected to produce more than 30'000 tree saplings for reforestation was also built.

These initiatives allowed for locals to become more involved in the development of their own community. Residents often volunteered and were interested in discussions on water conservation and reforestation. As one community leader aptly puts it, the pilot projects have been opportunities "[to gain] more income while at the same time preserving the forest and saving water."

(source: IUCN, *Guatemala – San Pablo-Suchiate River Midlands Micro-Watershed, http://www.waterandnature.org/en/resources/story-gallery/practical-stories-mesoamerica/ca6-guatemala-san-pablo-suchiate-river-midland*)

**Figure 3. Children helping with the construction of the water distribution system in Guatemala** Source: Taco Anema / IUCN, 2005

- Forest nurseries and promotion of agroforestry, with18 forestry and soil conservation demonstrations and 122 management plans for conservation of community forests;
- 10 pilot projects facilitating the development and interaction between cooperatives and community enterprises in beekeeping, fish farming, and butterfly farm ecotourism;
- Community gardens and organic farming, including demonstrations of organic fertilizer production at composting centers;
- Establishment of a training centers in Chiapas, Mexico for integrated watershed management;
- Production of edible mushrooms which improves both food and livelihood security;
- Support the building of a water treatment plant where ways to reduce wastewater in coffee bean processing were endorsed.

The activity brought by these pilot projects in these communities provided the incentive to form micro-watershed councils (IUCN, 2012).

**Figure 4. 3D map of micro-watershed councils**
Source: IUCN, 2009

**Creation of water governance bodies**

In Guatemala and Mexico, communities living in the Tacaná watersheds have organized themselves into micro-watershed councils to coordinate the management of shared water and land resources and support community development (IUCN, 2012). These watershed councils establish plans which help recognize, prioritize and design projects for sustainable use of water resources and thus improve local water governance (IUCN, 2012). Residents, farmers and local government members are integral parts of this integrated approach to tackle common water issues. One of the councils' pilot projects included small scale coffee farmers from the mid-section of the Suchiate river in the plans to improve organic plantations and reduce wastewater during the coffee bean processing (IUCN, 2012). Micro-watershed councils join forces to intervene in various levels of watershed management (IUCN, 2012).

In addition to micro-watershed councils, 16 governmental and non-governmental organizations formed the Inter-Institutional Coordinating Body for Natural Resources and the Environment of San Marcos or CORNASAM (IUCN-WANI(c), s.d.). This new governing entity operates at the department level and has been coordinating outreach and training in micro-watershed management (IUCN, 2012). A similar committee was formed to coordinate water management between municipalities along the Coatán River in Mexico.

The project is also backing the National Micro-Watershed Commission of Guatemala which has drafted national water policies and guides for community engagement in watershed management plans (IUCN, 2012). In Mexico, the Chiapas council on watersheds and the National Water Commission initiated a forum for dialogue which recognizes the Chiapas State as a role model in implementing the new water law which decentralizes water management in the country.

**Jovenes en mission (Youth on a Mission)**

In San Marcos, the Tacaná Project played a key role in the expansion of ***Jóvenes en la Missión*** (Youth on a Mission, JEM) from an environmental education initiative to a youth-run cooperative enterprise (IUCN, 2012). Established in 2003 with the motto "United for Water", JEM advocates for sustainable water use, leads watershed restoration activities, and enhances capacity for water governance (IUCN, 2012). A reforestation project has improved water supply for more than 800 people in the Esquiche watershed. JEM also established a virtual platform to reinforce collaboration on projects along the borders of Guatemala and Mexico. With the assistance from the Tacaná Project, JEM became a registered NGO and has obtained funding for their income-generating projects. In 2006, JEM received a US$ 75'000 loan to build 19 greenhouses with drip irrigation to produce various flowers and vegetables (IUCN-WANI(a), s.d.). Through their initiatives, JEM has become part of the youth movement participating in climate change and water-related activities at local and national levels (IUCN, 2012).

**Locally available knowledge and training**

Several examples demonstrate the spread of knowledge on IWRM in Guatemala. As part of the Tacaná watersheds project, virtual water resources libraries in the town halls of five municipalities in Mexico were established, providing up-to-date information on water resources and the environment.

In addition to a demonstration project entitled *Agua para el Futuro* ("Water for the Future"), a payment for ecosystem services (PES) process called *Fondo de Gestión Hídrica Participativa* or FOGESHIP was created in 2008 in Guatemala for the conservation and restoration of natural resources, especially water, in the Tacaná watersheds. With the support of local municipalities, the water fund will be financed through the adjustment of water rates in urban areas. By-products of the scheme include the systematization of national information on PES, a glossary of PES-related terminology, and the development of an online training course on PES[1] (IUCN, 2012). Guidelines for the development of micro-watershed management plans have been written and published at the national level. This document has been promoted by various high-level institutions as well as the FAO and IUCN among academic circles and political and technical establishments in Guatemala.

Lastly, WANI Concepts, approaches, and best practices have been incorporated into the University of San Carlos's curriculum through 10-month internships to produce a critical mass of professionals who will eventually implement what they have learned, thus creating a continuous learning feedback loop (IUCN, 2012).

## 5. Implications for Ecosystem-based DRR

Applying IWRM supports Eco-DRR and mitigates water-related disasters through its three main pillars: an enabling environment, an institutional and legal framework, and appropriate management of implementation tools (PEDRR, 2013).

The holistic IWRM approach considers the relationship between water and related resources as well as the impacts of interventions on different scales in order to design and implement efficient and sustainable measures. Reforestation and wastewater filtering pilot projects in the Tacaná watersheds are examples of such measures. Restoring and protecting forests increase wood supply for fuel and construction and enhances soil structure (IUCN-WANI(b), s.d.). The higher capacity of watersheds to hold water reduces flood risk and eases water shortage during the dry season. Lush forests also benefit farmers by enriching the soil and providing shade for coffee plants, while at the same time raising the value of their crops once their produce is certified as "bird-friendly coffee" (IUCN-WANI(b), s.d.). On the other hand, the water treatment tanks reduced groundwater pollution but also improved sanitation and reduced the risk of disease by eliminating the contaminated and pungent wastewater. The mulch from the tank filters can even be used to produce organic fertilizer (IUCN-WANI(b), s.d.). As for the longer term, reduced vulnerability of poor communities thanks to better and more sustainable livelihoods and lower risks of floods and landslides will allow them to better cope with storm-related disasters..

The Tacaná project has been instrumental in mainstreaming watershed management in development agenda across all levels. Through its support, water governance bodies were created and the institutional capacity to implement laws

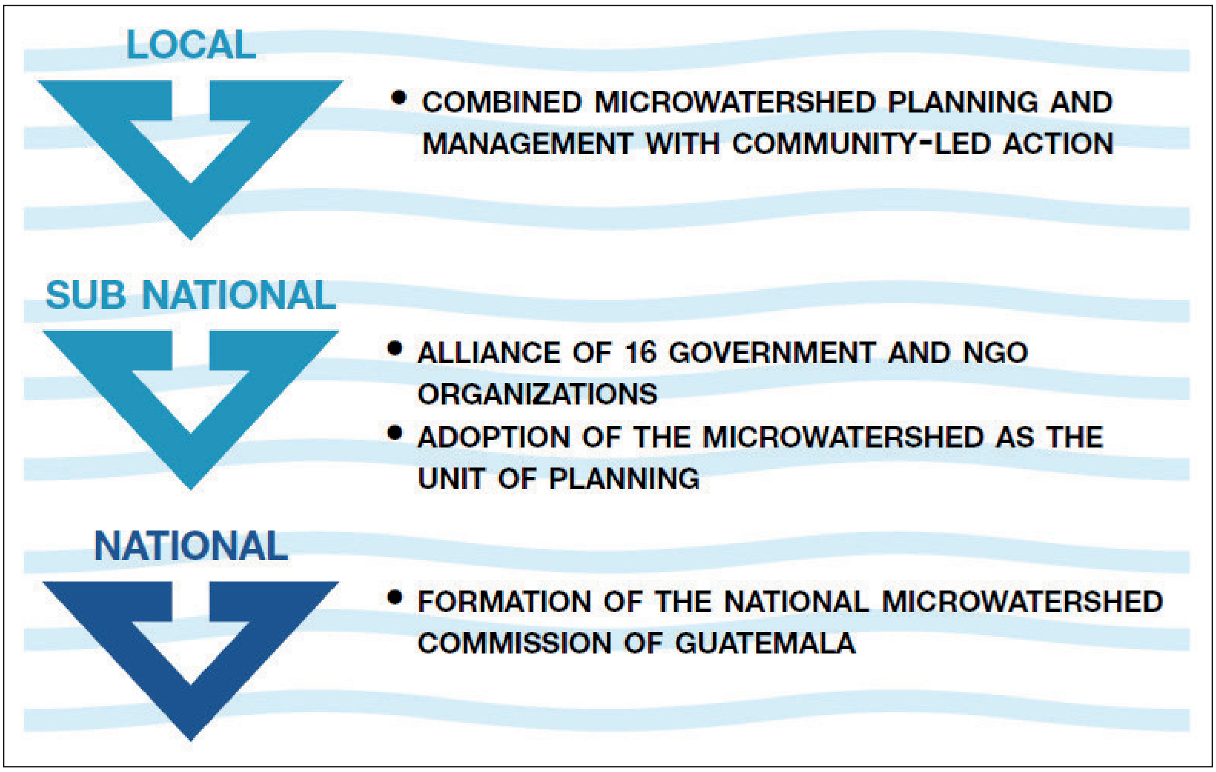


**Figure 5. Scaling up of interventions from the local to the national level for IWRM** Source: IUCN, 2012

and policies related to water management in Guatemala and Mexico were strengthened. Water management plans and guidelines have been drafted since and a new water law was passed in Mexico during the implementation of the projects. The initiative also facilitated networking between local committees and higher-level institutions as a means of compensating for the lack of vertical cooperation in water management (IUCN, 2012). Coordination between community development committees (COCODES) and municipal and development councils were initiated to integrate micro-watershed planning and management with community-led development (*see* Fig. 5 (IUCN, 2012))

The Tacaná watersheds project began its intervention on the transboundary level by convening the first bi-national forum to identify and discuss environmental problems in the Coátan and Suchiate basins. The forum culminated in the signing of the Tapachula Declaration of Intent in December 2006 where mayors of communities in Guatemala and Mexico pledged to cooperate in joint actions on watershed management (IUCN, 2012).

The reinforced institutional coordination in watershed management and development also proved beneficial in the aftermath of Tropical Storm Stan in 2005 which caused catastrophic flooding, property damages worth US$ 40 million, and numerous fatalities in San Marcos and Chiapas (IUCN, 2012). The Tacaná Project's extensive network connecting local community organizations, municipal governments and national ministries enabled rapid mobilization of resources, faster communication, post-disaster damage assessments, and organization of donor coordination (IUCN, 2012). The project coordinated reconstruction of water distribution systems in 78 communities through funding from the Dutch government. Work with various partners from different levels led to the development of a reconstruction plan for the department of San Marcos as well as disaster preparedness plans and mechanisms. The crisis also raised awareness among communities and governments about climate change which led to investment in capacity building and adaptation to reduce vulnerabilities to storms and flooding (IUCN, 2012).

Awareness campaigns and education initiatives have led to better recognition of the importance of protection and restoring watersheds in DRR and community development. The implementation of the pilot projects also showcased the added value of IWRM and has incited people, especially farmers, to adopt the ecosystem approach. Training and demonstrations increased the capacity of poor communities to improve their livelihoods and environment, thus effectively increasing resilience and boosting their overall well-being.

### Strengths and weaknesses

Integrated Water Resource Management is highly commended for its multiple benefits. By protecting nature, it also promotes social development and has the potential to reduce land-water related disaster risk. IWRM is an adaptive approach which has been tried and tested in various contexts (***see*** "Further reading" in Overview). Adhering to the principle of subsidiarity, IWRM favors a decentralized, bottom-up approach to dealing with water-related issues.

Close collaboration with local stakeholders from the private and public sectors is a defining quality of IWRM but which could also be a weakness as it could complicate planning processes and delay the implementation of measures. Nevertheless, negotiated solutions are more efficient, sustainable and often more acceptable to those concerned. According to Tacaná project staff members in Guatemala, elaborating on IWRM concepts, ensuring that the communities and local authorities are aware of the benefits of protecting natural resources to maintain the provision of water and local ecosystem goods and services, and emphasizing each person's responsibility towards the protection of water resources allowed the project to move forward. Collaboration with the locals was also facilitated by integrating environmental protection to livelihood development (IUCN-WANI, 2014).

With a long-term vision which takes the entire ecosystem into account, the Tacaná project ensured sustainability through the creation of water agencies, building partnerships, and involving political actors of all levels. WANI helped in the formation of micro-watershed councils, mainly composed of local citizens), as well as building their capacity in management fundraising. Their recognition by political authorities provided them access to government funding for their priority projects. The departmental entity CORNASAM regrouped and coordinated efforts and resources in San Marcos giving it more influence in the area and achieving optimized use of resources (IUCN-WANI, 2014). Reinforced links between partners on all levels enables faster responses during disasters (as was seen after the Tropical Storm Stan), avoids duplication of efforts and led to a more coordinated action to protect a common good: water.

## 6. Lessons learned and conclusions

The Tacaná Watersheds Project demonstrates the added value of IWRM in restoring degraded watersheds, building social and political alliances, and improving livelihoods (***see*** Fig. 6, (IUCN, 2012)). The other social benefits of the WANI project are also considerable. Integrating members of the local communities in the pilot projects led to stronger social cohesion (IUCN, 2012). Micro-watershed councils empower local women who now have the opportunity to participate in the development of their own community. Education and better environmental awareness makes people more inclined to favor ecosystem-based measures and become more prepared against future storms. Overall, it contributes to community resilience and their capacity to mitigate disaster risk.

Tropical Storm Stan in 2005 was the impetus needed for wider commitments to IWRM and water governance reforms. WANI's vast network of partners was instrumental in the rapid mobilization of resources immediately after the storm and during the recovery phase. However, the Tacaná Project is one of the few examples of IWRM initiatives which integrated a concrete DRR component by establishing disaster preparedness plans in addition to land restoration, livelihood improvement and governance capacity building.

From 2007, the Tacaná Project was funded by international donors who supported initiatives in both Guatemala and Mexico following best practices learned from WANI. After the project's completion in 2011, it is now up to local stakeholders and governments to pursue and build upon the work initiated by WANI in promoting intelligent use of

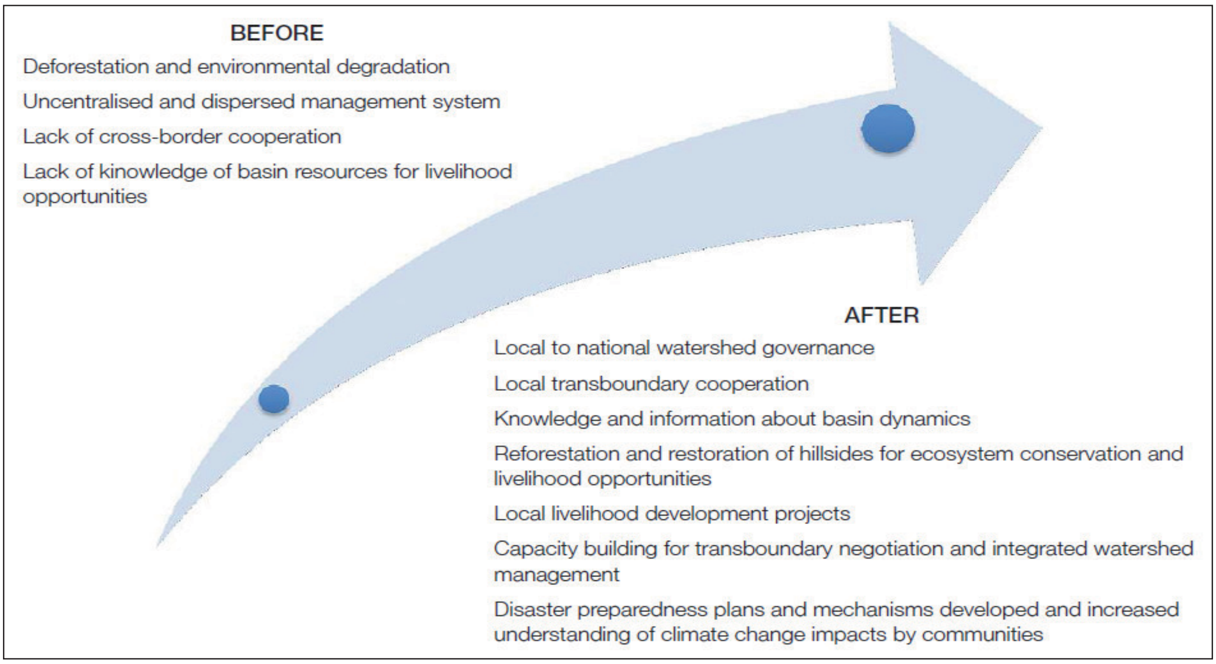


**Figure 6. The situation prior to and after the conclusion of the Tacaná watersheds project** Source: IUCN, 2012

water resources through ecosystem preservation, DRR, and sustainable livelihood development.

## 7. Exercise and teaching notes

*Instructor's notes: This exercise focuses on IWRM and its contribution to Eco-DRR. The answers can be found in the case study. Estimated duration of the exercise: 30 minutes.*

1. Why is an integrated approach important to managing water resources?
2. Based on the case study, in what ways did the WANI Tacaná Project contribute to disaster risk reduction?
3. What elements ensured the sustainability of the project?

### Answers

1. Why is an integrated approach important to managing water resources?

   Sample answer: A holistic approach allows to choose measures which have the least negative effect on the other components of the ecosystem.

2. Based on the case study, in what ways did the WANI Tacaná Project contribute to disaster risk reduction?

   - Reforestation projects and land restoration initiatives increase soil structure and improved the watersheds' ability to hold and store water.
   - Water treatment tanks eliminate the risk of disease spreading.
   - It helped develop livelihoods in poor communities.
   - Disaster management plans and mechanisms were made after Tropical Storm Stan in 2005.
   - Water-related plans and policies where adopted in the time of the project.
   - A proper water distribution system was set up in Tojoj to avoid being swept away.
   - Better watershed management by supporting the creation of water governing bodies and increased their capacity to manage water resources.
   - Increased vertical coordination between institutions, which could prove valuable prior to, during and after a disaster.

3. What elements ensured the sustainability of the project?

Integration of stakeholders in the project, creation of watershed councils and committees among the population, building capacity for self-governance.

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## Endnotes

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# Case Study 5

## Linkages between DRR and CCA
## Burkina Faso – Niger

## 1. Overview

| | |
|---|---|
| **Outline** | This case study on sustainable dryland management showcases innovations in traditional soil and water conservation and agroforestry techniques. It demonstrates how such approaches have helped to increase food production and rehabilitate degraded lands in the Central Plateau of Burkina Faso and the Marandi and Zinder regions of southern Niger. |
| **Learning objectives** | • Learn the techniques used to successfully rehabilitate degraded soils and increase vegetation cover in the Sahel drylands<br>• Discover how actors promoted their innovations, shared knowledge and experience, and scaled-up projects from local to regional level<br>• Understand the link between disaster risk reduction and climate change adaptation |
| **Guidance** | The Burkina Faso – Niger case study features improvements of traditional soil and water conservation practices (zaï and contour bunds) and a woodland management technique (FMNR). General guidelines on how to implement these measures are explained. The results of these innovations on disaster risk reduction and climate change adaption are also discussed. |
| **Recommended reading** | Turnbull M., Sterrett C., Hilleboe A., 2013. *Toward resilience: a guide to disaster risk reduction and climate change adaptation.* Warwickshire, Practical Action Publishing Ltd, pp. 11-16 and 111-124.<br>United Nations Convention to Combat Desertification, 2012. *Desertification: a visual synthesis*, Bonn, UNCCD Publications. |

## 2. Background

| | |
|---|---|
| **Case study area** | Central Plateau (Burkina Faso); Maradi and Zinder regions (Niger) |
| **Country** | Burkina Faso, Niger |
| **Ecosystems** | Drylands |
| **Hazards** | Drought, desertification |

The Central Plateau of Burkina Faso and the Maradi and Zinder regions of Southern Niger (see Fig. 1) are located in the Sahel, a narrow strip of semi-arid land between the Sahara desert to the north and the humid savannahs to the south. The region stretches from the Atlantic Ocean up to the Red Sea covering an area of approximately 3 million km$^2$ (Encyclopaedia Britannica, 2013; IRIN, 2008). This zone of transition is characterized by low annual precipitation of around 100-300 mm which falls between May and October (Wijkman & Timberlake, 1984). The Sahel drylands are one of the world's poorest regions and are currently inhabited by about 58 million people. Some living in the region survive through animal herding; however more than half of the working-age population are farmers who produce staple foods and cash crops such as sorghum, millet, and cowpea, groundnut, and cotton (IRIN, 2008).

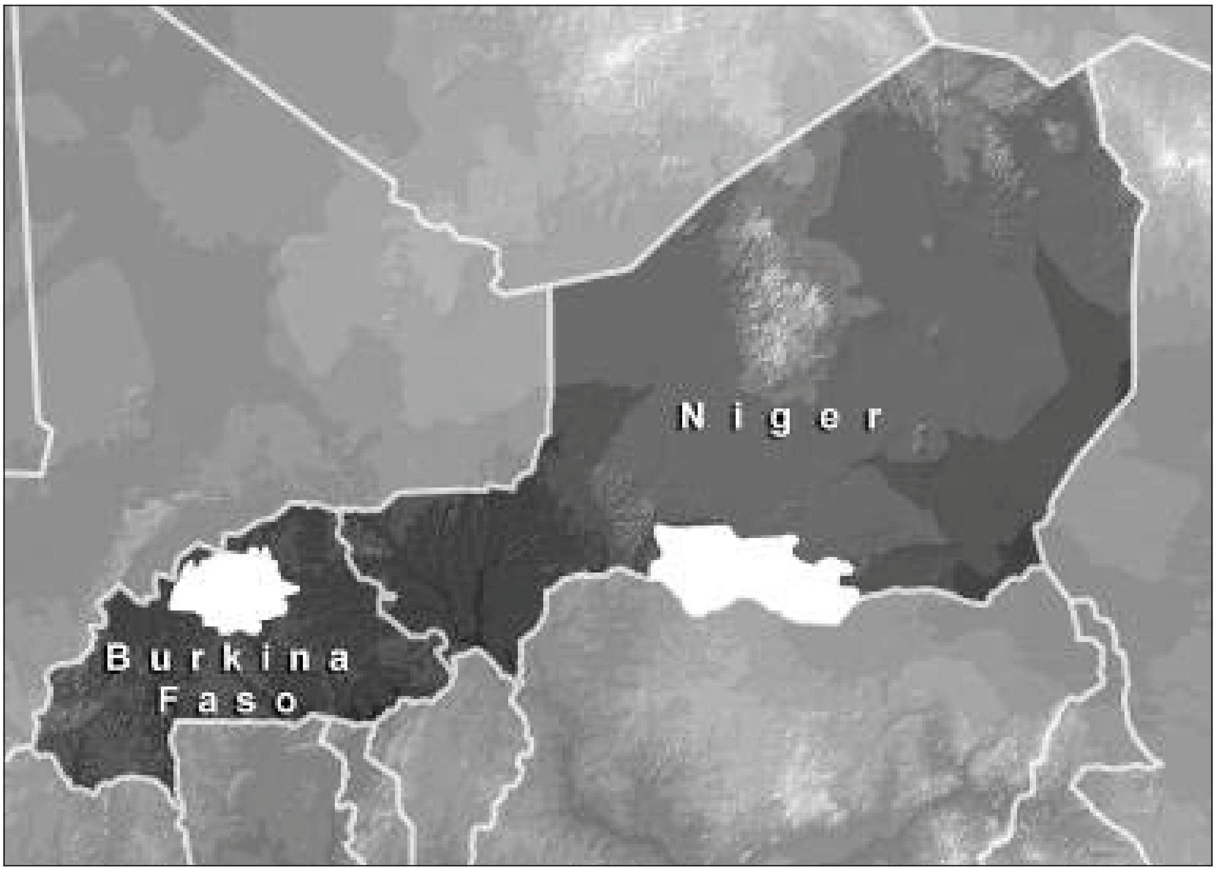


**Figure 1. Case study locations indicated in white: the central plateau of Burkina Faso and Maradi and Zinder regions in southern Niger** Source: Reij et al., 2009

## 3. Problem statement

Slow onset disasters such as drought and food insecurity have plagued the Sahelian drylands for many centuries. The high variability of water supply in the Sahel region has a direct impact on cereal production. Insufficient rainfall over prolonged periods of time results in diminished crop yields, water scarcity, and desertification. On the other hand, intense bursts of precipitation during the short rainy season can also destroy and wash away soil, newly planted seeds and crops, even whole villages, as seen in 2007 (IRIN, 2008). Scientists have observed pronounced peaks and troughs in the region's annual rainfall over the last forty years. Despite predictions of higher precipitations, results of most climate models show drylands becoming more arid in the future as evapotranspiration increases due to higher temperatures (Tacko Kandji et al., 2006; White & Nackoney, 2003).

Desertification refers to land degradation in arid, semi-arid and sub-humid regions due to climatic variations and human activities (UNCCD, 2012). Lower crop production is not the only environmental consequence of land degradation. Tree cover and water levels are also severely reduced. The loss of certain plant and animal species has also been attributed to desertification. Poor biodiversity means that plants and crops are more susceptible to pest attacks and therefore, become more prone to failure. Moreover, the Sahel region has one of the highest birth rates in the world. Rapid population growth, coupled with almost degraded farmlands, increases dependency on the land for food production and livelihoods. Increasingly aggressive means of harvesting the already scarce natural resources are being employed to meet the needs of millions of people. However, overgrazing, deforestation, shorter fallow periods, extension of agricultural activities to marginal areas contribute to further loss of soil fertility and a vicious cycle ensues (IRIN, 2008; Reij et al., 2009); according to the FAO (1995), about 80% of farmlands suffer from degradation. As the land degradation and the risk of famine intensify, men tend to search for work in urban areas in order to support themselves and their families. The lack of nearby water sources and surrounding vegetation forces women and children to travel longer distances to fetch water and gather firewood for cooking.

The worst Sahelian drought on record occurred between 1972 and 1984, which made 750'000 people in Mali, Niger and Mauritania dependent on food aid and led to an estimated 100'000 deaths (Wijkman & Timberlake, 1984). This disaster left dryland communities with two options: relocate to less drought-stricken areas or stay and find innovative solutions to fight desertification.

## 4. Measures implemented

Farmer-led initiatives to improve water availability restore soil fertility and increase vegetation cover began in the Central Plateau of Burkina Faso and in Southern Niger in the 1980s. Innovation and experimentation with traditional farming methods such as planting pits called *zaï,* contour stone bunds, and agroforestry techniques led to better crop yields, regeneration of tree cover, as well as other additional economic and environmental benefits stemming from better dryland management.

### Zaï

Planting pits, also locally known as ***tassa***, is a traditional farming method used to rehabilitate encrusted, degraded soils called ***zi-peele*** (World Bank, 2005). Improvements on this technique involve digging deeper and larger holes and adding organic matter and compost to enrich the soil. Starting in the dry season, farmers dig pits approximately 10-20 cm deep, 20-40 cm in diameter and spaced 80-120 cm apart. Removed soil is piled on the edge of each opening in a half moon shape to divert water into the pit (Fig. 2). The pits trap water and nutrients, including windblown sediments and organic matter. Attracted to the enriched soil, termites dig deep channels which aids in water and nutrient infiltration. Seeds are then planted in early June and the whole process is repeated the following year, except that new ***zaï*** are dug in between the old ones (UNESCO, 2003). The planting pits are not only beneficial in producing crops, but trees as well. An agroforestry system is possible as seeds are often found in the manure and compost used in ***zaï*** (Reij et al., 2009). Roose et al. (1993) have found that ***zaï*** works best in regions where annual rainfall is between 300 and 800 mm; insufficient rainfall may cause crop failure and too much raises the likelihood of the pits being waterlogged.

Farmer-organized market days and open-air fairs showcased the benefits of ***zaï*** and the tools used to dig the planting pits. These public events provided the occasion for farmers from more than 100 villages to discuss social and economic issues that affect them. Since 1992, ***zaï*** schools have also been established to promote and disseminate the novel techniques being used to increase crop yields. Knowledge transfer also occurred through farmer-to-farmer learning. Lead farmers taught fellow farmers and worked with them in the field. The exchange of ideas led to participating farmers experimenting with their own techniques. The personal satisfaction and higher social recognition are strong motivations for farmer-innovators to share their knowledge and experience to other farmers (Reij et al., 2009).

**Figure 2. Example of rehabilitated farmland with improved planting pits (zaï). In the foreground, a pile of organic matter to be placed in the pits** Source: Reij et al., 2009

## Contour stone bunds

Collaboration between local NGO technicians and farmers in the Yatenga region of Burkina Faso in the 1980s led to innovations in traditional stone bund building techniques. To increase effectiveness in harvesting rainwater and reducing soil erosion, the stones need to be placed as accurately as possible along the field's contours, i.e. imaginary lines of equal elevation. The key development was the introduction of a simple and low-cost (USD 6) hosepipe water level which was introduced to ensure correct alignment of the stones (Wright, 1985). The stones can be up to 20 cm thick with a base width of 35-40 cm (Fig. 3) and placing them 5 to 10 cm deep into the ground increases stability. The bunds are usually spaced 15 to 30 cm from each other. If stones are placed at equal height, the bund will allow even distribution of runoff throughout the field and better water infiltration into the soil (Reij et al., 2009). Excess water can trickle through the gaps and feed into other delimited areas. If the bunds are placed on a slope, farmers begin placing the bunds at the bottom of the slope and work upwards.

**Figure 3. Contour stone bund (left of the tree)**
Source: Reij et al., 2009

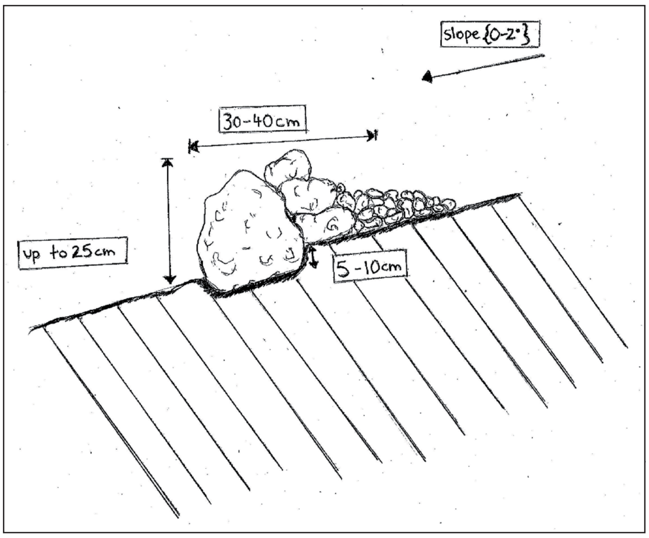


**Figure 4. Vertical section of a stone contour bund**
Source: Critchley et al., 1992

## Farmer-Managed Natural Regeneration

Since the 1980s, farmers in southern Niger have been successful in regenerating native trees and shrubs in what used to be barren farmlands through age-old woodland management methods (WRI, 2008). Farmer-Managed Natural Regeneration (FMNR), developed by Tony Rinaudo of the international NGO Serving in Mission in the 1970s and 1980s, involves several steps (Wright, 1985). First, farmers find and select tree stumps depending on the usefulness of the species with regards to producing food (or other tree products of commercial value), fuel wood, fodder or protection from the elements; for example, *Faidherbia albida*, locally known as *gao*, is highly favored for its benefits on soil fertility and fodder production (Reij et al., 2009). The tallest and straightest stems are then selected to be pruned and protected, while unwanted stems and side branches are removed. This is done regularly to avoid new sprouts from competing for resources with the selected stems.

Tree species which have the most chances of regeneration are those whose sprouting stumps and roots are already present in the field, whose seeds are already in the soil (albeit dormant until an event allows them to grow), and whose seeds can be found in livestock waste and bird droppings (Reij et al., 2009). In a study conducted in 2006, FMNR has been evaluated to be a "geographically extensive on-farm phenomenon" which works well with the sandy ferruginous soils of the Sahel (Adam et al., 2006). Researchers have also observed that FMNR is more successful in populated areas (Yamba et al., 2005). Scaling up from individual

**Figure 5. Drylands in the Zinder region of southern Niger regenerated through FMNR (taken February 2006)**
Source: Reij et al., 2009).
**Studies have shown that FMNR is all the more successful in rural areas with high population density**
(see Yamba et al., 2005; Raynaut, 2002)

farms to landscape level often required collective action. Farmer groups and village associations enabled organization of labor and allocation of usage rights and responsibilities (Reij et al., 2009).

## Strengths and weaknesses

There are many advantages to the innovations listed above. First, all three methods have been effective in rehabilitating the soil and generating crops in former degraded and barren farmlands. It has been estimated that over 200'000 ha of degraded land in the Central Plateau have been transformed through *zaï* and contour stone bund techniques over the last 30 years (Botoni & Reij, 2009). Through FMNR, farmers managed to grow entire parklands on a large scale. Analysis of high resolution satellite images of the Maradi and Zinder regions of Niger taken between 2003 and 2008 revealed a rehabilitated land area of approximately 4'828'500 ha, with a vegetation density of between 20 to 120 trees per hectare (WRI, 2008). Trees provide multiple environmental and economic benefits. They help reduce wind erosion, provide shade, and decrease evapotranspiration. They also produce fodder and allow more intensive on-farm livestock production (Reij et al., 2009). Tree products such as firewood, fruits, leaves, and medicine are harvested for personal consumption or sold to gain additional income.

Belemviré (2003) found that rehabilitated lands tend to be richer in biodiversity. In his study conducted in the Central Plateau, he observed that there are more tree species on regenerated farms than on control plots with degraded soil. The improved planting pit technique enables better water and nutrient retention which helps crops to survive dry spells (Ouedrago & Sawadogo, 2001). The capacity of *zaï* and contour stone bunds to retain moisture and FMNR's positive effect on water levels through land rehabilitation is particularly prized in this part of Africa where water is a very scarce resource. Higher groundwater recharge in villages where FMNR was adopted allowed locals to create vegetable patches around wells (Reij et al., 2009).

Increased yields have been observed in areas where the techniques have been adopted. *Zaï* and contour stone bunds have been proven effective individually (Kaboré & Reij, 2004; World Bank, 2005) but combining the two techniques further intensifies cereal production through time. Table 1 shows the results from two villages in Burkina Faso where farmers have adopted planting pits and contour stone bunds in their farms (see Table 1, adapted from Sawadogo, 2008).

**Table 1. Individual and combined impacts of *zaï* and contour stone bunds on cereal yields in two villages in Burkina Faso** (adapted from Sawadogo, 2008)

| Village | No intervention (kg/ha) | Zai (kg/ha) | Yield increase (kg/ha) | Contour stone bunds (kg/ha) | Yield increase (kg/ha) | Stone bunds + zaï (kg/ha) | Yield increase (kg/ha) |
|---|---|---|---|---|---|---|---|
| **Ziga** | 434 | 772 | +346 | 574 | +130 | 956 | +522 |
| **Ranawa** | 376 | 804 | +428 | 531 | +155 | 922 | +546 |

The ever pressing need to feed the growing population renders the capacity to produce quick returns highly important. When properly implemented, *zaï* and contour stone bunds on degraded lands were known to produce crops within the first year of implementation, while farms which developed agroforestry systems through FMNR reported a 40% increase in crop yield after the first year (Reij et al., 2009).

In addition to the rapid success of the practices, the simplicity of the techniques also makes them very attractive to other farmers. Replication occurred rapidly and naturally and the measures which began as pilot projects by individual farmers were soon adopted by entire villages. Knowledge transfer was facilitated through the support of government authorities, farmer groups, village associations, NGOs and international donors. Personal satisfaction and higher social recognition were strong motivations for "farmer-innovators" to share their knowledge and experience (Reij et al., 2009).

Cost-effectiveness of the measures is also one of their many strong points. The farming tools used (e.g. shovel, pick, manure, and hosepipe water level for contour stone bunds) and building materials (e.g. stones) are fairly cheap and widely available. FMNR has been more successful in regenerating entire forests than tree planting projects and for a fraction of the cost of maintaining tree nurseries (WRI, 2008). Weed removal costs are also lower in farmlands with improved planting pits (Reij et al., 2009).

Although general guidelines to implement these measures exist, farmers remain free to vary the dimensions and quantity of planting pits (including the amount of organic matter), stone bunds, or tree stumps according to their own capacities and needs (Hien & Ouedraogo, 2001). Lastly, the longevity of the innovation process and continuous usage of the practices demonstrates their sustainability (Reij et al., 2009). The techniques are well-adapted to their environment and the improvements were made by taking into account the availability of nearby resources.

The practices have nonetheless some weaknesses. Depending on the hardness of the soil and the size of the farmland to be rehabilitated, implementing these measures, especially *zaï*, could be labor-intensive. As a result, only well-off farmers who could hire labor would be able to exploit extensive stretches of land, thus deepening the divide between the rich and the poor (Reij et al., 2009). The popularity of building contour stone bunds as a water harvesting technique could lead to shortages in stone supply in the nearby area. Acquisition and transport costs would therefore be higher for farmers who adopt the technique. Readjustment of the stones would also be needed due to silting behind the stone bunds. In the case of FMNR, lack of appropriate policy and legal protection against corrupt officials and tree theft could discourage farmers from adopting this method (Sendzimir et al., 2011).

## 5. Implications for Ecosystem-based DRR

Disaster Risk Reduction (DRR) practitioners are beginning to take future climate variations into account in their choice of measures to reduce disaster risk demonstrating the extent to which the boundaries between DRR and climate change adaptation (CCA) are overlapping. This forward-looking strategy avoids applying palliative solutions and ensures sustainability of the measures in the long term. The ecosystem-based practices mentioned above have contributed to reducing slow-onset disaster risk while effectively adapting to climate variations in the Sahel. The restoration of tree cover and soil fertility mitigated the effects of cyclic drought over time and allowed communities to cope with rising temperatures and low precipitations rates.

Rehabilitation of degraded farmlands improved food and livelihood security and renewed vegetation cover eventually led to higher water levels and a greater variety of tree species. Villages suffered less during food shortages as they were able to stockpile cereals during years of good harvest. Crop production increased to the point that farmers in Niger even began exporting their surplus harvests. In the Central Plateau and Maradi and Zinder regions of Niger, agriculture became a viable and stable source of income to the extent that men became less inclined to leave for urban areas and worked in farming instead. Women were among the main beneficiaries of this "green movement". They no longer needed to travel long distances to fetch firewood and water. Some use this gained time to engage in economic activities and better care for their families. Local women gained some financial independence by owning trees and selling their products at the market. This additional income can be used to buy cereals and diversify their diet in times of food scarcity.

## 6. Lessons learned and conclusions

This case study features an almost simultaneous farmer-led green movement in Burkina Faso and Niger which led to the restoration of dryland ecosystem's goods and services over time and allowed communities to cope with the harsh climate in the Sahel. It proves that desertification is a reversible phenomenon that can be achieved through correct and sustainable management of dryland ecosystems. The methods' simplicity, cost-effectiveness, and rapid returns are among the advantages that made them highly attractive to farmers who were otherwise afraid to try these pioneering techniques for fear of failure and social embarrassment. Necessity instigated farmers and NGO project staff to rethink and improve on traditional soil and water harvesting and tree regeneration methods and it is through the combined efforts with various other stakeholders – villages associations, farmer groups, local and international NGOs, multilateral donors and Burkinabe and Niger governments – that made rapid and widespread replication possible (Reij et al., 2009).

The landscape transformation was beneficial for local communities and increased their resilience against recurring drought. By improving the farmlands, they have prepared themselves against the effects of climate change with regards to future variations in temperature and precipitation in the Sahel. Poverty is considered both a cause and consequence of land degradation (UNCCD, 2012) and is known to be one of the sources for vulnerability towards disasters. Relieving poverty by promoting sustainable agricultural livelihoods will therefore ensure the protection and restoration of natural resources as we have seen in this example. Enabling political and social environments, such as the technical support from NGOs, funding and encouragement from donors and governments, and guarantee of usage rights, can help sustain innovation and ensure promotion of agricultural practices on a larger scale for many years to come.

## 7. Exercise and teaching notes

1. What were the conditions that convinced farmers to adopt the innovations mentioned in this case study?

2. What ensured the adoption and replication of the measures?

3. What were the three ways of transferring knowledge of improved ***zaï*** techniques from farmer to farmer?

4. In this case study, we have seen that disaster risk reduction and climate change adaptation can be achieved by fighting desertification through sustainable and ecosystem-based practices. Explain how these measures…
   - Increase population resilience?
   - Regenerate soil fertility?
   - Diversify production?
   - Control erosion?
   - Adapt to climate change?

5. Based on this case study, what are the differences between ecosystem-based disaster risk reduction and ecosystem-based climate change adaptation?

*Teaching notes: This exercise reviews some features of the improved dryland farming measures featured in the case study. It also meant to show these ecosystem-based approaches contribute to disaster risk reduction concepts.*

## Answers

1. What were the conditions that convinced farmers to adopt the farming innovations featured in this case study?

   Drought and food insecurity attributed to land degradation and climate change.

2. What ensured the adoption and replication of the measures by other farmers in the Sahel?

   - **Bottom-up approach:** The techniques resulted either from experimentations of the farmers themselves (zaï) or from collaboration between farmers and NGO technicians (stone contour bunds, FMNR).
   - **Quick results:** Crop production began (even in former barren farmlands) within a short period of time.
   - **Cost-effectiveness:** Techniques and tools used were cheap and simple and therefore easily replicated throughout Burkina Faso and Niger.
   - **Technical, financial and legislative backing:** Support from village associations, farmer groups, donors and government authorities encourage the use of these innovations through enabling the organization of labor, allocation of usage rights, responsibilities, protection from theft and funding.

3. What were the three ways of transferring knowledge of improved ***zai*** techniques from farmer to farmer?

   - *Zaï* demonstrations during market days and open fairs
   - *Zaï* schools
   - Farmer-to-farmer learning

4. In this case study, we have seen that disaster risk reduction and climate change adaptation can be achieved by fighting desertification through sustainable and ecosystem-based practices. Explain how these measures…

   - Increase population resilience?

     Through higher and better quality crop production. Due to their capacity to produce rapid results (within a year or so), the measures helped to fight famine and increase water levels. Along with food security, land regeneration provided sources of income to communities. Securing livelihood through farming and sale of tree products increased resilience of farmers and participating citizens since they were able to buy food and other basic necessities.

   - Regenerate soil fertility?

     In FMNR, the gao tree (Faidherbia albida) fixes the nitrate in the ground, thus enriching the soil. Compost and organic matter placed in zaï are also natural fertilizers that improve soil fertility. Reforestation and agroforestry systems, possible in all three cases, are also a way to restore degraded lands.

   - Diversify production?

     With higher water levels, farmers began diversifying their crops. On-farm trees also produce fodder which allows intensification of livestock production.

   - Control erosion?

     Contour stone bunds retain as much sediments as possible within the delimited area. The zaï trap windblown or water swept sediments. Enhanced vegetation cover also controls erosion. Trees, shrubs and crops stabilize the soil and prevent wind and water erosion.

   - Adapt to climate change?

     Enhanced tree density will contribute to lowering temperatures and decreasing evapotranspiration which dries up the soil. Vegetation cover maintains moisture in the ground and could maintain sufficient groundwater levels in times of drought.

5. Based on this case study, what are the differences between ecosystem-based disaster risk reduction and ecosystem-based climate change adaptation?

Although DRR and CCA are often discussed in different policy fora with few NGOs developing projects to address both DRR and CCA, the similarities between the two are greater than the differences. In the case of slow on-set disasters such as in Burkina Faso, the two are mostly the same.

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# Case Study 6

## Cost-benefit analysis
## City of Stamford, Connecticut, United States of America

## 1. Overview

| | |
|---|---|
| **Outline** | This case study features vegetated sand dunes enhanced with geotextile tubes, a soft engineering flood and storm surge prevention measure, as well as the methods used to identify it as the most suitable and sustainable short-term measure to increase beach resilience against coastal hazards. The case study take places in the city of Stamford, Connecticut, in the north-eastern coast of the United States. |
| **Learning objectives** | • Learn to conduct a multi-criteria and cost-benefit analysis to select the best option among a variety of flood and storm surge mitigation technologies.<br>• Learn more about soft engineering measures against coastal hazards, namely sand dunes, salt marshes and oyster beds. |
| **Guidance** | This case study is largely based on a report conducted by a group from Columbia University for the spatial planning authorities of the city of Stamford, Connecticut, wherein reinforced sand dunes have been recommended to reduce storm and flood damage, while preserving the recreational and aesthetic values of the beach parks. However, to increase resilience to coastal hazards in the long-term will require reducing exposure by relocating beach infrastructures and allowing the beach to retreat further inland. |
| **Recommended reading** | On identifying and quantifying costs and benefits in disaster risk management:<br>• Mechler, R., *Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries*, 2005, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Eschborn, Germany:<br>On assigning monetary value to ecosystem services:<br>• Department for Environment, Food and Rural Affairs (DEFRA UK), 2007. *An introductory guide to valuing ecosystem services*, London UK |

## 2. Background

| | |
|---|---|
| **Case study area** | Stamford, Connecticut |
| **Country** | United States of America |
| **Ecosystems** | Urbanized coastal area |
| **Hazards** | Flooding, erosion, storm surge |

The city of Stamford, Connecticut (41°05’48”N 73°33’08” W) is located on the northern Atlantic Coast of the United States. This densely populated city is home to numerous major corporations, making the city one of the country’s largest financial districts (The Daily Voice, 2013; State of Connecticut, 2013). It lies along the banks of the Long Island Sound. This estuary, known as Connecticut’s “largest and most important natural resource”, is inhabited by more than a hundred of species of fish and birds (Department of Energy & Environment, 2013). Stamford has a harbor and three beach parks (City of Stamford, 2013). One of them, Cove Island Park, includes two beaches, a salt marsh, intertidal mudflats, and a nesting ground for waterfowl (Connecticut Dept. of Energy & Environmental Protection (DEEP), 2013).

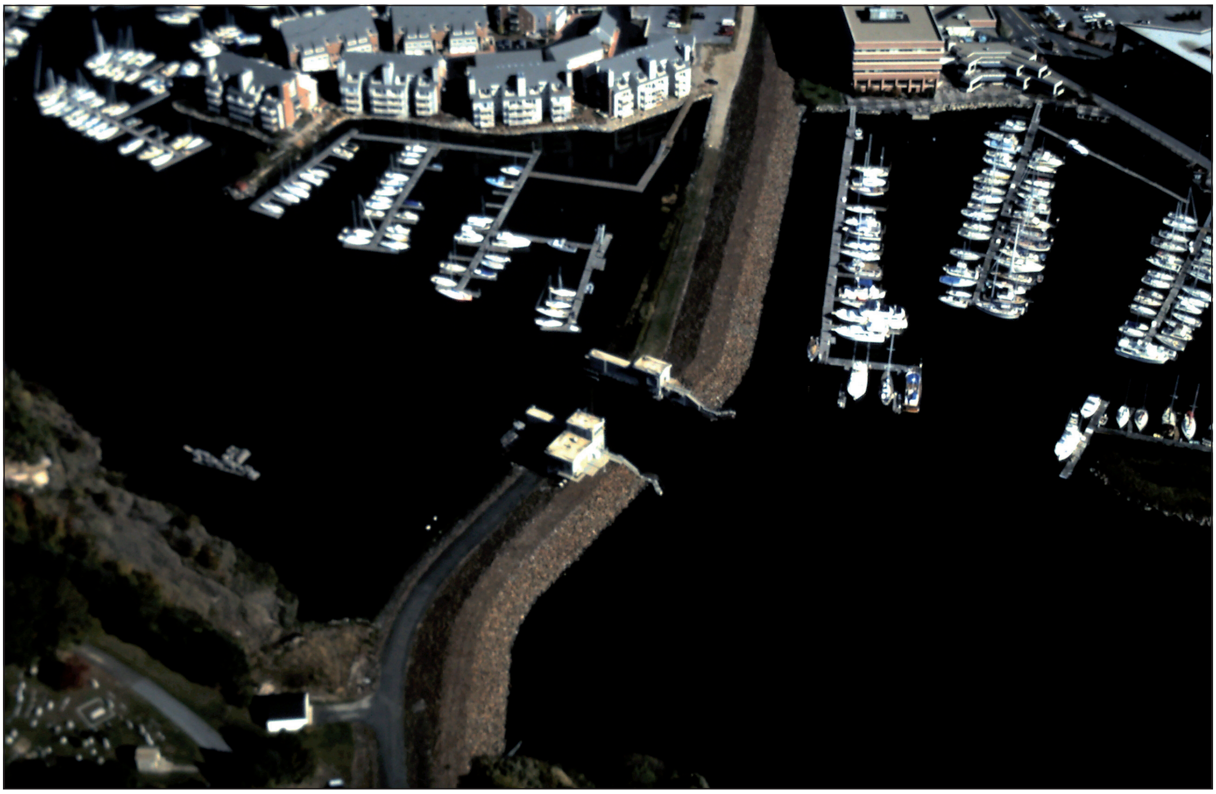

**Figure 1. Aerial view of the hurricane barrier in Stamford harbor taken by U.S. Army Corps of Engineers in 1986**
Source: Navarro, 2012

These parks also act as areas where people can relax and enjoy leisure activities.

In October 2012, Hurricane Sandy, considered one of the deadliest storms in United States history and the second costliest after Hurricane Katrina (Blake et al., 2012), hit the north-eastern U.S. Strong winds and high storm surge levels caused widespread flooding, power outages, wind damage and other impacts. New Jersey, where the hurricane made landfall, along with neighboring States of New York, Connecticut, Rhode Island, and Massachusetts were affected.

In Connecticut, storm surges as high as 9.83 feet (~3 meters) above normal tide levels were reported (Blake et al., 2012). A 17-foot-high (5.2 meters), a USD14.5-million hurricane barrier on Stamford Harbor, managed to block an 11-foot (3.4 meters) wave that protected the main commercial district, residential sections, and manufacturing plants of the city (U.S. Army Corps of Engineers, 2013; Navarro, 2012). The U.S. Army Corps of Engineers estimated that the reinforced structure prevented almost USD 25 million in damage (Navarro, 2012).[1] Waterfront homes built on high ground or behind the seawalls were also largely spared (Kirkham, 2012), and landowners who suffered flood damage received compensation from the federal government and the National Flood Insurance Program (Walsh, 2012). The areas most affected in Stamford, however, were the city's beaches and the littoral parks. Park installations and seawalls were damaged (AFB Management, 2012) and several feet of displaced sand covered parking lots and playgrounds. Coastal erosion and flooding damages led to clean-up and repair costs of around USD 2.5 million (Dawson et al., 2013).

## 3. Problem Statement

Beaches are vulnerable to flooding and other damages linked to coastal storms (Beck et al., 2013). The combination of strong winds and heavy precipitation result in high storm surges. These waves then cause severe and high-impact flooding which destroys infrastructures and displaces sand, sometimes in areas where there used to be none. Clean-up and repair expenditures are considered too costly and unsustainable in the long-run.

The effects of a changing climate are reflected in the increasing disaster risks faced by coastal areas like Stamford. Scientists predict that winter storms and very strong hurricanes have more than 50% chance of increasing in the future (Bender et al., 2010; Kunkel et al., 2008). Bender et al. (2010) have calculated that by 2100, the frequency of category 4 and 5 hurricanes will have multiplied by a factor of 2.

Warming air and sea temperatures have been linked to intensification of hurricanes as well as to sea level rise (SLR). Studies have shown that SLR is particularly higher along the north-eastern coast of the United States. This phenomenon has been attributed to a number of factors including the proximity to melting polar ice caps, slowing down of the Atlantic Ocean currents and land subsidence (Ezer et al., 2012; Horton  et al., 2011). Based on the current snowmelt rate of land-based ice, researchers predict sea levels to increase by 5-10 inches (12.7-25.4 cm) between 2010 and 2039 and 19-55 inches (48.3-– 139.7 cm) between 2040 and 2069 (Rosenzweig et al., 2009).

The combination of SLR and more frequent intense storms are likely to result in increased coastal flooding. The flood forecasts for 100-year floods in Table 1 (below) in current conditions (2010-2039) can already easily inundate Stamford's shores that have a maximum elevation of 6-8 feet. Higher flood waters could also affect high-value properties along the coast, where some of the most expensive real estate in the country is located. Ensuring that beaches are able to withstand future weather systems with the potential to exact significant property damage and loss of lives is therefore an urgent priority.

**Table 1. Predicted flood frequency and height (minimum – maximum height in meters) according to flood type** (adapted from Rosenzweig et al., 2009)

| Flood type | Flood frequency | Flood height (m) | Time period |
|---|---|---|---|
| 1-in-10 year flood | Once every 8 - 10 years | 1.98 - 2.07 | 2010 - 2039 |
| | Once every 3 - 6 years | 2.13 - 2.22 | 2040 - 2069 |
| | Once every 1 - 3 years | 2.26 - 2.50 | 2070 - 2099 |
| 1-in-100 year flood | Once every 65 - 80 years | 2.68 - 2.74 | 2010 - 2039 |
| | Once every 35 - 55 years | 2.80 - 2.93 | 2040 - 2069 |
| | Once every 15 - 35 years | 2.93 - 3.20 | 2070 - 2099 |
| 1-in-500 year flood | Once every 380 - 450 years | 3.22 - 3.41 | 2010 - 2039 |
| | Once every 250 - 330 years | 3.47 - 3.57 | 2040 - 2069 |
| | Once every 120 - 150 years | 3.60 - 3.84 | 2070 - 2099 |


**Figure 2. Federal Emergency Management Agency (FEMA)'s simulated 100-year old flood map showing the West Beach Park, Cummings Beach Park and Cove Island Park substantially inundated**

## 4. Measures proposed: Selection of suitable hazard-mitigation technology

### Rationale

Following the aftermath of Hurricane Sandy, the city of Stamford has been exploring possibilities to enhance the beach parks' ability to withstand and recover from coastal flooding and beach erosion (Cassidy, 2013). Enhancing the resilience of Stamford's beaches is driven by the local government's need to reduce duration of beach closure as well as reduce clean-up costs and damages sustained after intense storms. Another key objective is to preserve the aesthetic and recreational value of the coastline. In addition, the uncertainty related to the effects of climate change also needs to be considered, as it calls for flood protection measures to be adaptable to beach dynamics and increasing coastal risks.

In May 2013, a research group at the Earth Institute in Columbia University presented a study to the city's Board of Representatives (Dawson, 2014). In the report, they proposed a range of solutions to reduce storm damage in Stamford's beach parks (*see* Box 1).

**Box 1. Coastal hazard mitigation technologies**

Technologies to mitigate flooding and reduce the impact of storm surges can be categorized into two main groups: macro-engineering and micro-engineering measures (Buonaiuto et al., 2011).

Macro-engineering technologies refers to structures often built to protect highly urbanized areas from storm damage (Dutch Ministry of Infrastructure and the Environment, 2004; United Kingdom Environment Agency, 2010). Implementation of these measures requires extensive research and involves economic, social and environmental costs (Rosenzweig et al., 2011b).

*Micro-engineering technologies* are applied on a smaller scale and could be further divided into two types: hard and soft engineering measures (Fig. 2). Hard (or "grey") structures are designed to resist strong winds and waves and have a long lifespan, but they are rarely flexible to coastal dynamics and require substantial construction and maintenance costs. On the other hand, soft (or "green") engineering structures absorb incoming forces, and since they mimic natural processes, soft engineering approaches tend to easily adapt to changes in the environment (Dawson et al., 2013). They also require lower financial investments than "grey" infrastructures.

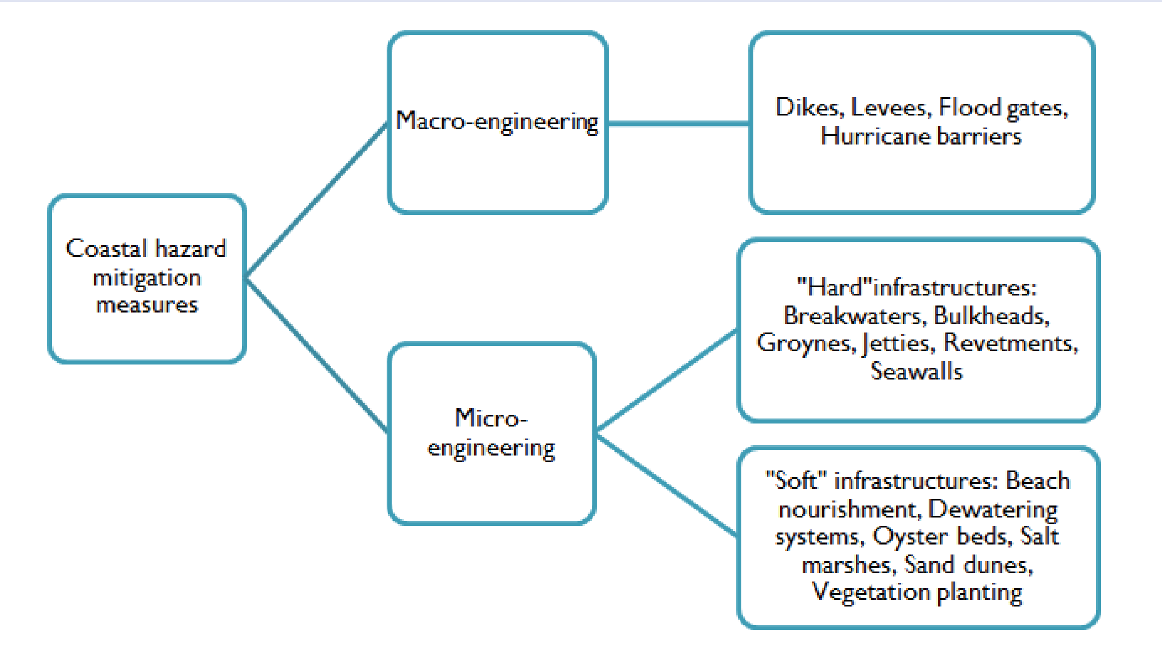


**Figure 3. Examples of micro-level engineering measures**
(Buonaiuto et al., 2011; Rosenzweig et al., 2011a; Rosenzweig et al., 2011b)

Dawson et al. (2013) found that in the short term, constructing vegetated sand dunes reinforced with geotextile tubes and reducing exposure of beach park infrastructure is the most suitable hazard mitigation technology to achieve better resilience against coastal hazards. In the long-term, Dawson et al. (2013) also came to the conclusion that yielding to rising sea levels and allowing beaches to retreat landward is the only long-term solution. Based on the group's proposal, Stamford urban planners incorporated enhanced vegetated sand dunes into a master replanting plan for Cove Island Park[2] (Cassidy, 2013).

## Main components of the proposed measures

Vegetated sand dunes enhanced with geotextile tubes is a type of soft engineering measure which resembles and acts like a natural barrier against strong waves and wind. At its core are tubular containers made of high-strength, woven, permeable geotextile filled with sand (Ginter, 2013). The circumference of a tube varies from 15 to 60 feet (4.6 to 18.3 meters) and could be as long as 200 feet (61 meters). The tubes can be individually placed or stacked to form a pyramid depending on the desired height of the dune. (Industrial Fabrics, Inc., 2008). Geotextile tubes are placed along the shoreline then covered with sand and vegetation to mitigate erosion. They function as barriers protecting infrastructure behind them and absorbing most of the damage from flooding and storm surge (City of Stamford, 2013) (Dawson et al., 2013).

## Methodology: multi-criteria analysis used in selection protocol

In their report, Dawson et al. (2013) followed a multi-step approach to identify the most suitable hazard mitigation technology for the Stamford coastal area. Their **multi-criteria analysis** allows taking into account both the quantifiable and non-quantifiable aspects of each technology. An important step of their selection protocol is the implementation of a **cost-benefit analysis**, which allows estimating quantifiable financial costs and benefits (*see* Box 2).

**Box 2. Cost-Benefit Analysis**

Cost-benefit analysis (CBA) is a method of appraising the value of a project, programme or policy in monetary terms by comparing the costs with the benefits of implementation (Donga & Mechler, 2005; New Zealand Treasury, 2005). It provides a consistent basis for comparison between different proposals and aids decision-makers in choosing the appropriate action that maximises allocated resources (New Zealand Treasury, 2005).

Prior to any calculations, one has to determine the objectives and constraints of the project. A reference situation also needs to be defined in order to allow comparison between the conditions before and after a project. This baseline scenario may either be a state of no intervention, minimum intervention or the current level of intervention.

Quantifying all negative and positive elements of a project is essential to a successful CBA. Costs are often linked to expenditures while benefits may be in terms of savings in operation or maintenance costs; in disaster risk management, avoided or reduced damages are considered as benefits (Donga & Mechler, 2005). Intangible costs and benefits that cannot be quantified are usually excluded from the quantitative analysis but should nevertheless be highlighted if they significantly affect the final decision (New Zealand Treasury, 2005).

It is possible to estimate the current value of a future cost or benefit by discounting the forecasted amounts to the present value (PV) using the following formula,

$$PV = \frac{Future\ value\ in\ n^{th}\ period}{(1 + discount\ rate)^n}$$

where *n* indicates the time periods (*year* 0, 1, 2, 3, …, n etc.) and the *discount rate* is the "desired return that an investor would expect to receive on some other typical proposal of equal risk" (New Zealand Treasury, 2005).

In order to determine the overall net benefit of a project, one needs to calculate the sum of the discounted net cash flows (net benefits) for each time interval, over the entire period considered. The resulting value is known as the *net present value* (NPV or PVNB). Assuming yearly time intervals and the current year (year 0) being also the year of the start of construction, the formula for the NPV is:

$$NPV = NCF_0 + \frac{NCF_1}{1+discount\ rate} + \frac{NCF_2}{(1+discount\ rate)^2} + \cdots + \frac{NCF_n}{(1+discount\ rate)^n}$$

where $NCF_n$ is the net cash flow (benefit *minus* cost of period n). $NCF_0$ is not discounted if it occurs within the same year of the beginning of the project (New Zealand Treasury, 2005).

**What is the appropriate discount rate?**

U.S. Office of Management and Budget (OMB) published guidance on discount rate and benefit-cost analysis in Circular A-4 (September 2003) [54] and suggests that a real discount rate of 7% may be used as a base-case for regulatory analysis. Why? The 7% rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. It is the returns to real estate and small business capital as well as corporate capital. It approximates the opportunity cost of capital. In short, 7% is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector. If the value of NPV (i.e. PVNB) is positive, the project will yield a return higher than the market interest rate.

But regulations do not always affect exclusively the allocation of capital. When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate is appropriate, such as for instance, the real rate of return on long-term government debt ( 3%).

The alternative most often used is sometimes called the *Social Rate of Time Preference*: the rate at which society is ready to substitute present for future consumption, that is the rate at qhich society discounts future consumption flows to their present value. A high discount rate discounts more (gives less importance) to future consumption. The federal opportunity cost of capital (interest rate on treasury bonds) is generally used as a proxy.

**Box 2. Cost-Benefit Analysis (continued)**

**Why choosing a discount rate matters?**

From what we just described above, it is evident that choice of discount rate incorporates considerations of intergenerational equity. Low discount rates give more importance to what happens in the future. For instance, when costs are incurred up front and benefits occur in the future, using low discount rates result in higher NPVs for benefits than using high discount rates.

**Uncertainty Factors**

CBA is a useful framework to consistently organizing disparate information; however it may often be non-sufficient for designing sensible public policy. Sources of uncertainty when developing a cost-benefit analysis are both in the denominator and numerator of the formula, respectively the discount rate chosen (as already discussed), and the estimates of costs and benefits. Indeed, there may be benefits and costs that are not measurable, for example the benefit derived from the existence value of an ecosystem.

In order to maximize transparency in decision making it is usually necessary to provide a sensitivity analysis to reveal whether, and to what extent, the results of the CBA are sensitive to plausible changes in the main assumptions and numeric inputs (Arrow et al., 1996; Goulder and Stavins, 2002; Kelman, 1981; Graham, 2008).

Given the uncertainty on the correct discount rate, it is therefore appropriate to use a range of rates. We should give less confidence to a project for which the sign of the NPV is highly sensitive to the discount rate or to small changes in projected future benefits and costs (Arrow et al., 1996; Goulder and Stavins, 2002; Kelman, 1981; Graham, 2008).

Best estimates of costs and benefits should always be presented with a description of uncertainties (Arrow et al., 1996; Goulder and Stavins, 2002; Kelman, 1981; Graham, 2008). Also, in the case of disaster risk reduction, the benefits associated to damage avoidance may correspond to a probability curve. Picking only one probability value increases the level of uncertainty. For this reason, when developing a CBA, sensitivity test should be also performed to check the robustness of the measure in case of changes in conditions. This can be used to forecast uncertainty and assess projected risks. A common approach is to modify the variables according to three scenarios: pessimistic, most probable and optimistic (New Zealand Treasury, 2005).

**Are cost-benefit analysis results sufficient to make policy decisions?**

CBA is useful to compare favorable and non-favorable effects of policies. However, if there is too much uncertainty about the outcomes CBA results are not conclusive. Economic efficiency can be one of the criteria to assess regulatory options. However, efficiency does not inform regulators about intra-generational equity and distributional issues. All relevant information has to be considered when identifying the most suitable option. This would require ranking options by their monetary value and NPV as well as considering qualitative but pertinent costs and benefits.

The 5-step protocol developed by Dawson et al. (2013) takes into account Stamford's goals and the uncertainty due to climate change, and includes the following criteria (*see* Fig. 4).

1. **feasibility**,
2. **effectiveness**,
3. **dynamic cost-efficiency** evaluated using **Cost-benefit Analysis**,
4. **flexibility**, and
5. **positive externalities**.

**Feasibility** refers to the level at which the measure could be practically implemented in relation to technical and budgetary constraints. For example, the authors of the report deemed macro-level measures to be unfeasible because of their exorbitant financial and environmental costs which outweighed the benefits they provide.

A technology is effective if it is capable of accomplishing the city's twofold goal of enhancing resilience against storm damage and "preserving the aesthetic and recreational values of the beach parks" (Dawson et al., 2013). **Effectiveness** to reduce storm damage is evaluated through capacity of the technology to cope with 100-year

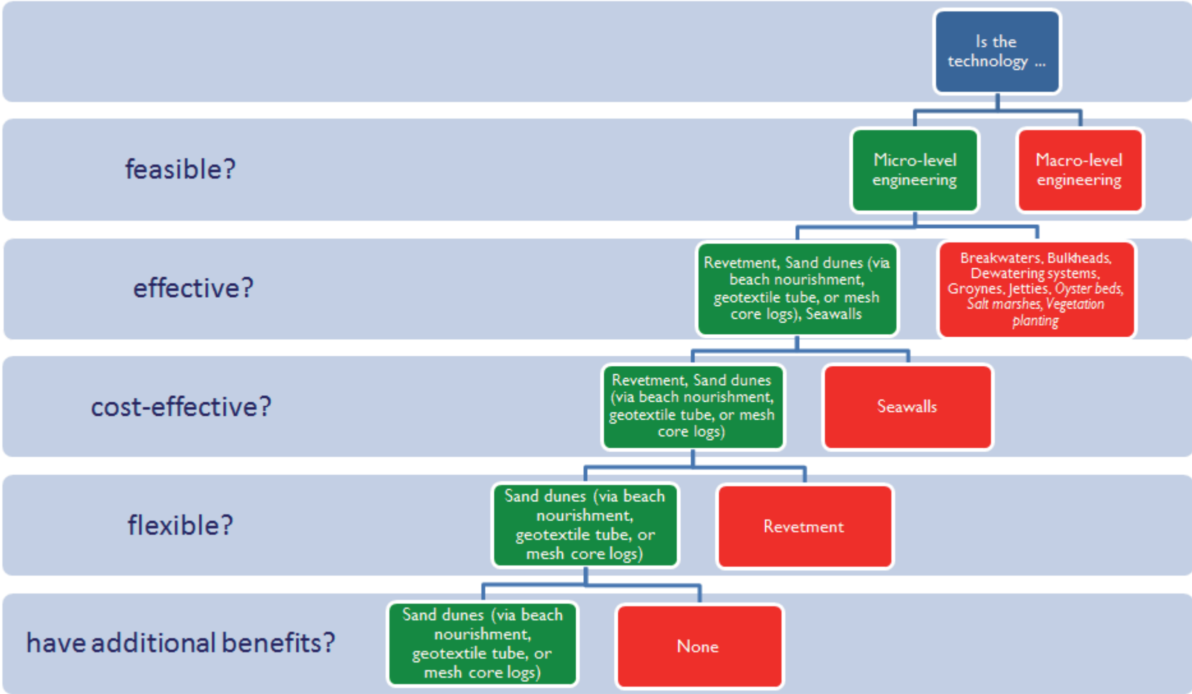


**Figure 5. Evaluation criteria decision tree. Technologies in green boxes satisfy the criteria while those in red boxes do not. "Green" solutions in italics (oyster bed, salt marsh, vegetation planting) are not effective by themselves to resist a 1-in-100 year flood level but could be combined with other "grey" technologies to enhance resilience. Through a process of elimination, Dawson et al., 2013 found sand dunes to be the most appropriate solution for Stamford** (adapted from Dawson et al., 2013)

flood levels equivalent to 8.6 feet (2.6 meters) high. Based on estimates obtained by Dawson et al. (2013), geotextiles units of 45 feet (13.8 meters) in circumference and 6.5 feet (~2 meters) in height and covered by 2 to 4 feet (0.6-1.2 meters) of sand can effectively resist this level of flooding.

The subsequent step in the technology selection process is a quantitative assessment to identify the most cost-efficient solution. **Cost-efficiency** is a performance measure based on net benefits that is the benefits minus the costs. A policy is cost efficient if the net benefits are maximized. In a dynamic setting (over multiple time periods), we speak of **dynamic cost efficiency**; in this case an efficient policy maximizes the present value of the net benefits to society. Assessing efficiency in a dynamic setting requires discounting: reducing the stream of costs and benefits to a single dollar amount, the present value of net benefits (NPV or PVNB). This process is a **Cost-benefit Analysis**, a methodology described in detail in box 2.

To present graphically the cost-effectiveness of seawalls and sand dunes, Dawson et al. (2013) compared the initial costs of constructing each technology with the total Present Value (PV) of the projected net benefits (figure 6). For each year, the projected net benefits correspond to the avoided future damages, estimated using damage costs from Hurricane Sandy (US$ 945'000) and taking into account the probability of 100-year level floods between 2010 and 2039 (see Table1). The pessimistic scenario corresponds to an annual probability 0.0154 (1/65), while the optimistic scenario corresponds to 0.01 (1/100) chance of occurrence[3]. 5% is the chosen discount rate to calculate the PV of benefits for a period of 30 years[4]. The formula may be written as follows:

$$PV\ Damages = \sum_{n=1}^{30} \frac{damage\ costs * probability}{(1 + discount\ rate)^n}$$

The calculated amount of damages that could be avoided was between USD 145,269 to USD 223,491, for the optimistic and pessimistic scenarios, respectively. Figure 6 shows the approximate construction costs of the remaining

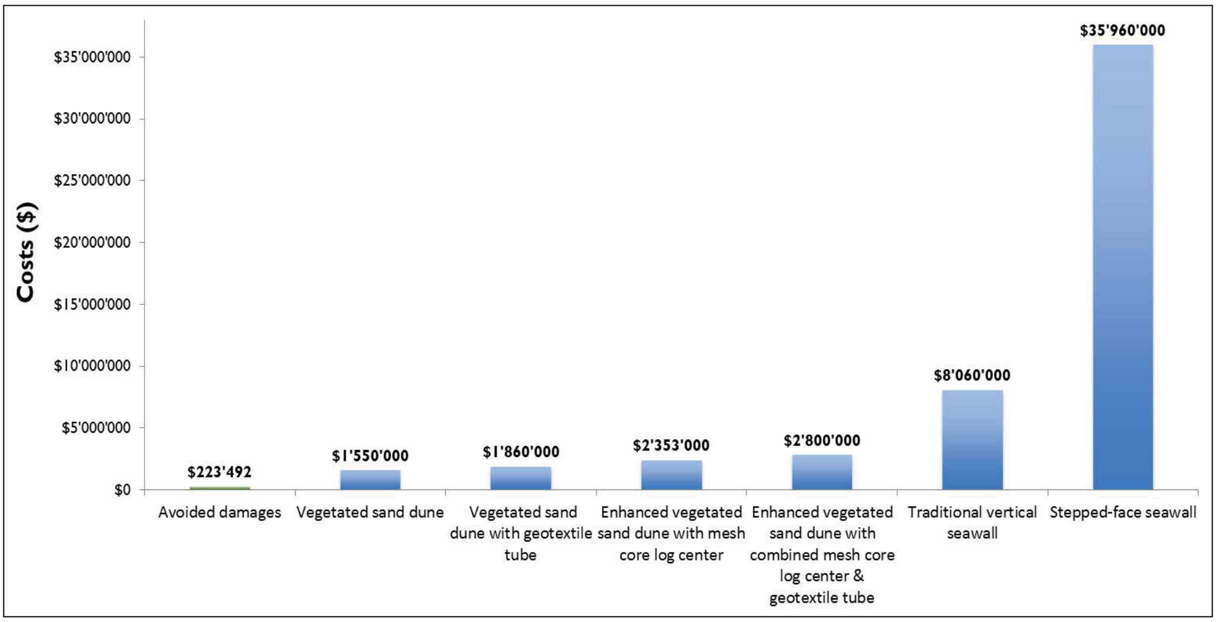


**Figure 6. Comparison between the costs of constructing each technology and the benefits in the form of avoided damage (assuming 100% damage prevention). Despite not having met the cost-efficiency criterion, seawalls were still considered among the options after Stamford expressed interest in this technology. Breakdown of costs for each of these measures can be found in Annex 1**

resilience technologies.

**Flexibility** of a technology depends on whether it could be modified subsequently to adjust to changing climate conditions. Sand dunes, for example, are more flexible than seawalls because they can migrate in response to beach dynamics and storm conditions. And finally, **positive externalities** or **additional benefits** and usages other than those intended initially (here, storm damage reduction) also increase the value of the technology. Examples of sand dunes' additional benefits are improving water quality, contributing to the beauty of the landscape and preserving wildlife habitat.

Among the four varieties of sand dunes, the proposal for vegetated sand dunes enhanced with geotextile tubes was chosen because it has the same benefits as the one for vegetated sand dunes but has the advantage of being more stable. This option is also less costly than the two other enhanced vegetated sand dune alternatives, i.e. dunes with mesh core logs and dunes reinforced with combined mesh core logs and geotextile tubes (*see* Fig. 6) (Dawson et al., 2013).

## Implementation guidelines for hazard-migation technology

In summer 2013, the city government of Stanford included the report's recommendation to create vegetated sand dunes enhanced with geotextile tubes into a master replanting programme for Cove Island Park. A landscaping firm presented city authorities with a proposal on how to construct the sand dunes (McKenna, 2013). As also mentioned in the study, several elements need to be considered when installing such structures. Site location has to be thoroughly assessed as elements such as beach profile, wave direction and height, sand volume and current and future tide levels will affect the effectiveness of the dune. This is particularly the case for Connecticut's beaches which are small and have rock outcrops (Associated Press, 2013).

The appropriate width and height should be defined based on a worst-case scenario (i.e. strong storm during high tide). In the proposal put forward by the contractors, the dunes will be 25 feet (7.6 meters) wide and about 7 feet (2.1 meters) tall. The geotextile tubes should be placed at least 50 feet (15 meters) from the water and will be covered by fabric shrouds and 15,000 cubic yards (11,468.3 $m^3$) of locally dredged sand and native plant species (Dawson et al., 2013; Hettiarachchi et al., 2013).

The report also suggested building the dunes continuously along the shoreline. If not, water could pass through the breaks in the system and accumulate behind the sand dunes, thus undermining and

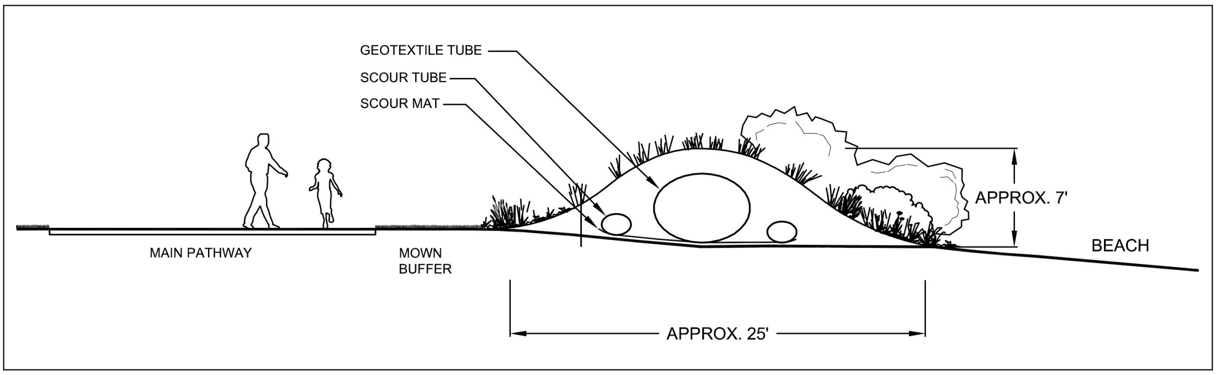


**Figure 7. Graphic representation of the vegetated sand dunes enhanced with geotextile tubes for Cove Island Park as proposed by the landscaping firm** (Larry Weaner Landscape Associates, 2013)

destabilizing them as the water retreats. Elevated pathways to access the dunes would be better alternatives to breaks (Dawson et al., 2013).

### Quantitative Example: Net Present Value Calculation

| Year | Cost | Benefit | Net Benefit | Present Value of Net Benefit |
|---|---|---|---|---|
| y | C | B = DA * p | NCF = B - C | PVNB=NCF/[(1+r)^y] |
| 0 | 700,000 | 0 | -700,000 | -700,000 |
| 1 | 10,000 | 118,750 | 108,750 | 101,636 |
| 2 | 10,000 | 118,750 | 108,750 | 94,986 |
| 3 | 10,000 | 118,750 | 108,750 | 88,772 |
| 4 | 10,000 | 118,750 | 108,750 | 82,965 |
| 5 | 10,000 | 118,750 | 108,750 | 77,537 |
| 6 | 10,000 | 118,750 | 108,750 | 72,465 |
| 7 | 10,000 | 118,750 | 108,750 | 67,724 |
| 8 | 10,000 | 118,750 | 108,750 | 63,293 |
| 9 | 10,000 | 118,750 | 108,750 | 59,153 |
| 10 | 10,000 | 118,750 | 108,750 | 55,283 |
| | | | | |
| | | | NPV | 63,814 |

Estimate the net present value of a flood mitigation measure with a 10-year design life (see Figure 8).

The table below shows the values of PVNCF

| Year | Cost | Benefit | Net Benefit | Present Value of Net Benefit |
|---|---|---|---|---|
| y | C | B = DA * p | NCF = B - C | PVNB=NCF/[(1+r)^y] |
| 0 | 700,000 | 0 | -700,000 | -700,000 |
| 1 | 10,000 | 118,750 | 108,750 | 98,864 |
| 2 | 10,000 | 118,750 | 108,750 | 89,876 |
| 3 | 10,000 | 118,750 | 108,750 | 81,705 |
| 4 | 10,000 | 118,750 | 108,750 | 74,278 |
| 5 | 10,000 | 118,750 | 108,750 | 67,525 |
| 6 | 10,000 | 118,750 | 108,750 | 61,387 |
| 7 | 10,000 | 118,750 | 108,750 | 55,806 |
| 8 | 10,000 | 118,750 | 108,750 | 50,733 |
| 9 | 10,000 | 118,750 | 108,750 | 46,121 |
| 10 | 10,000 | 118,750 | 108,750 | 41,928 |
| | | | | |
| | | | NPV | -31,778 |

(Present Value of net benefits) year by year:

Information provided:

- **Costs:**
  - Year 0: material & installation cost $C_0$ = USD 700'000 at year 0,
  - Following years: maintenance cost USD 10,000 (every year for years 1 to 10)
- **Benefits:**
  - Monetary gain associated to 100% damage avoidance (DA) corresponds to **DA** = USD 950'000 (every year for years 1 to 10)
  - **Probability** of 100% damage avoidance corresponds to **P** = 0.125 (1/8). This value is the probability of flood, where floods occur with a frequency of once every 8 years (refer to Table 1)
  - Hence, the yearly **benefit** is: B = DA* P
- **Discount rate**: r = 7% (0.07)

SOLUTION

**year 0:** $NCF_0 = B_0 – C_0 = (DA_0 *P_0) – C_0$
$C_0$ = 700,000
$B_0 = (DA_0 *P_0) = 0$ [because DA=0 on year 0]
$NCF_0$ = - 700,000 [net benefits in year 0]
! Remember ! PV for year 0 is not discounted

**year 1:** $NCF_1 = B_1 – C_1 = (DA_1 *P_1) – C_1$
$C_1$ = 10,000 [maintenance cost]
$B_1 = (DA_1 *P_1)$ = 950,000 * (1/8) = 118,750
$NCF_1$ = 118,750 – 10,000 = 108,750 [net benefits in year 1]
$PVNCF_1$ Present Value of net benefits when years y=1 is
$PVNB_1 = NCF_1/(1+ r)$ = 108,750 / (1.07)

**year 2:** $NCF_2 = C_2 – B_2 = C_2 – B_2$
$C_2$ = 10,000 [maintenance cost]
$B_2 = (DA_2 *P_2)$ = 950,000 * (1/8) = 118,750
$NCF_2$ = 118,750 – 10,000 = 108,750 [net benefits in year 2]
$PVNCF_2$ Present Value of net benefits when years y=2 is
$PVNCF_2 = NCF_2/(1+ r)^y = 108{,}750/(1.07)^2 = 101{,}636$

**year 3:** $NCF_3 = C_3 – B_3 = C_3 – B_3$
…

**year 10:** $NCF_{10} = C_{10} – B_{10} = C_{10} – B_{10}$
$PVNCF_{10}$ Present Value of net benefits when years y=10 is
$PVNCF_{10} = NCF_{10}/(1+ r)^y = 108{,}750/(1.07)^2 = 41{,}928$

The present value of net benefits is the sum of $NCF_0$ , $PVNB_1$ , $PVNB_2$ … $PVNCF_{10}$

$$NPV = NCF_0 + \frac{NCF_1}{1 + discount\ rate} + \frac{NCF_2}{(1 + discount\ rate)^2} + \cdots + \frac{NCF_n}{(1 + discount\ rate)^n}$$

**Figure 8. Net present value of a flood mitigation measure with a 10-year design life**

if we pick a higher discount rate say r = 10% the future benefits will be discounted more and as a consequence we expect the NPV to be smaller. And indeed, in this case it will be negative:

This exercise shows the importance of the interest rate in assessing NPV.

## 5. Implications for Ecosystem-based DRR

Reinforcing vegetated sand dunes with geotextiles is an innovative way of improving coastal hazard resilience while adapting to environmental processes and maintaining the natural landscape. This technique allows for more steeper and more stable dunes which can cope with the rising tides and storm surge. Sand dunes act as a line of defence by absorbing wave and wind forces and by preventing floodwaters from travelling further inland. They also act as sand reservoirs due to accretion and natural replenishment of the beach, thus lessening beach erosion (Hettiarachchi et al., 2013; Rogers & Nash, 2003).

Enhanced vegetated sand dunes with geotextile tubes easily blend in with the beach scenery than other hard engineering structures. Nonetheless, building sand dunes to mitigate coastal hazards has often been met with opposition. Although, residents of Stamford have not voiced their opinions against the dune project in Cove Island Park (Dawson, 2014), some homeowners in similar coastal towns in Connecticut feel that the sand dunes will obstruct their seaside view and, potentially, reduce the value of their property. This is a particularly sensitive issue in an area which has some of the most prized real estate in the United States (Associated Press, 2013). Moreover, displaced sand often deposits on public and private properties, and the expensive clean-up costs, as seen after Hurricane Sandy, pose a huge deterrent.

In the Columbia University report, alternative ways of reducing hazards through the promotion of ecosystem services were also discussed. Although not effective to resist a 100-year flood level on their own, the oyster beds and salt marshes already existing in Stamford's beach parks were endorsed as complementary risk mitigation solutions (Dawson et al., 2013). Both attenuate wave energy, attract wildlife, and improve the water quality by trapping pollutants. The salt marshes' extensive root system allows them to withstand sporadic storm surges and absorb floodwaters, while oyster beds act as bio-indicators of the surrounding marine ecosystem (Oyster Reef Restoration, 2013). Restoring or rehabilitating these ecosystems are also inexpensive compared to other techniques: an acre of salt marsh costs between USD 24,000 to 33,000, and an acre of oyster bed is anywhere between USD 2,000-100,000 (Dawson et al., 2013). In addition to building enhanced sand dunes, the city of Stamford also applied for a National Fish and Wildlife grant to add a living shoreline to the Cove Island Park plan (McKenna, 2014). This project involves using plants, sand and rock to stabilize the coast, create and protect aquatic and terrestrial wildlife, and improve water quality (NOAA, 2013).

### Strengths and weaknesses: Vegetated sand dunes enhanced with geotextile tubes

Sand dunes are part of the natural coastal ecosystem in which they play an important role. In terms of ecological benefits, they enrich biodiversity by providing habitats and breeding ground for bird species and turtles as well as allowing native plant species to grow. Water filtration is one of the many benefits sand dunes offer. They can be built in stages over time and are a good long-term solution to mitigating coastal hazards (Cassidy, 2013). They are flexible structures that change in response to the winds, waves and tides. Moreover, they contribute to the beauty of the landscape by blocking views of urban structure and creating a more serene beach environment.

Vegetated sand dunes with geotextile tubes are improved versions of naturally-occurring dunes. Firstly, this type of sand dunes benefits from a dual armouring system. The plant's root system binds the sand on the surface of the dune and prevents overtopping (Hettiarachchi et al., 2013), while the geotextile tubes increase stability in the core. Secondly, the tubes are cost-effective, as they allow construction of higher dunes with less sand and are as erosion-resistant as mesh core logs (another dune armouring alternative) for almost 21% less the cost (Dawson et al., 2013). Maintenance costs are minimal unless the sand cover is eroded during a storm, thus exposing the tubes. Designed for long-term use, the tubes are made of durable woven polymer impervious to weathering, corrosive liquids and biodegradation (GEOfabrics, 2011). Finally, enhanced vegetated sand dunes can be removed which involves unravelling the fabric, draining the sand filler and moving the tubes away from its location (Dawson et al., 2013).

This technology, like any other, also has a few drawbacks. In general, overwash[5] spreads sands behind the dunes and could cause nuisance to nearby urban or residential areas. Enhanced sand dunes are not as adaptable to beach dynamics as natural sand dunes and cannot migrate as easily. In addition, exposed tubes act as hard structures and contribute to erosion due to wave action of the beach directly in front of it (Dawson et al., 2013). Maintenance requires regular beach nourishment which could be costly in the long term, considering the predicted further increase in sea level and coastal storm intensity. Repairs must also be done as early and as quickly as possible to avoid collapse of the dune system.

### Methodology: Multi-criteria Selection Process

Dawson et al.'s (2013) approach to conduct a multi-criteria analysis with elements of cost-benefit analysis allowed a holistic review of the different aspects of coastal hazard mitigation strategies. Their method is comprehensible, easy to apply and flexible when comparing options that has significant qualitative and quantitative impacts (New Zealand Treasury, 2005).

However, financial costs other than material expenditures, such as labour and maintenance/repair costs, as well as unquantified intangible benefits of the measures were not part of the cost-benefit calculations. Failing to do so might have led to over- or underestimation of some of the costs and benefits. Positive and negative factors were nevertheless discussed and considered in the multi-criteria analysis and in the final evaluation of the retained measures. Another issue with applying CBA in the context of disaster management is that the benefits are probabilistic, since hazard events themselves are random in nature. A way to counter this problem is to include this factor in the calculation of the net present value (NPV) of expected benefits such as Dawson et al. (2013) did in their report.

The close partnership with the local authorities is also a key component in this study. Not only did it guide their research but also contributed to the integration of their recommendation into the city's plans to improve resilience and sustainability of the parks and beaches. By taking into account Stamford's interests and expectations in addition to conducting a thorough scientific study, their findings were more likely to be accepted by the local city planners.

## 6. Lessons learned and conclusions

The City of Stamford's case is one successful example of collaboration between government authorities and members of academia, resulting in better informed decision-making. We have seen that multi-criteria and cost-benefit analysis can help determine the most appropriate solution by evaluating its positive and negative aspects relative to other options. Properly identifying and quantifying these variables are a key component of CBA. Therefore, better valuation of intangible costs and benefits, such as the effects of environmental damage or the enrichment of biodiversity, will contribute to a more comprehensive and successful analysis.

Enhanced vegetated sand dunes with geotextile tubes are stable and cost-effective structures which could adapt to beach dynamics and changes in the environment. Many private homeowners in Connecticut who live along the coast support the creation or expansion of sand dunes for flood mitigation; however, some remain unconvinced because they fear that their seaside views could be compromised or heavy costs would be incurred in removing displaced sand on their properties (Associated Press, 2013; Mayko, 2013). For now, hard engineered structures still remain the norm when it comes to protecting against floodwaters and storm surges. Stamford expressed their interest in seawalls despite the considerable financial investment. New York City is also considering building a hurricane barrier, such as the one on Stamford Harbor, after having been proved effective during Hurricane Sandy (Navarro, 2012).

In any case, few residents have considered the long-term solution of yielding to the rising tides and relocating to less risky areas. Government-backed initiatives, such as the National Flood

Insurance Program or the recently passed State Bill easing restrictions on home retrofitting against storms, have the perverse effect of encouraging people to stay in flood-prone zones (Walsh, 2012; Mayko, 2013). Allowing people to rebuild in these areas not only will end up being too costly over the long run but also avoids addressing exposure of people and properties as the root cause of increasing storm damage. Only by reducing exposure to hazards can we effectively and sustainably enhance resilience.

## 7. Exercise and teaching notes[6]

1. Enumerate the advantages and disadvantages to building either a vegetated sand dune or a hurricane barrier to prevent storm surge and coastal flooding in Stamford (see table below). *Note: answers are in blue. Some information about the hurricane barriers may be found online.*

2. Net Present Value Calculation

   2.1 Estimate the net present value of a flood mitigation measure (A) with a 10-year design life. Information provided:

Costs:

– Year 0: material & installation cost $C_0$ = USD 400'000 at year 0,

– Following years: maintenance cost USD 0 (every year for years 1 to 10)

Benefits:

– Monetary gain associated to 100% damage avoidance (DA) corresponds to

| y | C | B = DA * p | NCF = B - C | PVNB=NCF/[(1+r)^y] |
|---|---|---|---|---|
| 0 | *400,000* | *0* | *-400,000* | *-400,000* |
| 1 | *0* | *70,000* | *70,000* | *65,421* |
| 2 | *0* | *70,000* | *70,000* | *61,141* |
| 3 | *0* | *70,000* | *70,000* | *57,141* |
| 4 | *0* | *70,000* | *70,000* | *53,403* |
| 5 | *0* | *70,000* | *70,000* | *49,909* |
| 6 | *0* | *70,000* | *70,000* | *46,644* |
| 7 | *0* | *70,000* | *70,000* | *43,592* |
| 8 | *0* | *70,000* | *70,000* | *40,741* |
| 9 | *0* | *70,000* | *70,000* | *38,075* |
| 10 | *0* | *70,000* | *70,000* | *35,584* |
| | | | | |
| | | | ***NPV*** | ***91,651*** |

| Vegetated Sand Dune (VSD) | | Hurricane Barrier (HB) | |
|---|---|---|---|
| **PROS** | **CONS** | **PROS** | **CONS** |
| Cost-effective: USD 1,860,000 | Erosion over time | Proven effectiveness against high storm surges and flooding (e.g. Stamford during Hurricane Sandy) | Costly: Stamford HB cost USD14.5 million; in general, costs could be in millions, even billions |
| Blocks storm surges, floods, winds and protects infrastructures behind them | Displaced sand deposits on public and private properties, where there should be no sand deposition | | Environmental consequences (e.g. pollution trapped behind the barrier when closed; disruption of tidal flows and water salinity; reduced marshlands have effects on local marine ecosystem and bird habitats) |
| Provides habitats for wildlife | Rate of effectiveness still remains to be evaluated | | |
| Act as sand banks in case of erosion | | | |
| Geotextile tubes reinforce vegetated sand dunes | | | Disturbs the landscape |
| | | | Non-flexible structure once installed |
| Contribute to beautifying the landscape | | | Can cause/aggravate flooding in surrounding areas not protected by the barrier |
| Adaptable to changes in the environment | | | |

**DA** = USD700'000 (every year for years 1 to 10)

- **Probability** of 100% damage avoidance corresponds to **P** = 0.1 (1/10). This value is the probability of flood, where floods occur with a frequency of once every 10 years (1-in-10 year flood level, time period 2010-2039; refer to Table 1)
- Hence, the yearly **benefit** is: B = DA* P

**Discount rate**: r = 7% (0.07)

2.2 Estimate the net present value of another flood mitigation measure (B) with a 10-year design life. Information provided:

Costs:

- Year 0: material & installation cost $\mathbf{C_0}$ = USD 200'000 at year 0
- Following years: maintenance cost USD 25,000 (every year for years 1 to 10)

Benefits:

- Monetary gain associated to 100% damage avoidance (DA) corresponds to **DA** = USD700'000 (every year for years 1 to 10)
- **Probability** of 100% damage avoidance corresponds to **P** = 0.1 (1/10). This value is the probability of flood, where floods occur with a frequency of once every 10 years (1-in-10 year flood level, time period 2010-2039; refer to Table 1)
- Hence, the yearly **benefit** is: **B = DA* P**

**Discount rate**: r = 7% (0.07)

2.3 Based on your calculations which measure is the most efficient?

Using 7% discount rate, measure B is the most efficient because it has the largest NPV.

2.4 Repeat all your calculations at points 2.1 and 2.2 using discount rate 2%

Solution

**Table Appendix. Breakdown of estimated costs for each measure in all three beach parks** (Dawson et al., 2013)

| TECHNOLOGY | UNIT COST | COVE ISLAND PARK | CUMMINGS PARK | WEST BEACH PARK | TOTAL COST |
|---|---|---|---|---|---|
| **Vegetated sand dune** | $370/linear ft | 1300ft long, 10ft tall, 30 ft wide=$480,000 | 1000ft long, 10ft tall, 30 ft wide=$370,000 | 800ft long, 10ft tall, 30ft wide=$296,000 | **$1'550'000** |
| **Enhanced vegetated sand dune with mesh core log center** | $760/linear ft for 5=10 foot tall dune using 15 18" diameter Soxx | 1300ft long, 10ft tall=$987,000 | 1000ft long, 10ft tall=$760,000 | 800 ft long, 10ft tall=$606,000 | **$2'353'000** |
| **Enhanced vegetated sand dune with mesh core log & geotextile tube combination center** | $900/linear ft for 10 foot tall dune using Soxx and geotextile tubes of varying diameters | 1300ft long, 10ft tall=$1,170,000 | 1000ft long, 10ft tall=$900,000 | 800 ft long, 10ft tall=$720,000 | **$2'800'000** |
| **Enhanced vegetated sand dune with geotextile tube center** | $250/linear ft of tube and $50/ton of sand | 1300ft long, 10ft tall, 30 ft wide=$780,000 | 1000ft long, 10ft tall, 30 ft wide=$600,000 | 800ft long, 10ft tall, 30ft wide=$480,000 | **$1'860'000** |
| **Stepped-face seawall** | $11,600/linear ft | 1300ft=$15,080,000 | 1000ft=$11,600,000 | 800ft=$9,280,000 | **$35'960'000** |
| **Traditional vertical seawall** | $2600/linear ft | 1300ft=$3,380,000 | 1000ft=$2,600,000 | 800ft=$2,080,000 | **$8'060'000** |
| **Salt marsh** | $24,200-33,000/ac | 2 ac=$48,400-$66,000 | 0 ac=$0 | 0 ac=$0 | **$48,400-66,000** |
| **Oyster bed** | $2,000-100,000/ac | 2 ac=$4,000-$200,000 | 0 ac=$0 | 0 ac=$0 | **$4,000-200,000** |

Intervention A (discount rate r=2%)
Solution
Intervention B (discount rate r=2%)

2.5 Based solely on the cost-benefit analysis results (2.4), which intervention will the regulator choose?

Now, using a lower discount rate, the policy makers are likely to choose project B because it has the highest NPV (226,209 USD).

# Appendix

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## Endnotes

1 This only partly explains why the city of Stamford sustained relatively little damage from Hurricane Sandy; its arrival before the high tide and the shift in winds contributed in lessening the impact of the storm (Applebome & Rivera, 2012).

2 The capital budget to install the sand dunes in 2014-2015 was still awaiting approval at the time of publication of this sourcebook (McKenna, 2014).

3 In table 1, scientists have given upper and lower boundaries for flood frequency depending on each flood type and per time period. The higher the frequency of a flood event is, the more pessimistic the scenario is. For example, a 1-in-100 year flood event to occur during the time period 2010-2039 has an average frequency of 1 every 65 years (pessimistic scenario) or 1 every 80 years (optimistic scenario). The probability of a scenario is calculated by dividing 1 over the number of years; e.g. 1/65 = 0.0154.

4 Dawson et al. (2013) calculated over 30 years following a convention among scientists who make climate projections over a 30-year period [19].

5 The process of wave-induced dune toppling and deposition of sand inland (U.S. Geological Society (USGS), 2013).

# Case Study 7

## Mountain ecosystems: Protection forests of Switzerland and other Alpine countries

## 1. Overview

| | |
|---|---|
| **Outline** | In the alpine region, the role of protection forests in mitigating mountain hazards has been known since the 1870s. This study explains how forests keep alpine roads safer and provides an overview of the tools and strategies being used by national and local governments of alpine countries to effectively manage and protect mountain ecosystems. The exercise at the end of the case study will enable participants to better understand the protective role of forests as well as the approach taken by authorities to optimize forest management. |
| **Learning objectives** | • Learn how forests protect lives and assets in mountain areas;<br>• Find out which elements influence the effectiveness of forests in mitigating natural hazards;<br>• Gain insight into the political and economic measures being implemented by alpine countries to manage protection forests. |
| **Guidance** | This case study aims to highlight the multiple benefits of protection forests, namely in reducing mountain hazard risk in one of the main transport axis in Europe. We will also discuss the measures and guidelines developed by governments to effectively manage protection forests. |
| **Recommended reading** | Wehrli, A. and Dorren L., 2013. Protection forests: A key factor in integrated risk management in the Alps. In: The Role of Ecosystems in Disaster Risk Reduction. Renaud, Sudmeier-Rieux, and Estrella (eds.). Tokyo: United Nations University Press. pp. 321-342<br>Dorren et al., 2004. Integrity, stability and management of protection forests in the European Alps. Forest Ecology and Management 195, pp. 165-176<br>Frehner et al., 2005. Gestion durable des forêts de protection. Soins sylvicoles et contrôle des résultats : instructions pratiques. Bern. Office Federal of the Environment. [Online] Available at: file:///C:/Users/tst/Downloads/Gestion+durable+des+for%C3%AAts+de+protection+2005.pdf |

## 2. Background

| | |
|---|---|
| **Case study area** | Alps |
| **Country** | Alpine countries, in particular Switzerland, Germany and Austria |
| **Ecosystems** | Mountain |
| **Hazards** | Mass movements (rock fall, snow avalanches, erosion, landslides, debris flow), flooding |

The Alps are one of the most important mountain range systems in Europe stretching approximately 1,200 km (750 mi) across eight alpine countries encompassing Switzerland, France, Austria, Italy, Liechtenstein, Germany, Slovenia, and Monaco, with the first four countries containing within their borders the majority of alpine territory. The Alps provide lowland Europe with drinking water, water for irrigation, and hydroelectric power. Although the area is only about 11 % of the surface area of Europe, the Alps provide up to 90 % of water to lowland Europe, particularly to arid areas and during the summer months. The alpine region has a strong cultural identity. The traditional culture of farming, cheese making, and woodworking still exists in alpine villages, although the tourist industry has greatly expanded to become the dominant industry. At present the region is home to 14 million people and has 120 million annual visitors.

The alpine landscape is characterized by a great variety of elevations, which in turn contribute to extreme differences in climate. Several vegetation zones found in the Alps are mainly influenced by the differences in elevation and climate. In the valleys grow a variety of deciduous tree species (oak, beech, poplar, elm, birch, chestnut, etc.). At higher elevations, the largest extent of forest is coniferous (spruce, larch, pine). Above the tree line and below the permanent snow line are areas covered with alpine meadows, where sheep and cows usually graze during the short summer months.

Forests play an important role in disaster risk management in the Alps. Known as "protection forests", forests are managed to protect people and their assets from rock fall, snow avalanches, , landslides, debris flows and flooding – hazardous events that are relatively frequent in the Alps. In Austria, the role of protective forests has been recognized since 1870 and their management is coordinated through the "Protection Forest Platforms" of every federal state. Measures to manage protection forests in Switzerland have been established since the early 1980s. Today, forests play a key role in Switzerland's integrated risk management strategy and are considered alongside engineered measures.

The extent of protection forests vary from country to country. In Austria, 31% of the entire forest area has a protective function, while according to the Third Swiss National Forest Inventory, between 43 and 50 % of forests in Switzerland play a protective function against natural hazards. In south-eastern Germany, protective forests account for approximately 60% of all forests in the Bavarian Alps. In the Tyrol region between Austria and Italy, the proportion of protection forests is even larger at about 66%.

## 3. Problem statement

Alpine landscapes have changed significantly in the last hundred years, due to and infrastructural and economic development, increasing temperatures, and other factors, shifting from predominantly agrarian to greater reliance on tourism. In parallel, forests had become hazardous due to lack of maintenance, while public support favored protection forests and natural protection measures over engineered solutions whenever possible (Metral, pers communication, 2013). Higher probability of hazard events in the Alps, such as avalanches, landslides and rock fall, together with more people travelling on mountain roads prompted the Government of Switzerland to create a forest management policy for managing alpine forests for reducing mountain hazards.

## 4. Measure(s) implemented

### Rationale

During the past 50 years, the importance of protection forests in the Alps has increased. Population expansion has led to high-density settlements located in areas previously considered to be unsafe. Transportation infrastructures crossing the Alps have significantly increased, making this region one of the main thoroughfares in Europe. Alpine tourism has also gained popularity and remote mountainous areas that were formerly avoided in winter time are now expected to be permanently accessible for tourism For example, 4.5 million tourists per year visit the Bavarian Alps. In the Tyrol region, 8 million guests spend summer or winter holidays, raising the population density to 800 inhabitants per km$^2$ during the peak seasons. The total assets exposed to hazards in mountainous regions have been steadily increasing, thus calling for larger investments in protective measures.

### Main components of the measure(s)

The main function of a protection forest is the protection of people, their assets and infrastructure against natural hazards. The protection forest

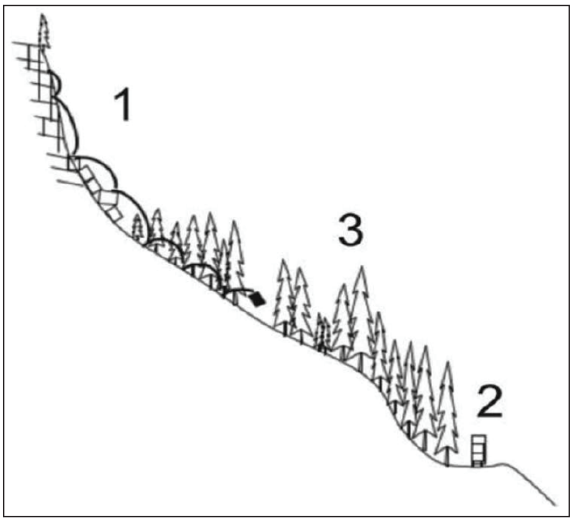


**Figure 1. Protection forest system. The forest (3) protects exposed assets (2) from the hazard (1), which in a mountain setting could be land-slides, rock fall, debris-flow, snow avalanches, erosion, and flooding.** Source: Brang et al., 2001

system consists of three main components: (1) the hazard potential, (2) the exposed assets, and (3) the forest in between. The third element is considered a protection forest if it is able to reduce or prevent the impact of a natural hazard at a given site (see Figure 1 below).

In addition to being more cost-effective, protection forests can have a ***direct*** protective effect, an ***indirect*** protective effect, or a combination of both. A protection forest has a direct protective effect if its protective functions are directly related to its particular location, usually right above the exposed assets. For example, an avalanche protection forest is usually located above a village or road. On the other hand, the indirect protective effect is related not to the particular location of a forest but rather to the presence of this forest in the landscape as a whole. An example would be a forest located in river catchments, where they could prevent or at least contribute to the mitigation of erosive processes or flooding. Additionally, forests can be considered more reassuring in terms of protection rather than avalanche barriers, which provide a reminder of the avalanche threat (Metral, pers communication, 2013).

The protective benefits of a forest depend on the following criteria:

- Type of hazard (including its probability and intensity)

| **Natural Hazard** | Direct protective effect of forests / trees |
|---|---|
| **Snow avalanche** | Forests used mainly for hazard prevention; trees (e.g. coniferous species) impede the building up of a homogenous snow layer, thus avoiding the initiation of such a compact layer and preventing release of a snow avalanche. |
| **Rock fall** | Forests used mainly to mitigate rock fall up to maximum volume of 5 $m^3$. Trees, trunks lying on the ground and root plates act as barriers, reducing the energy of falling rocks and preventing rocks from reaching the lowest part of the slope. |
| **Shallow landslides** | Tree roots can prevent or reduce shallow landslides by mechanical reinforcement of the soil; trees and vegetation reduce superficial erosion through permanent provision of litter, intercept precipitation and positively influence balance of evapotranspiration, which can lead to an improved water balance of the soil. |

- State of the forest itself (type of tree, stem structure, age, density, extent of tree regeneration, susceptibility to infestation
- Position and location of the forest
- Slope characteristics

## Implementation and guidelines

The delimitation and management of protection forests differ across the alpine region, posing major challenges to coherent protection forest management strategies and approaches across national borders.

In Switzerland, the cantons (or state-level governments) are required to delineate protection forests and undertake forest management planning, and they have a high degree of independence from the federal (national) government. Swiss cantons concretize federal forest law through cantonal regulations. The federal government provides national guidelines and strategic leadership, and allocates subsidies to the cantons for protection forest management. Subsidies are awarded based on performances and services delivered by the cantons, although overall costs are meant to be divided between the federation and the cantons and municipalities.

The Swiss forest management system relies heavily on private forest owners (and their foresters) to promote the use of protection forests and follow forest management guidelines. It is estimated that 67% of protection forests in Switzerland are privately owned and 33% are public. Forest owners receive cash incentives for the proper management of protection forests. In some areas such as Davos, private land owners receive a percentage of the profits earned from the ski operations, in return for the use of their land and maintenance of forest cover. Hence, strategic forest planning takes place at the cantonal level and the operational planning at the level of the forest owner. In recent years, there has been a stronger push for more rational risk-based assessments and cost-benefit analysis to determine funding allocations for protection forest projects in the country. Allocation of subsidies and other financial incentives to private forest owners to support protection forest management are also commonly practiced in other alpine countries.

Since forests are dynamic systems, their protective effects change over time. It is therefore necessary to establish forest management systems focusing on maximizing the sustainable, long-term protective effects against hazards. This can be achieved through silvicultural measures, such as thinning or cutting to make room for tree regeneration. These practices aim at establishing a small-scale patchwork of trees of all ages and development stages.

The management of protection forests in alpine countries has been optimized through the elaboration and implementation of specific guidelines, such as the Swiss publication entitled "Sustainability and Success Monitoring in Protection Forests" written in 2005. Also known as the "NaiS guidelines", this handbook allows comparison of the current state of a forest with a minimum and ideal forest profiles depending on the natural hazards involved and the site types in order to reduce the effects of hazardous processes to an acceptable level. These "target profiles" refer mainly to structural elements, such as stem numbers, the size of forest clearings, and canopy density. According to these guidelines, the forest structure should be diverse, with single trees or clusters able to resist disturbances, and tree regeneration should be continuous. The range in variation of tree development within the forest will determine the long-term protective effect of the forest. Heterogeneous forests are preferred over homogenous ones as they are considered to provide the best, long-term protective effect against natural hazards, and demonstrate greater resistance and resilience to natural disturbances. However, many forest stands in the Alps are homogenous, such as protection forests in Switzerland dominated by the Norway spruce (*Picea abies*), and suffer from poor tree regeneration. Table 1 below shows an example of target profiles from the NaiS guidelines.

The NaiS guidelines establish a standardized decision-making process, which is the key to the development and improvement of protection forests. The goal in monitoring protection forests is to achieve a high protective effect as efficiently as possible. NaiS guidelines allow for prioritization of silvicultural measures, and operations are only undertaken when they are viewed to be cost-effective.

## 5. Implications for Ecosystem-based DRR

Protection forests play an important role in disaster risk management in the Alps. Forests in the Alps protect people and their assets from rock fall, snow avalanches, erosion, landslides, debris flows and flooding – hazardous processes that are relatively frequent in the Alps by reducing the intensity (mitigating effect) as well as the probability (preventive effect) of a hazard.

However, protection forests cannot provide complete protection and the residual risk may be further reduced by additional engineered measures such as rock fall nets or snow avalanche barriers.

The Government of Switzerland has spent 120-150 million Swiss francs per year over the past decade on protective measures in forests, but also including engineered measures (avalanche barriers, flexible rock fall nets, etc.). In Bavaria, Germany, about 60 million Euros have been invested since the start of the protection forest rehabilitation programme in 1986, equaling 250 euros per ha for the last 20 years.

Techniques are being developed to estimate the costs and benefits of protection forests. Rock fall risk was evaluated for those driving on the roads downslope from the forest-covered, active rock fall slope, using 3D rock fall simulations with and without the mitigation effect of the existing forest. It shows that the forest reduces the risk for road users at this particular site by 91%. In monetary terms, this corresponds to about 1,000 Swiss francs per ha per year, which does not include the additional monetary benefits provided by forests from tourism, wildlife or agroforestry, which could also be substantial (Wehrli and Dorren, 2013).

## Strengths and weaknesses

Protection forests are in general very effective and efficient in reducing mountain hazards. For instance, they can provide protective effects over large areas, e.g. an entire slope, and can be used against different types of natural hazards at the same time, e.g. avalanche and rock fall. Therefore, they have clear advantages when compared with technical measures, which are often spatially restricted and normally provide protection against only one type of hazard. The management of protection forests is also considered 5-10 times less expensive than the construction and maintenance of technical or engineered measures

**Table 1. Minimum and ideal forest profiles for a given site type and natural hazard**
Source: Modified from Frehner et al., 2005

| **Natural Hazard:** | **Site type:** |
|---|---|
| Rockfall in the transit zone<br>Relevant rock size about 50cm<br>Target profile see Appendix 1 | Typical Silver fir-Beech forest on carbonatic bedrock |

| **Stand and tree characteristics** | **Minimum Profile** | **Ideal profile** |
|---|---|---|
| **Mixture**<br>Type and degree | Beech 30-80%<br>Silver fir 10-60%<br>Norway Spruce 0-30%<br>Sycamore maple Seed trees | Beech 40-60%<br>Silver fir 30-50%<br>Norway Spruce 0-20%<br>Sycamore maple, ash 10-30% |
| ***Structure**<br>Stem diameter (dbh variation) | Sufficient number of trees with development potential in at least 2 different dbh classes per ha | Sufficient number of trees with development potential in at least 3 different dbh classes per ha |
| Horizontal structure | Individual trees, possibly clusters<br>At least 300 trees/ha with dbh> 24cm | Individual trees, possibly clusters, canopy closure open<br>At least 400 trees/ha with dbh> 24cm |
| **Stability carriers**<br>Crowns | Crown length of silver fir at least 2/3 of Norway at least 1/2 | Crown length at least 2/3 |
| Coefficient and slenderness | <80 | <70 |
| Stand/ anchoring | Upright stems, well anchored, few trees leaning at extreme angles | Upright stems, well anchored, no trees leaning at extreme angles |
| **Regeneration**<br>Seedbed | Area with strongly competing vegetation <1/3 | Area with strongly competing vegetation <1/4 |
| Small saplings (10cm to 40cm tall) | At canopy closure <0.6 at least 10 beech/silver fir per 0.01 ha (on average one saplings every 3 m).<br>In openings maple present | At canopy closure <0.6 at least 50 beech/silver fir per 0.01 ha (on average one saplings every 1.5 m).<br>In openings maple present |
| Large saplings (40cm tall to 12cm dbh) | On each ha, at least 1 group (0.02-0.05 ha), on average 1 group every 100m) or canopy cover at least 4%<br>Mixture in line with target profile | On each ha, at least 3 group (0.02-0.05 ha), on average 1 group every 60m) or canopy cover at least 7%<br>Mixture in line with target profile |

(Wehrli and Dorren, 2013).

Although effective in reducing dissipating the impact of mass movements such as rock fall, debris flow, and snow avalanches, obviously forests do not completely protect against mountain hazards. As an added measure to protect important transportation infrastructures, governments combined this "green measure" with structural solutions such as rock fall nets or snow avalanche barriers (Figure 3).

Moreover, optimal protection of forests requires several elements, such as diversity and resistance against pest infestation. Forests which lack these characteristics are less effective in mitigating hazards.

## 6. Lessons learned and conclusions

Protection forests are regarded to be a highly effective and efficient measure against natural hazards in the Alps, playing a key role in integrated disaster risk management strategies in the region. Modern management of protection forests is mainly based on harnessing the protection potential of natural ecosystems (structures and processes), aiming to maximize both effectiveness and efficiency.

Several factors are critical to successful management of protection forests, such as the development of high-quality guidelines and trainings for foresters and forest owners to ensure proper implementation of the recommended measures. Knowledge gaps about the entire forest protection system also need to be addressed, for example, by improving natural hazard-protection forest simulation models, in order to gain better insights into the forest protection systems as well as to improve existing guidelines. Adopting an interdisciplinary approach will allow to address wide array of biological, silvicultural, technical and economic challenges. These measures are underpinned

**Figure 2. Protection forest, Davos, Swithzerland.**
Credit: UNEP

**Figure 3. An Austrian mountain road threatened by rock fall with three different protection measures commonly used in the Alps: a rock fall net, a rock fall dam and a protection forest** Credit: L. Dorren, 2004

by continuous political and financial support to ensure sustainable forest management.

## 7. Exercise and teaching notes

1. Protection forests offer both direct and indirect protection functions. Explain the link between these two functions.

2. Enumerate the four factors which influence the effectiveness of protection forests and explain in what way they affect the protective function of the forests.

    I. Type of hazard

    II. State of the forest

    III. Position and location of the forest

    IV. Slope characteristics

3. In Switzerland, at which political level is forest management undertaken? What is the role of the Federal government? Give an advantage to decentralizing forest management.

4. Imagine yourself as the mayor of an alpine community. Being at the border between two countries, your community is along a busy route used to transport people and merchandises by train, trucks and private vehicles. However, this important axis often experiences avalanches in winter and rock falls in the summer. Which measure(s) would you choose to mitigate these risks and why?

### Answers

1. Protection forests offer both direct and indirect protection functions. Explain the link between these two functions.

    Direct protection is site-related, meaning that the forest protects by being in between the hazard and the exposed people and infrastructure.

    Indirect protective function is important as it protects the forest site against processes such as flooding and excessive soil erosion. For example, through its root system, a forest stabilizes the soil structure, thus reducing the risk of erosive processes.

The indirect protective function supports the direct protective function by enabling an environment for the forest to survive and pursue its role of protecting assets. If the indirect function is compromised, the forest site erodes and leads to destruction, in part or in whole, of the mountain ecosystem.

2. Enumerate the four factors which influence the effectiveness of protection forests and describe in what way they affect the protective function of the forests.

   I. Type of hazard: the protection forests provide differs on the hazard in question; a forest prevents snow avalanche by inhibiting homogenous build-up of snow layer. On the other hand, protection forests slow down rock fall and reduce its energy as it travels downslope.

   II. State of the forest: a diverse forest composed of different tree species at various growth stages is more effective in reducing hazards and also more resilient to infestation. Rapid tree regeneration ensures continue supply of trees in the forest.

   III. Position and location of the forest: Evidently, a healthy mountain forest protects better if it is located directly between the hazard and the asset to be protected.

   IV. Slope characteristics: a high slope gradient increases the energy and therefore the impact of the mountain hazard, be it rock fall, snow avalanche, debris-flow, or flood.

3. In Switzerland, at which political level is forest management undertaken? What is the role of the Federal government? Give an advantage to decentralizing forest management.

   The Cantons or state-level government are in charge of undertaking forest management planning. The Confederation or the Swiss Federal government allocates subsidies and passes national forest management laws and develops strategic guidelines, which are then implemented by the Cantons. Decentralization facilitates protection forest management as the state governments have direct influence on forest policies within their jurisdiction and have more freedom in their choice strategies.

4. Imagine yourself as the mayor of an alpine community. Being at the border between two countries, your community is along a busy route used to transport people and merchandises by train, trucks and private vehicles. However, this important axis often experiences avalanches in winter and rock falls in the summer. Which measure(s) would you choose to mitigate these risks and why?

   Given the importance of this route, a hybrid approach may be the best option in this case. Protection forests combined with steel wire mesh nets, anchors, bots, or retaining walls to reinforce unstable rock masses and snow barriers against avalanche would mitigate rock fall and snow avalanche risks.

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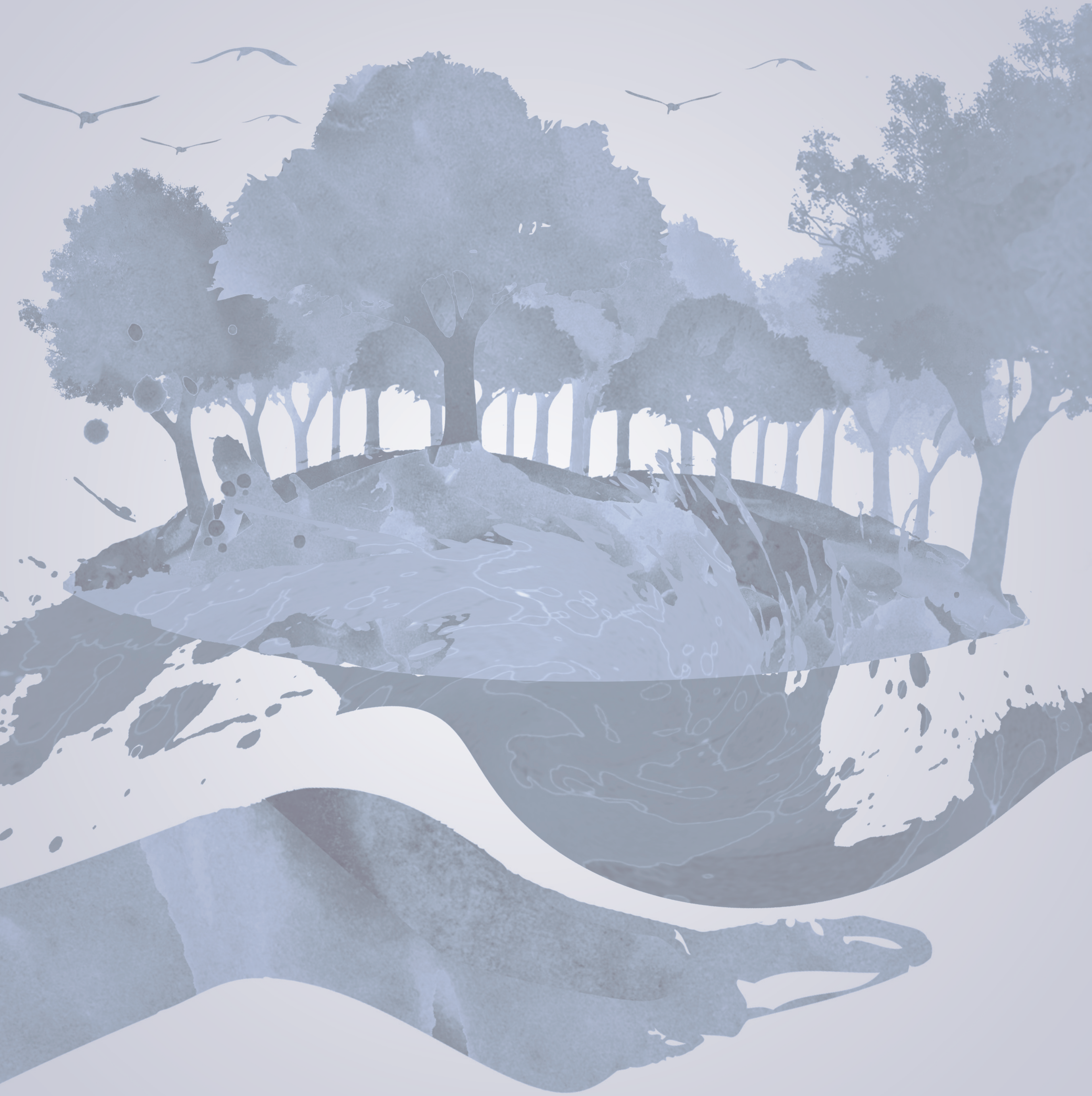

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