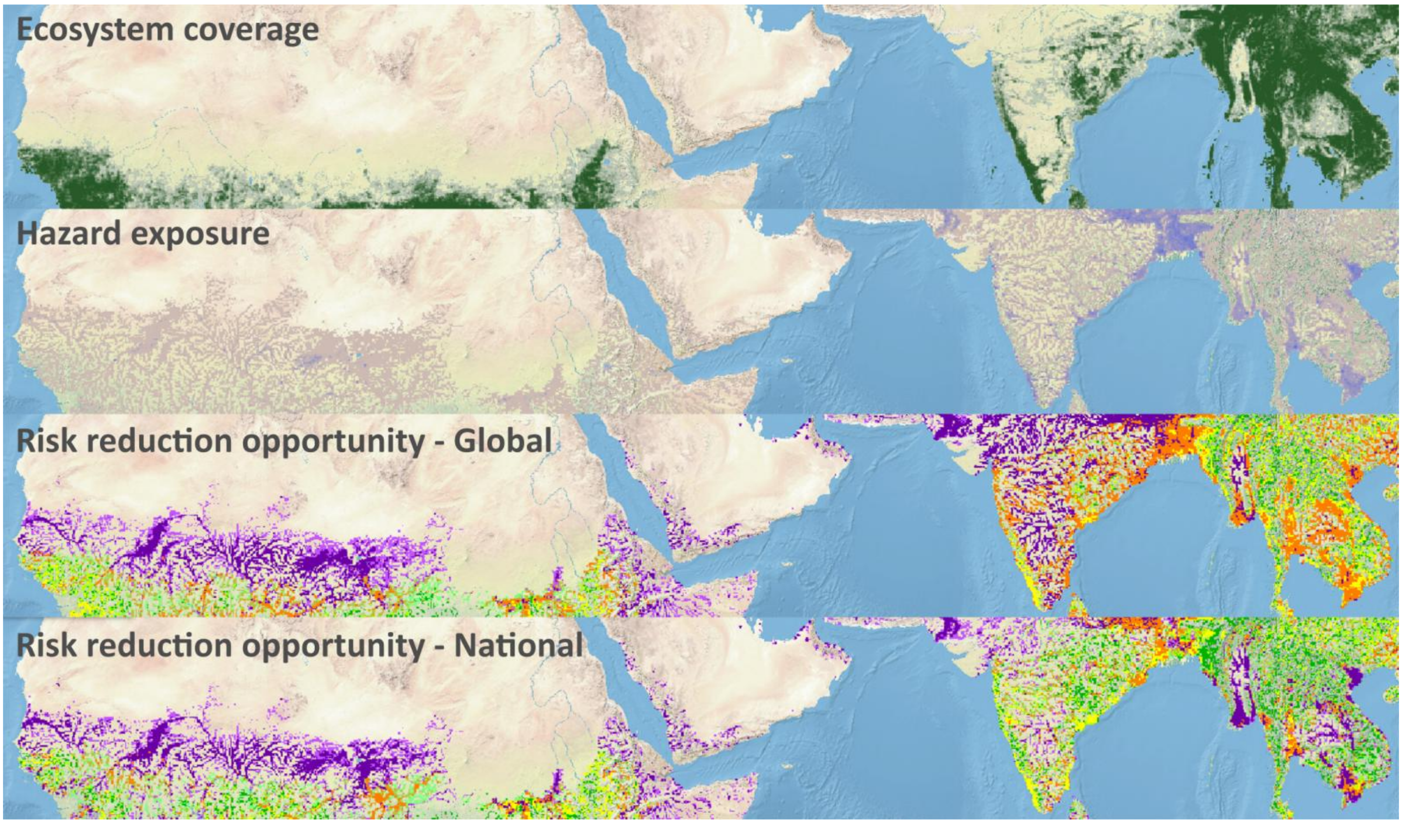
Eco-DRR Opportunity Mapping Tool



Background from Natural Earth (http://www.naturalearthdata.com)

Promoting Improved Ecosystem Management for Sustainable and Disaster-Resilient Development

Technical report – February 2017

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Table of Contents

Executive summary

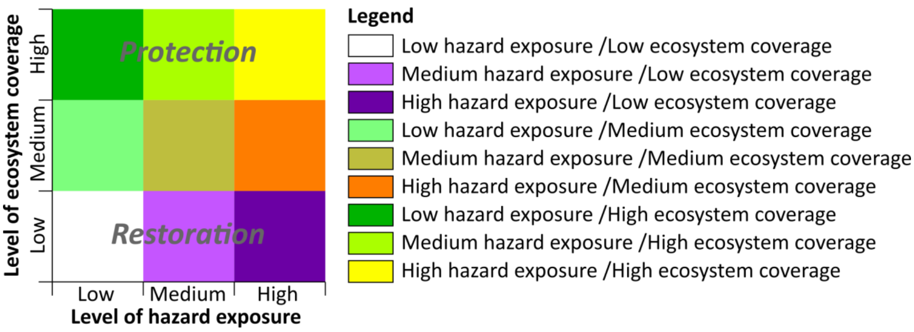
In the past few years, UN Environment has been promoting Ecosystem-based Disaster Risk Reduction (Eco-DRR) through policy advocacy, capacity building and pilot demonstration projects and has developed country profiles that link ecosystems and disasters at the national and sub-national levels. By developing a global Eco-DRR opportunity mapping tool that is freely accessible to all and easy to use, UN Environment aims to scale up its efforts in promoting Eco-DRR globally.

The objectives of the opportunity-mapping tool are:

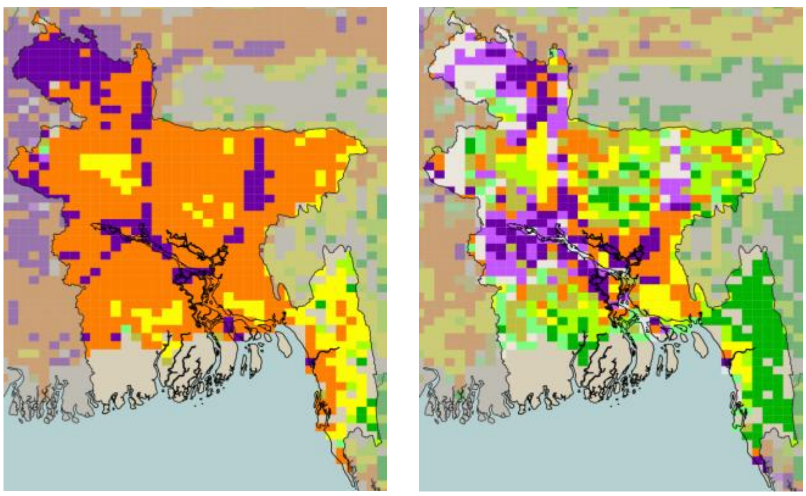
- To visually demonstrate the locations of ecosystems in relation to human exposure for a range of natural hazards and ecosystem types in each country;
- To identify potential areas for ecosystem conservation and/or restoration as a means to reducing exposure to hazards for the highest number of people;
- To identify protected areas that play an important role in reducing exposure of population to hazards;
- To provide a powerful visual tool to promote and scale-up Eco-DRR investments and actions globally, including protected areas for disaster risk reduction.

The opportunity mapping tool overlays global data on ecosystem coverage, with exposure to various hazards. The opportunity mapping tool also includes a global dataset on population, to visually demonstrate areas where large numbers of people are at risk, and could benefit from restoration or protection of ecosystems. A global dataset on protected areas is also included, to identify opportunities for using protected areas for disaster risk reduction, for instance protecting forests to reduce flood risk.

In areas where ecosystem coverage is low, but exposure to hazards is high, ecosystem restoration can provide an opportunity to reduce disaster risk (purple shades on the maps). Where ecosystem coverage is high and exposure is also high, ecosystem protection provides an opportunity to reduce risks to the population.



The figure on the right shows Eco-DRR opportunities for Bangladesh at global level (left) and national level (right) for the combination of flood exposure and forest ecosystems.



A global opportunity-mapping tool is timely as countries are now faced with the challenge to operationalize Eco-DRR and Ecosystem-based adaptation. As international attention moves from passing global agreements to actual implementation, governments, practitioners and development agencies are seeking to translate these global goals into coordinated national action plans, legislations, and development programs. This opportunity-mapping tool adds value by guiding the implementation of ecosystem-based aspects of these agreements.

The potential users of the Opportunity Mapping tool for Eco-DRR are decision makers and practitioners within Governments, communities, private sector and international development agencies. However, the online platform is available to allas an open access tool at http://EcoDRRmapping.grid.unep.ch

Introduction

Ecosystems provide a range of services such as provision of food, fiber and other resources, as well as supporting biodiversity, providing recreational opportunities, economic benefits (e.g. fisheries), and carbon sequestration. Ecosystems are also increasingly recognized for their role in reducing disaster risk and the harmful impacts of climate change. Mangroves, sea grasses and coral reefs have been proven to reduce wave energy and related impacts from storm surges; forests and other vegetation can reduce landslide susceptibility by removing excessive soil water content and stabilizing the soil through root networks; forests can also buffer drought by regulating humidity and increasing precipitations, through albedo, roughness, shadow, heat absorption and evapotranspiration processes.

The extent of our knowledge on exposure to hazards has improved drastically in the past few years. Pioneer global research such as identification of Disaster Risk Index (UNDP 2004), World Bank Global Hotspots Project (Dilley et al., 2005) and the iterative versions of the UNISDR Global Assessment Reports (UNISDR, 2009, 2011, 2013 and 2015) have helped us better understand disaster risk world wide. Other global initiatives have also contributed to the improvement of data availability on hazards, for instance: the Global Flood Model (Rudari et al., 2015), Global Tropical Cyclones Model (Peduzzi et al. 2012), Global Landslides from precipitation and earthquakes models (Nadim et al., 2009), and the Global Tsunami model (Løvholt et al., 2012).

In parallel, global datasets have also been compiled on various ecosystems; these include the World Resources Institute's (WRI) forest and forest opportunity dataset[1], UN Environment/World Conservation Monitoring Center (WCMC) datasets on sea grasses, mangroves and coral reefs[2] and the World Database on Protected Areas[3].

While regional assessments have been conducted (Chatenoux and Peduzzi, 2007; Peduzzi, 2010; UNEP, 2010; Chatenoux & Wolf, 2013), no cross mapping of ecosystem distributions and human exposure to hazards at a global scale has been made to date. The availability of global datasets provides an opportunity to compare the restoration and conservation potential of various ecosystems to population exposure to hazards in order to find opportunity areas where ecosystem management can be used to protect the highest number of people from disasters.

In the past few years, UN Environment has been promoting Ecosystem-based Disaster Risk Reduction (Eco-DRR) through policy advocacy, capacity building and pilot demonstration projects, and has developed country profiles that link ecosystems and disasters at the national and sub-national levels. However, individual profiling efforts have had a limited reach. Therefore UN Environment aimed to scale up its efforts and extend its reach, by developing a standard opportunity-mapping tool for Eco-DRR, which is visual and applicable to all countries.

The objectives of the opportunity-mapping tool are:

- To visually demonstrate the locations of ecosystems in relation to human exposure for a range of natural hazards and ecosystem types in each country;
- To identify potential areas for ecosystem conservation and/or restoration as a means to reducing exposure to hazards for the highest number of people;
- To identify protected areas that play an important role in reducing exposure of population to hazards;
- To provide a powerful visual tool to promote and scale-up Eco-DRR investments and actions globally, including protected areas for disaster risk reduction.

In areas where ecosystem coverage is low, but exposure to hazards is high, ecosystem restoration can provide an opportunity to reduce disaster risk. Where ecosystem coverage is high and exposure is also high, ecosystem

[1] http://www.wri.org/applications/maps/flr-atlas/#&init=y
[2] http://data.unep-wcmc.org/datasets/6
[3] https://www.protectedplanet.net/

protection provides an opportunity to reduce risks to the population, while loss of the existing ecosystem may lead to higher exposure of the population. The opportunity mapping tool also includes a global dataset on population, to visually demonstrate areas where large numbers of people are exposed to hazards, and could benefit from restoration or protection of ecosystems. A global dataset on protected areas is also included, to identify opportunities for using protected areas for disaster risk reduction, for instance protecting forests to reduce flood risk.

A global opportunity-mapping tool is timely as countries are now faced with the challenge to operationalize Eco-DRR and Ecosystem-based adaptation. In 2015 a number of major global agreements were adopted which recognize the key role of ecosystems and ecosystem services in helping achieve disaster risk reduction, sustainable development and climate change adaptation; these include the Sendai Framework for Disaster Risk Reduction (SFDRR), the Sustainable Development Goals (SDGs), the Paris Agreement of UNFCCC CoP21 and the Decision XXII.13 of the Convention on Wetlands of International Importance (Ramsar). As international attention moves from passing global agreements to actual implementation, governments, practitioners and development agencies are seeking to translate these global goals into coordinated national action plans, legislations, and development programs. The opportunity-mapping tool adds value by guiding the implementation of ecosystem-based aspects of these agreements.

The target users of the Opportunity Mapping tool for Eco-DRR are decision makers and practitioners within Governments, communities, private sector and international development agencies. However, the online platform is available to all as an open access tool at http://EcoDRRmapping.grid.unep.ch [4]

It should be noted that the cross mapping of ecosystem coverage and hazard exposure consists simply of the quantification of the intersection of a hazard exposure with an ecosystem coverage. These outputs do not include an analysis of capabilities for action at a local scale (e.g. restoration or protection activities cannot be implemented wisely in urban areas).

Data used and methodology

Data

Three sets of data were used:

1) **global coverage of several ecosystems** :

- Forests (includes closed forests, open forests and woodlands)
- Mangroves
- Sea grasses
- Coral reefs

2) **hazard exposure datasets** which include hazard frequencies and intensities, as well as location of population. The hazard types assessed were:

- Storm surge
- Tsunami
- Landslides trigerred by earthquakes
- Landslides trigerred by precipitation
- Flood
- Tropical cyclone

[4] For the full dataset see http://ecodrrmapping.grid.unep.ch/maps/73

3) **the World Database on Protected Areas (WDPA)** which provides a picture of the extent, location, name, status and other useful information on the world's protected areas. Launched in 1981, this joint project between UN Environment and the International Union for Conservation of Nature (IUCN) World Commission on Protected Areas represents the most complete data set on the world's terrestrial and marine protected areas.

The datasets used in this project are freely available on the internet, with two exceptions: 1) The World Resources Institute's (WRI) Forest coverage data set was made available to the developers upon request, and 2) the LandScan population dataset was purchased by GRID-Geneva, due to the lack of a representative and homogeneous free global population dataset. More information about the datasets used is presented in tables 1 and 2.

The various reference periods of the dataset have been chosen to balance between the most recent data and usability. For example, although a more recent (2015, ~30 km resolution) version is available,[5] the 2013 version of tropical cyclone wind data was selected because it has a higher resolution (10 km) and was therefore more suitable to the present study.

Table 1: Ecosystem datasets used

Title	Provider	Reference Period	Resolution	Url
WRI Current forest coverage	World Resources Institute (WRI) Atlas of Forest	2000 - 2009	~1 km	http://www.wri.org/applications/maps/flr-atlas/
WCMC Global Distribution of Mangroves USGS	World Conservation Monitoring Center (WCMC) Ocean Data Viewer	1997 - 2000	~30 m	http://data.unep-wcmc.org/
WCMC Global Distribution of Sea grasses	WCMC Ocean Data Viewer	1934 - 2011	vector	http://data.unep-wcmc.org/
WCMC Global Distribution of Coral Reefs	WCMC Ocean Data Viewer	1954 - 2009	vector	http://data.unep-wcmc.org/
World Database on Protected Areas (WDPA)	Protected Planet	-	vector	https://www.protectedplanet.net/

Table 2: Datasets used to compute physical exposures to hazards

Title	Provider	Reference Period	Resolution	Url
PREVIEW Storm surge frequency	GAR 2009, PREVIEW / Global Risk Data Platform	1970 - 2009	~1 km	http://preview.grid.unep.ch
Tsunami hazard (run up) RP 500 years	GAR 2015	model	vector	http://preview.grid.unep.ch
PREVIEW Landslides (triggered by earthquake) frequency	GAR 2009, PREVIEW / Global Risk Data Platform	model	~1 km	http://preview.grid.unep.ch
PREVIEW Landslides (triggered by precipitation) frequency	GAR 2009, PREVIEW / Global Risk Data Platform	model	~1 km	http://preview.grid.unep.ch
Flood hazard # years	GAR 2015	model	~1 km	http://preview.grid.unep.ch
PREVIEW Tropical cyclones frequency	GAR 2013, PREVIEW / Global Risk Data Platform	1970 - 2011	~1 km	http://preview.grid.unep.ch
Population 2011	LandScan[6]	2011	~1 km	Licensed

[5] http://preview.grid.unep.ch/index.php?preview=home&lang=eng

[6] Cost constrains did not allow the acquisition of a more recent version of LandScan.

Methodology

This section describes briefly the process used to develop the Eco-DRR opportunity mapping tool using standard GIS functions. This process was implemented using bash[7] scripts using Grass GIS[8], FME ©[9] and R[10].

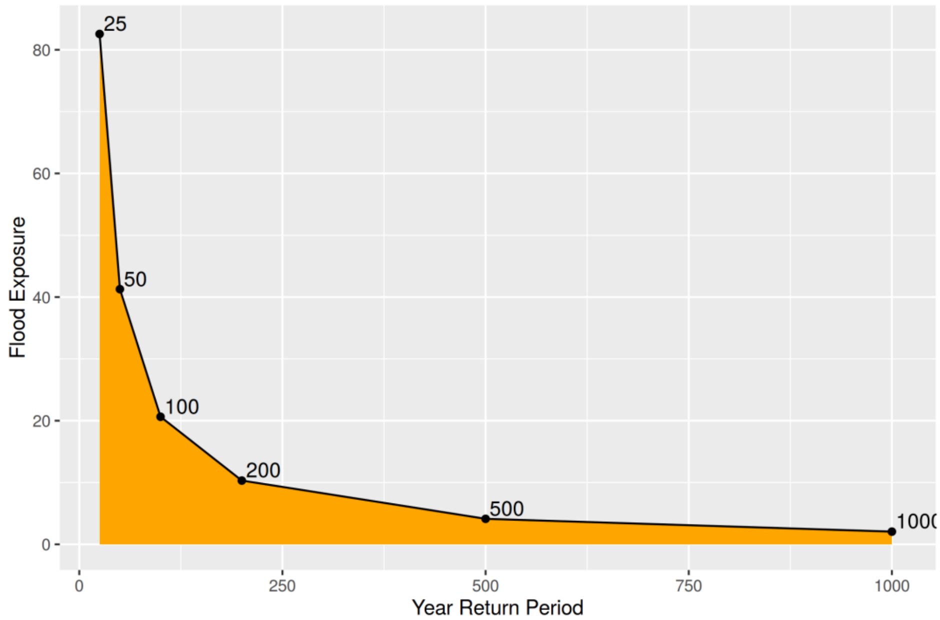
Physical exposure computation

Physical exposure was computed by multiplying the frequency of occurrence of a given hazard in any location by the population of that location (both datasets are in raster format). Depending on the type of frequency dataset available, two different types of physical exposure were computed.

> ***Approximated physical exposure:*** In cases where the frequency dataset was based on past events (as opposed to mathematically modelled), physical exposure was approximated as "population affected in hazard location" (poploc hereafter). In this case a "_pl" suffix is used in the name of the generated dataset (Table 3).
>
> ***Modelled physical exposure:*** In cases where the hazard frequency dataset was the result of a mathematical model (as in the case of flood and landslide), modelled physical exposure was computed. In this case, a "_pe" suffix is used in name of the generated dataset (Table 3).

In the case of a dataset modelled with several return periods, exposure was calculated as the integral of the exposure of each return period (orange surface in Figure 1).

Figure 1: Physical exposure integration for flood hazard



7 https://www.gnu.org/software/bash/
8 https://grass.osgeo.org/
9 http://www.safe.com/
10 https://www.r-project.org/

Data aggregation

Ecosystem coverage and physical exposure to a given hazard (including population location or poploc) were aggregated at the global scale at a 10 kilometres resolution grid (created using a Gall Peters equal-area coordinate system), by measuring the surface of ecosystem coverage and summing the physical exposure (Figure 2) in each cell.

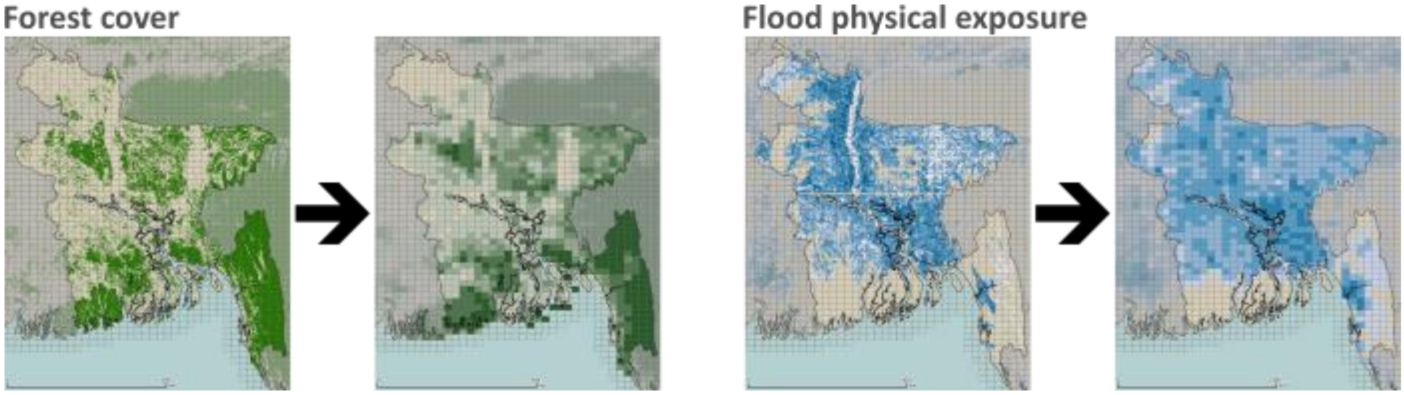


Figure 2: Example of aggregation at 10 km resolution in Bangladesh

In order to include underwater marine ecosystems such as seagrasses, coral reefs and partially mangroves, a shoreline buffer was created using a 20 km limit around land masses. This buffer covers the area of the ocean that includes shallow marine and coastal ecosystems in the grid. Each underwater cell was assigned to the closest country.

The output of this data aggregation phase is a global vector grid at a 10 kilometers resolution, containing the following data layers:

Table 3: Description of the attributes generated during the aggregation phase and available in the vector dataset

Attribute	Description	Provider
cellid	Unique cell ID	Project
gc	Country Grid Code (ISO3 number)	Project
iso3	Three letter country code name (ISO3)	Project
terr_name	Country name	Project
buff	Buffer size (0 = inland, 1 = 10 km, 2 = 20 km)	Project
cell_km2	Cell size in km^2 (in present case 100 km^2)	Project
land_km2	Land surface in km^2	project
population	Population	Landscan 2011
closed_km2	Closed forest surface in km^2	WRI
opened_km2	Open forest surface in km^2	WRI
woodl_km2	Woodland surface in km^2	WRI
mangr_km2	Mangrove surface in km^2	WCMC
seagr_km2	Sea grass surface in km^2	WCMC
coral_km2	Coral surface in km^2	WCMC
tsun_pl	Population in tsunami exposed area (Tsunami poploc)	GAR 2015
tcw_1_pl	Population exposed to tropical cyclone category 2 winds (TC Wind (SSCat 1) poploc)	GAR 2013
tcw_2_pl	Population exposed to tropical cyclone category 1 winds (TC Wind (SSCat 2) poploc)	GAR 2013

tcw_3_pl	Population exposed to tropical cyclone category 3 winds (TC Wind (SSCat 3) poploc)	GAR 2013
tcw_4_pl	Population exposed to tropical cyclone category 4 winds (TC Wind (SSCat 4) poploc)	GAR 2013
tcw_5_pl	Population exposed to tropical cyclone category 5 winds (TC Wind (SSCat 5) poploc)	GAR 2013
tcs_1_pl	Population exposed to tropical cyclone category 1 surge (TC Surge (SSCat 1) poploc)	GAR 2009
tcs_2_pl	Population exposed to tropical cyclone category 2 surge (TC Surge (SSCat 2) poploc)	GAR 2009
tcs_3_pl	Population exposed to tropical cyclone category 3 surge (TC Surge (SSCat 3) poploc)	GAR 2009
tcs_4_pl	Population exposed to tropical cyclone category 4 surge (TC Surge (SSCat 4) poploc)	GAR 2009
tcs_5_pl	Population exposed to tropical cyclone category 5 surge (TC Surge (SSCat 5) poploc)	GAR 2009
lseq_pe	Landslide (earthquake triggered) physical exposure	GAR 2009
lspr_pe	Landslide (precipitation triggered) physical exposure	GAR 2009
flood_pe	Flood physical exposure	GAR 2015

Hazard exposure/Ecosystem coverage combinations (cross-mapping)

The next step consisted of combining a given hazard exposure with a given ecosystem cover. Each ecosystem type can effectively reduce exposure to a particular set of hazards, but not all. For example, coral reefs can reduce exposure to tsunami and storm surge, but are not effective buffers against winds, landslides or flooding that originates inland. Therefore only the relevant hazard types were cross-mapped with each ecosystem type. Table 4 shows the hazard and ecosystem types that were cross mapped.

Table 4: Combinations (V = applied, x = not applied)

	Tsunami	Tropical cyclone Wind	Tropical cyclone surge	Landslide	Flood
Forest	✓	✓	✓	✓	✓
Mangrove	✓	×	✓	×	×
Sea grass	✓	×	✓	×	×
Coral reef	✓	×	✓	×	×

In order to simplify analysis and interpretation of output some data were aggregated:

- Closed and opened forest data, as well as woodland data were summed into a single ecosystem category named "Forest".
- The stronger the tropical cyclone (the higher on the Saffir-Simpson categories), the higher is the elevation of the flooded area. Therefore the extent of tropical cyclone surge varies with its category. For this reason, we used the maximum exposure of all categories to ensure that the entire area exposed is covered by the analysis, while minimizing the number of tropical cyclone exposure categories.

- Contrary to storm surge, the extent of tropical cyclone wind of a given Saffir-Simpson[11] category is entirely contained in the extent covered by the inferior category. Therefore only category I exposure to wind was used in this analysis as it includes the extent of higher categories.

However users can also find the disaggregated datasets freely available online at http://EcoDRRmapping.grid.unep.ch/.

Figure 3 (left) shows the global distribution of hazard exposure/ecosystem coverage combinations for a Flood/Forest combination, with the density curves in blue (as the values are not homogeneously spread. Notice the logarithmic scale used for the x-axis, i.e. exposure. On the right, the raw data was split in 3 groups of equal number of records on each axis, therefore 1/3 of records along each axis in each group. Each grid cell (10 x 10 km) on the map has a value for its exposure to each hazard type, and a value for coverage of each ecosystem type. By adding three category limits along the x axis (exposure), 33% of grid cells fall to the right of the first vertical line (highly exposed cells), 33% fall between the two vertical red lines (medium exposure), and 33% fall on the left side of the last vertical line (low exposure). Similarly, the horizontal lines divide ecosystem coverage into three equal groups. 33% of cells fall above the top horizontal line (have high ecosystem coverage), 33% fall between the two (have medium ecosystem coverage), and 33% fall below the lowest line (have low ecosystem coverage). The same categorization was done for all ecosystem/hazard combinations.

Combining the groups along the two axes gives a total of 9 groups: white, blue-green, dark green, light green, yellow, mustard, orange, light purple and dark purple. These groups create our 9 Eco-DRR opportunity categories (Figure 4).

Figure 3: From raw hazard exposure/ecosystem coverage combination (left) to Eco-DRR opportunity categories (right)

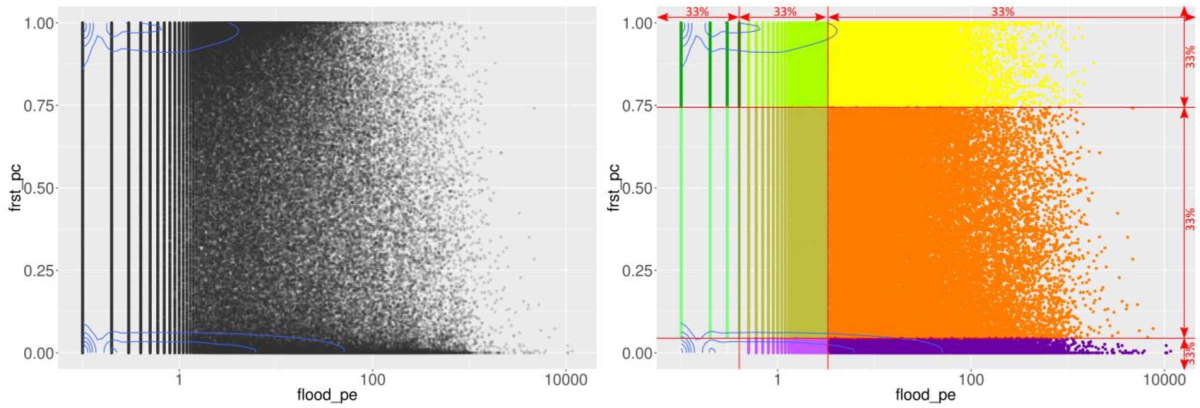
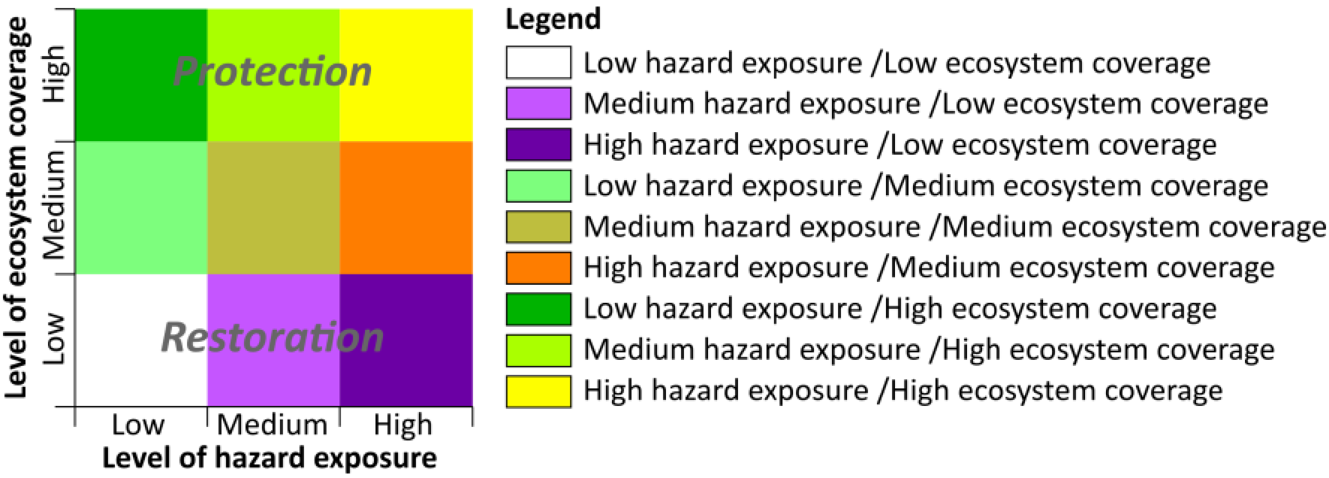


Figure 4: Eco-DRR opportunity categories

[11] http://www.nhc.noaa.gov/aboutsshws.php



Using 9 colored categories allows the user to easily differentiate colours in maps and figures and identify in each location (10 x 10 km area) around the world:

- the level of **exposure** for a given hazard,
- the level of coverage for a given **ecosystem**,
- the type of **priority action** to be undertaken.

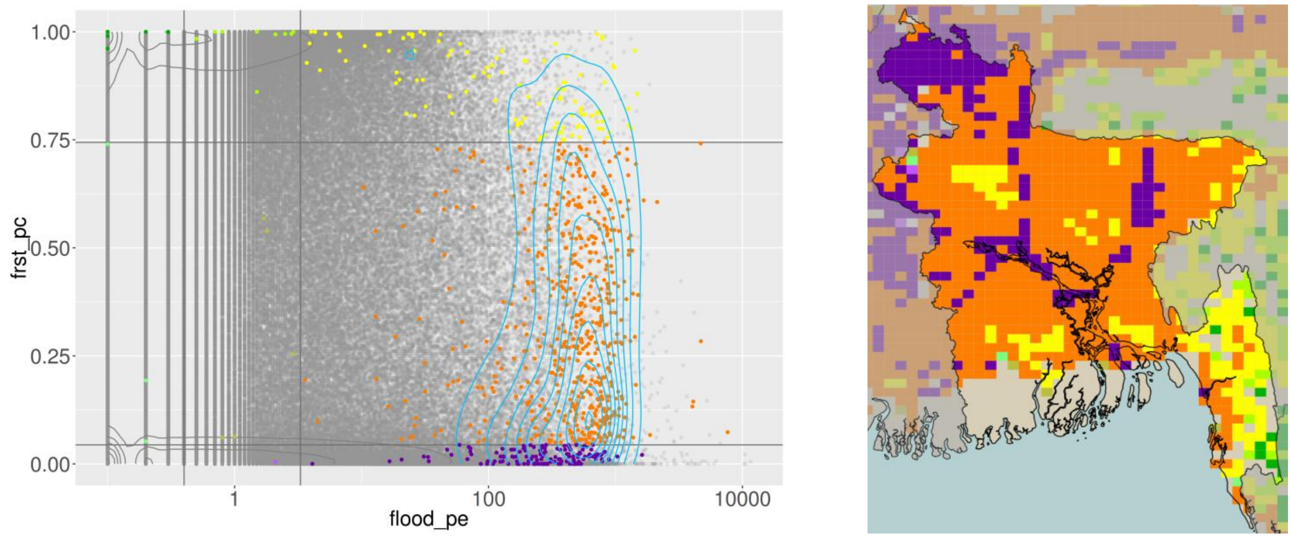
Two possible approaches for future action emerge from these 9 categories. In areas where the ecosystem coverage is high (dark green to yellow), eventual initiatives should focus on protecting the existing ecosystem, in order to avoid the reduction of its coverage. In other words, ecosystem protection will ensure that the area does not become more exposed (move down to blue-green to orange categories). This is especially important for areas where the level of exposure to a given hazard is medium or high, therefore yellow and light green areas are priorities for ecosystem protection. In areas where the ecosystem coverage is low and particularly when the hazard exposure is medium to high (purple colors), possible actions should focus on restoring the ecosystem, with eventually the aim, in the long-run, of increasing the ecosystem coverage (moving up in scale to pale green to orange categories).

Country normalisation

Using the same Eco-DRR opportunity category limits for each country allows for comparison at a global scale and between countries. However keeping the same category limits reduces the number of categories for a given country. This is because the distribution of data from all countries combined is much wider than that of data from one country alone. For example the level of ecosystem coverage can be very different between two cells from two different countries, while two grid cells from the same country are more likely to have similar ecosystem coverage. Similarly, the level of exposure to a certain hazard varies widely among countries in the world, while the variation is lower within the same country. It was therefore necessary to conduct an additional level of analysis to make the Eco-DRR opportunity mapping tool useful for decision makers at the national level: datasets were normalized for each country.

Let us examine the case of Bangladesh. The left part of Figure 65 highlights the distribution of flood exposure / forest cover combination for Bangladesh (coloured dots). Hazard exposure is concentrated in high categories and ecosystem coverage is concentrated in lower and medium categories. Consequently, the majority of classified cells are orange or purple.

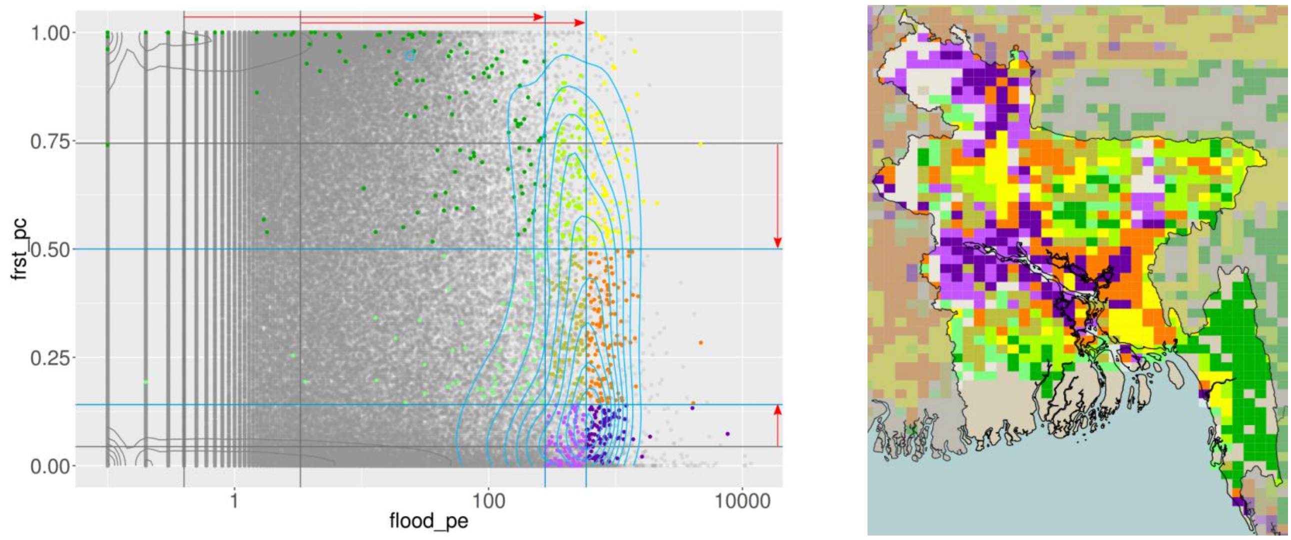
Figure 5: Bangladesh Eco-DRR opportunities (combination flood exposure / forest coverage) categories without country normalization



While such classification allows global users to prioritize actions to be undertaken and compare situations between Bangladesh and other countries, such maps are less useful for users interested to find opportunity areas for Eco-DRR within Bangladesh.

The Figure 6 shows how the data from Bangladesh was normalized, i.e. category limits were moved (from grey vertical and horizontal lines to blue lines). Unlike with the previous non-normalized map, national users can now visualize the type of action that could be undertaken at national level within the 9 categories.

Figure 6: Bangladesh Eco-DRR opportunities (combination flood exposure / forest coverage) categories with country normalization



Limitations of normalization

Defining restoration opportunity categories using national limits instead of global limits, allows for splitting national data into 9 categories with data as equally distributed as possible. However it should be noted that:

- depending on the distribution of values, splitting the hazard exposure and the ecosystem coverage in 3 groups with the same amount of records is a target impossible to reach,
- combining hazard exposure and ecosystem coverage categories does not guarantee that each category will contain 1/9 of the records.

TTable 5 shows the actual number of records in each category.

Table 5: Percentage of records in each non-normalized (left) and normalized (right) categories for Bangladesh (Figure 6)

Level of ecosystem coverage	**High**	0.8%	1.1%	13.4%
	Medium	0.4%	0.6%	67.1%
	Low	0.0%	0.1%	16.6%
		Low	**Medium**	**High**
		Level of hazard exposure		

Level of ecosystem coverage	**High**	13.5%	10.7%	9.0%
	Medium	7.5%	11.8%	14.1%
	Low	12.4%	10.8%	10.2%
		Low	**Medium**	**High**
		Level of hazard exposure		

Restoration opportunity dataset

In the cross-mapping phase, new attributes were added to the previous output dataset (described in Table 3) to reflect the combination of datasets.

Table 6: Description of the new attributes generated during the cross-mapping phase

Attribute	Description	Provider
frst_pc	Forest coverage percentage	project
flo_fr_gl	Combination Flood/Forest non-normalized (global)	project
flo_fr_na	Combination Flood/Forest normalized (national)	project
ls_fr_gl	Combination Landslide/Forest non-normalized (global)	project
ls_fr_na	Combination Landslide/Forest normalized (national)	project
tcs_co_gl	Combination Tropical Cyclone Surge/Coral non-normalized (global)	project
tcs_co_na	Combination Tropical Cyclone Surge/Coral normalized (national)	project
tcs_fr_na	Combination Tropical Cyclone Surge/Forest non-normalized (global)	project
tcs_fr_gl	Combination Tropical Cyclone Surge/Forest normalized (national)	project
tcs_ma_gl	Combination Tropical Cyclone Surge/Mangrove non-normalized (global)	project
tcs_ma_na	Combination Tropical Cyclone Surge/Mangrove normalized (national)	project
tcs_se_gl	Combination Tropical Cyclone Surge/Sea grass non-normalized (global)	project
tcs_se_na	Combination Tropical Cyclone Surge/Sea grass normalized (national)	project
tcw_fr_gl	Combination Tropical Cyclone Wind/Forest non-normalized (global)	project
tcw_fr_na	Combination Tropical Cyclone Wind/Forest normalized (national)	project
tsu_co_gl	Combination Tsunami/Coral non-normalized (global)	project
tsu_co_na	Combination Tsunami/Coral normalized (national)	project
tsu_fr_na	Combination Tsunami/Forest non-normalized (global)	project
tsu_fr_gl	Combination Tsunami/Forest normalized (national)	project
tsu_ma_gl	Combination Tsunami/Mangrove non-normalized (global)	project
tsu_ma_na	Combination Tsunami/Mangrove normalized (national)	project
tsu_se_gl	Combination Tsunami/Sea grass non-normalized (global)	project
tsu_se_na	Combination Tsunami/Sea grass normalized (national)	project

Each combination in Table 4 (with a ✓ symbol) corresponds to two attributes in Table 6. The first one, without normalization (with the _gl postfix) for a global analysis, the second one with a normalization per country (with the _na post fix) for a national analysis.

Data use

The outputs from this project are viewable and freely accessible at http://EcoDRRmapping.grid.unep.ch where users can:

- visualize and export pre-created maps of hazard exposure and ecosystem coverage combinations;
- create and download personalized maps, using the available layers;
- download the full output dataset in GIS format;
- visualize and download the metadata of each layer displayed on maps;
- download documentation about this global mapping tool (methodology note, guidelines for users, presentation brochure).

Statistics per country (number of cells of each restoration opportunity category) were also computed and are available in http://ecodrrmapping.grid.unep.ch/documents as a zip file named *Eco-DRR_Synthesis.zip*.

Examples of Eco-DRR opportunity maps

Global opportunity maps

The Eco-DRR opportunity mapping tool could be used to create global and national maps showing opportunities for reducing people's exposure to hazards by protecting or restoring ecosystems. Figure 7**Error! Reference source not found.** is an example of a global map showing opportunity areas for reducing flood exposure by protecting forests (combination of flood exposure / forest coverage) at the global scale. It highlights areas where protection of forests is needed in order to reduce flood exposure (e.g. the central African region). **Error! Reference source not found.**8 is an example of a global opportunity map showing areas where flood exposure could be reduced through forest restoration. Notice that the two maps are very different: areas for forest protection are different from areas where the priority action for reducing flood risk is forest restoration. The former highlights areas with already medium to high forest cover and medium to high flood risk, while the latter shows areas where forest cover is low and flood risk is mediuem or high.

Figure 7: Opportunity areas for reducing flood exposure through forest protection at the global scale (combination of flood exposure / forest coverage, showing only areas with high forest cover).

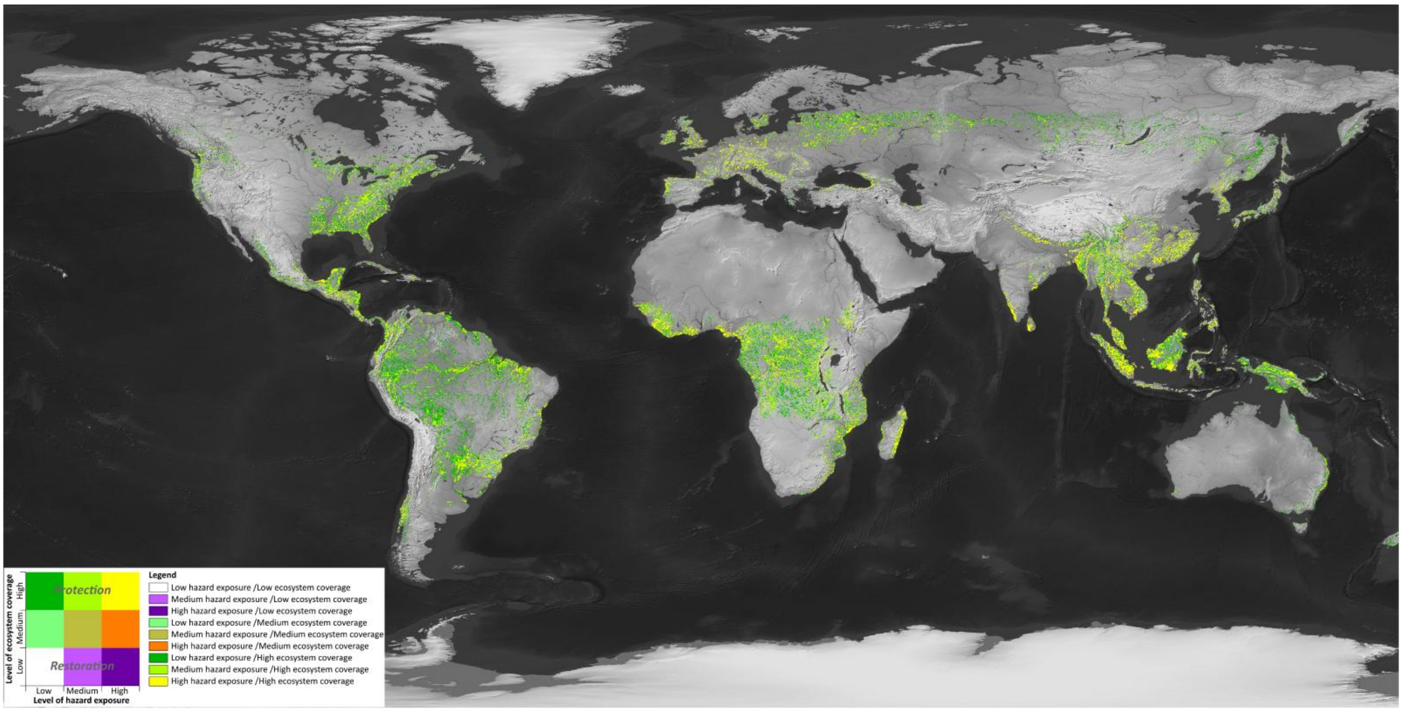
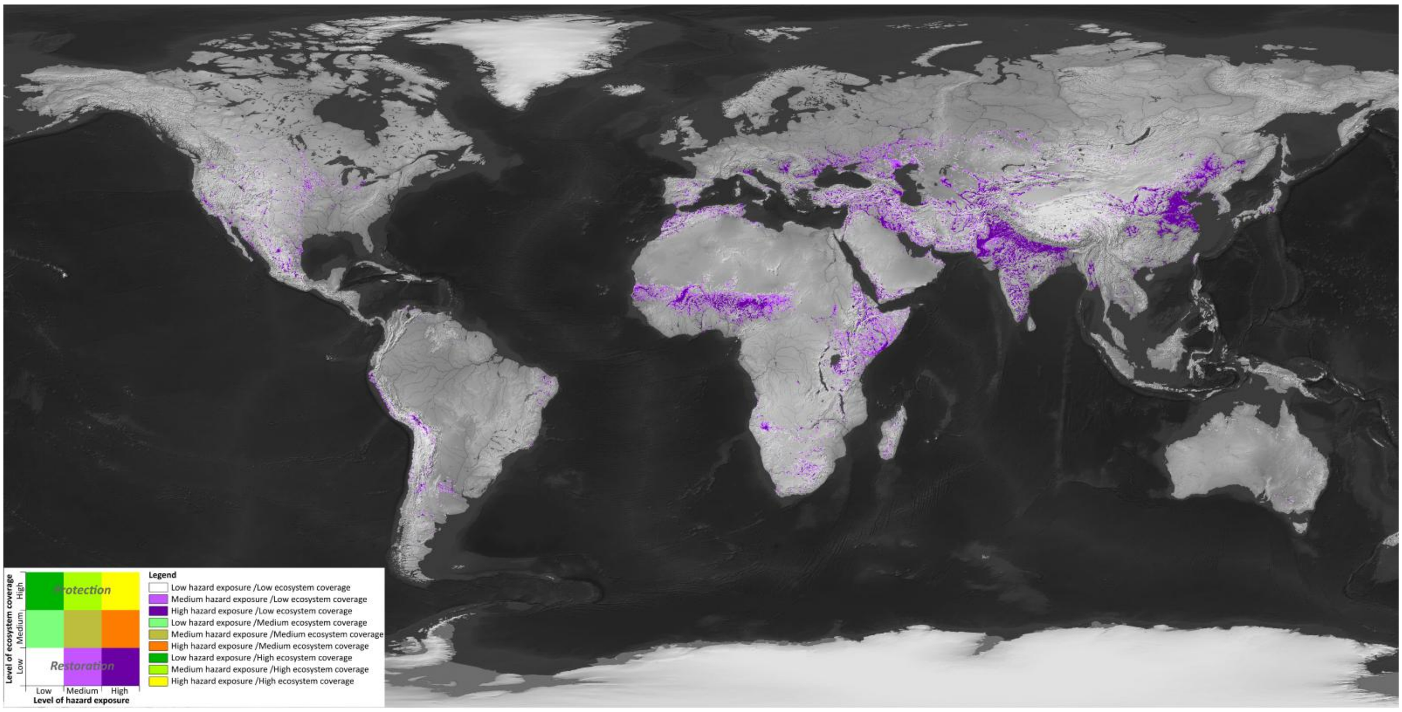


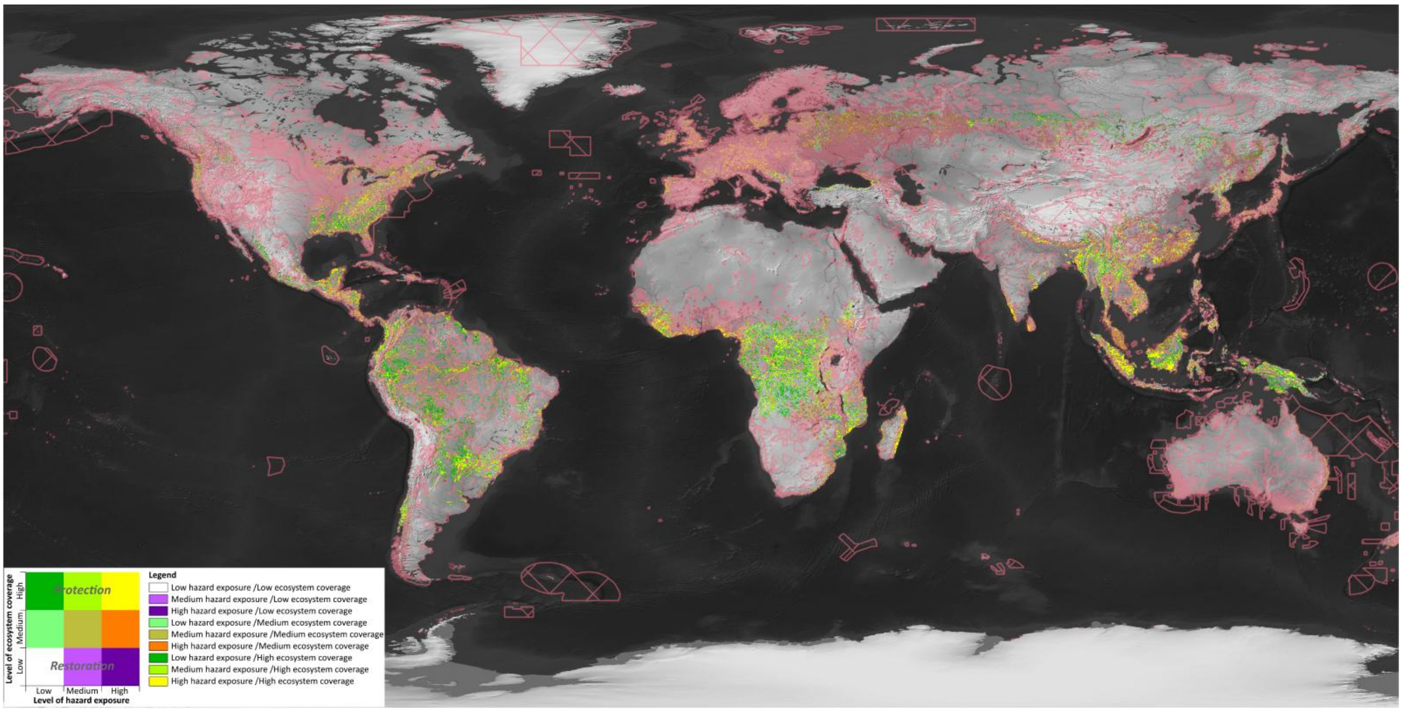
Figure 8: Opportunity areas for reducing flood exposure through the restoration of forests comparison at a global scale (combination of flood exposure / forest coverage, showing only areas with low forest cover) .



Promoting protected areas for Eco-DRR

The Eco-DRR opportunity mapping tool could be used to demonstrate the value of protected areas in conserving ecosystems that serve as natural hazard buffers. For instance, Figure 9 shows protected areas (in red) that overlap with forests that play a role in protecting people from floods (in green, similar to figure 7). This maps can be used to show in a snapshot, protected areas that are providing an Eco-DRR service to people by reducing flood risk, and can therefore be used for Eco-DRR and protected area advocacy.

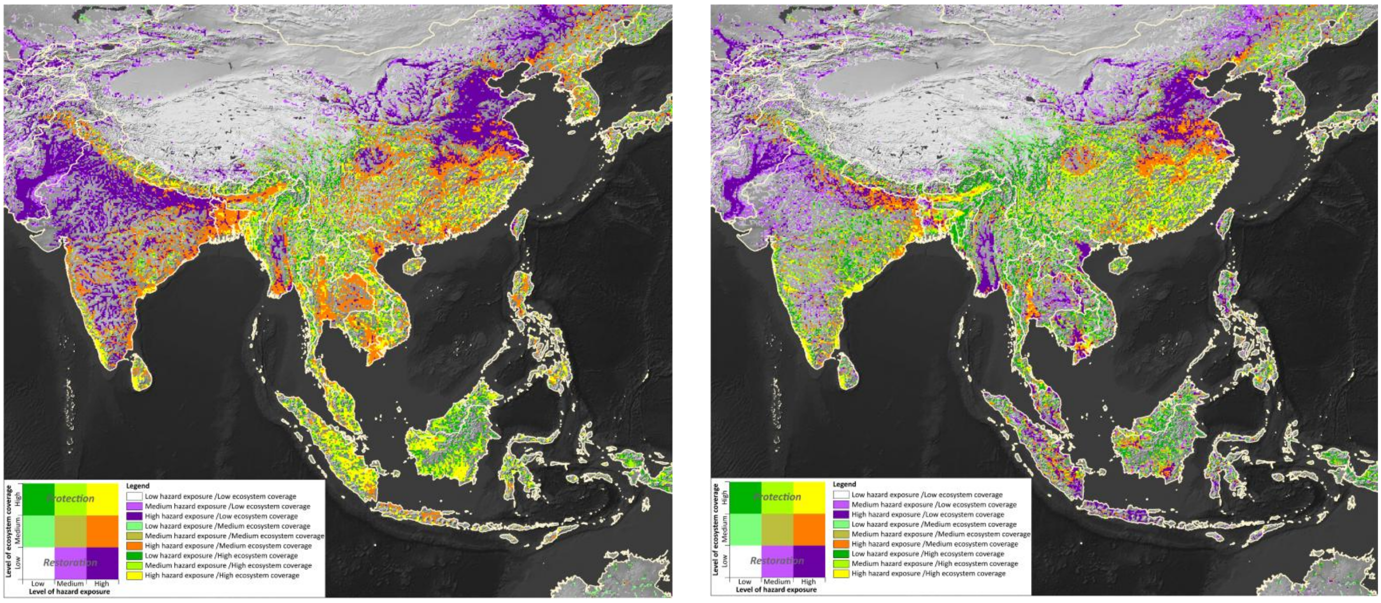
Figure 9: Figure 7 plus World Database on Protected Areas (WDPA) layer using a red style



Comparing opportunities at the global vs. national level

The two-level analysis provided by the opportunity mapping tool expands the use of the tool for different purposes. For regional analyses, the global opportunity map layers (Figure 10 left panel) could be used to compare countries and find priority countries for implementing Eco-DRR programs (e.g. protecting mangroves to reduce storm exposure). This is while national level (normalized) maps can then be used to identify areas within a certain country that present opportunities for Eco-DRR (Figure 10 right panel). Figure 10 displays side by side the two levels of analysis possible with the flood exposure / forest coverage dataset (at a global level and at a national level). Differences between global and national data are stricking for India and Bangladesh for example.

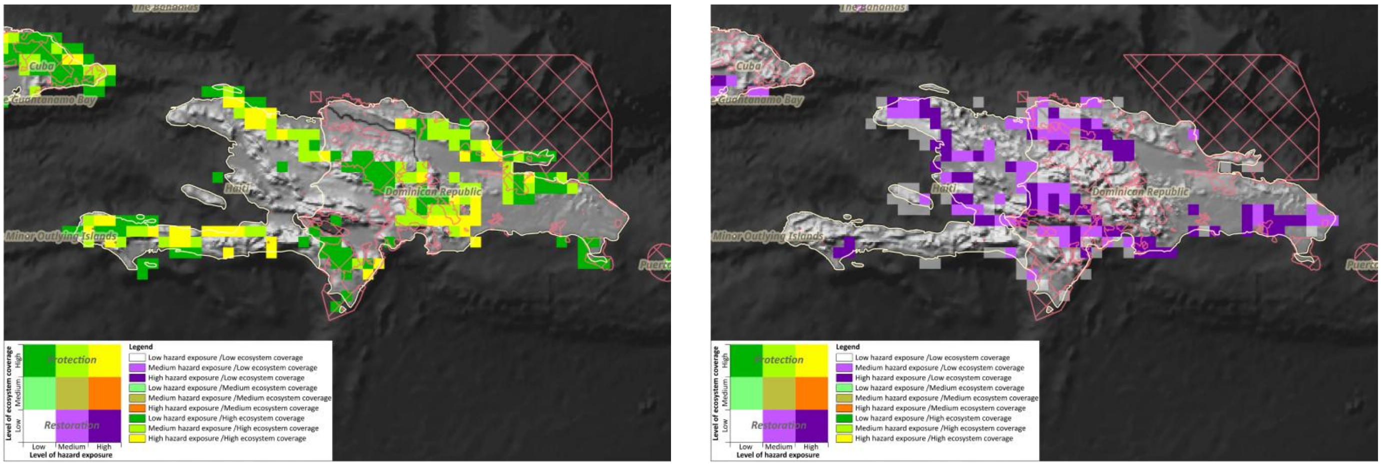
Figure 10: Examples of East-Asian regional maps showing the 9 Eco-DRR opportunity categories for the combination of flood exposure / forest coverage (global comparison on the left, national comparison on the right)



Example of regional maps: focus on Central America and the Caribbean

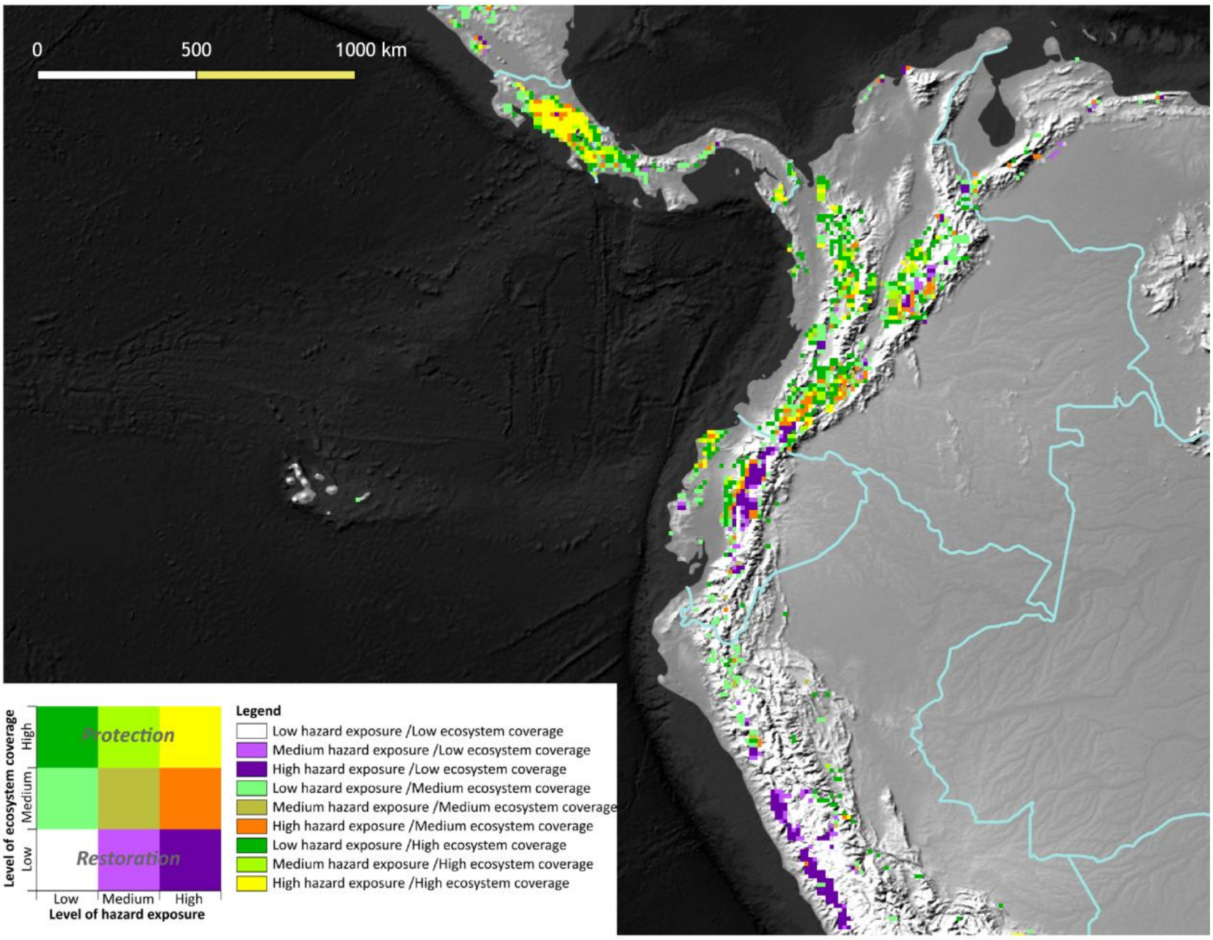
The following sets of maps were developed to demonstrate the different types of potential use of the opportunity mapping tool, with a focus on Central America and the Caribbean region. The range of exposure and ecosystem combinations allows the user to analyse various Eco-DRR options. For example in countries such as Haiti and Dominican Republic which are highly exposed to tropical cyclones, users may use to tool to visualize opportunites for forests restoration (Figure 11 left panel) or protection (Figure 11 right panel) to reduce the exposure of populations to tropical cyclone winds.

Figure 11: Example of maps focusing on the island of Hispaniola, where Haiti and Dominican Republic are located. The left map shows protection and the right map shows restoration opportunities categories for the combination of tropical cyclone wind exposure and forest coverage (green and purple shades), as well as protected areas (in red).



Central America as well as Colombia, Equador and Peru is one of the hotspot regions for landslides in the world, with areas facing landslides hazard from moderate (class 5) to very high (class 9) according to the Center for Hazards and Risk Research. The tool can be used to visualize areas were vegetation might have a mitigating effect on landslides and mudflows susceptibility because it can act as a soil stabiliser (Peduzzi, 2012). Figure 12 shows opportunity areas for restoration (purple) and protection of forests (green) in areas prone to landslides.

Figure 12: Example of regional map focusing on central America and Peru/Equator/Colombia showing restoration and protection opportunity categories for the combination of landslides exposure and forest coverage



In the Caribbean region, coastal populations are becoming more prone to risk of flooding due to tropical cyclones, as a result of accelerated sea-level rise and shoreline changes. There is an increasing concern regarding the North Atlantic region, as the region accounts for 60% of economic losses from tropical cyclones (since 1970) (EM-DAT The OFDA/CRED International Disaster Database) and as intensity of tropical cyclones is expected to increase due to climate change (Peduzzi, 2012). The opportunity mapping tool can show areas where mangroves could act as a natural buffer for coastal societies in case of tropical cyclone surge (figure 13) and protection of forested areas might help reducing tropical cyclone wind impacts (figure 14).

Figure 13: Example of regional map focusing on the Caribbean region showing restoration and protection opportunity categories for the combination tropical cyclone surge exposure and mangrove coverage

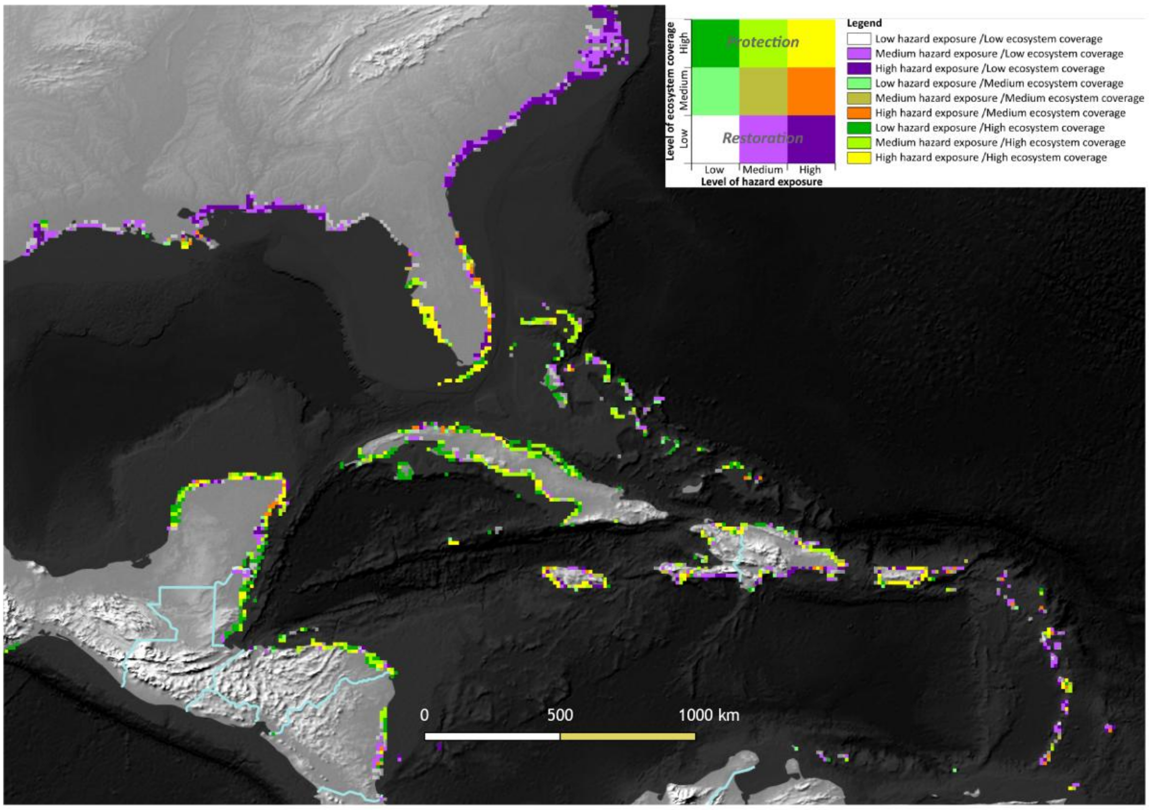
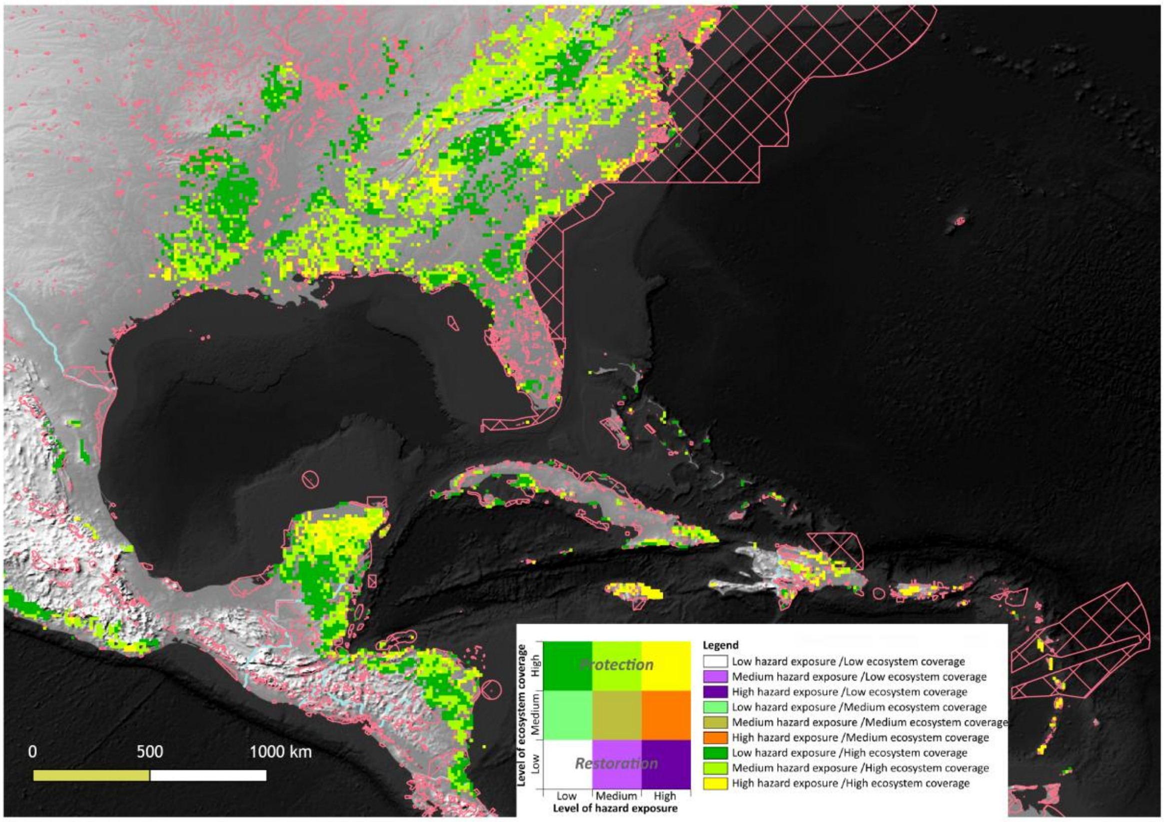


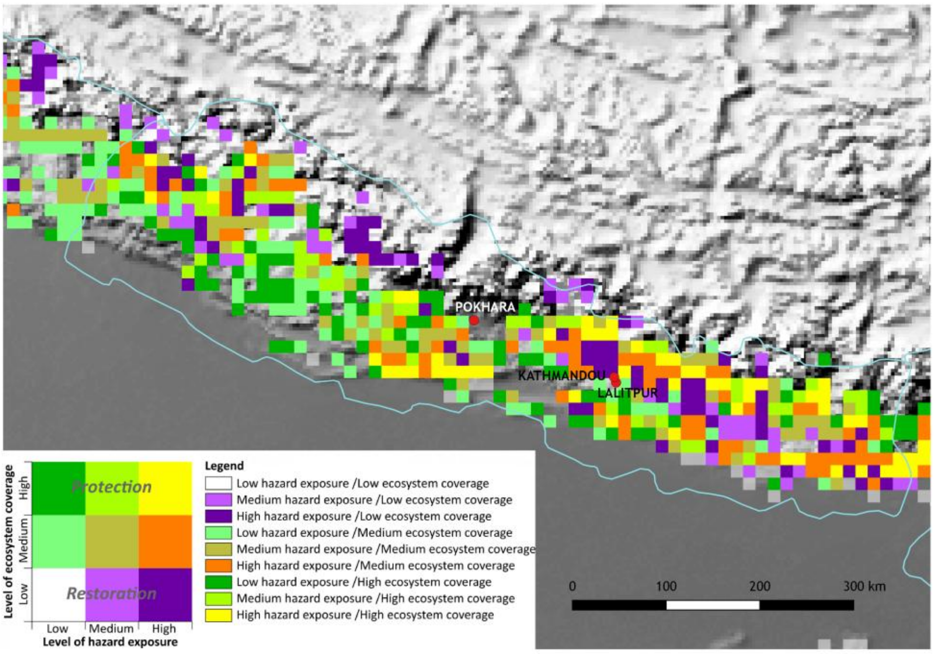
Figure 14: Example of regional map focusing on the Caribbean region showing protection opportunity categories for the combination tropical cyclone wind exposure and forest coverage (green) as well as protected areas (red polygons)



Example of national maps: Focus on Nepal

After the earthquake of April 2015, Nepal is still highly exposed to landslides in an area also prone to monsoon's effects. Himalayan countries in general face landslides because of deforestation, road construction and population growth. According to the reported losses between 1990-2014 (Preview platform), 32.5% of mortality in disaster account for landslides in Nepal, urging for DRR measures. The tool can show areas where vegetation might have a mitigating effect on landslides and mudflows susceptibility because it can act as a soil stabiliser (Peduzzi, 2012) (Figure 15).

Figure 15: Example of a national level map focusing on Nepal showing protection and restoration opportunity categories for the combination of landslides exposure and forest coverage



Guidance on creating maps

Users have the possibility to customize online maps by adding layers (from the current project or from external OGC web services) to the existing map. They can create their own maps in different manners by:

- using the standard OGC web services (WMS and WCS) in a GIS software;
- using the *Print* button available on each map and layer view;
- taking simple screenshots;
- downloading the Eco-DRR dataset from http://ecodrrmapping.grid.unep.ch/documents and using it in a GIS software.

Below we will describe (basic knowledge of GIS is required) the first option which uses OGC services and an open-source and free GIS software, QGIS (http://www.qgis.org), to create the following figures of this chapter. The background image and countries boundaries layers were downloaded from http://www.naturalearthdata.com/ and added and stylized in a new QGIS project.

Here are the steps to create maps using the OGC web services in a GIS software:

- Create a composer (*Project > New Print Composer*) containing a map section.
- Zoom in the area to be mapped and add a legend section.
- Then initiate a connection to the project WMS and add layers to the map. To do so in QGIS, select 'Layers', then 'Add layers' and 'Add Layer(s) from a WM(T)S Server'. Create a new WMS connection by giving it a name and entering the following URL: http://ecodrrmapping.grid.unep.ch/geoserver/ows
- You can then select layers, with the three following pre-defined styles available:
  - '9 cats' by default, which displays all Eco-DRR opportunity categories
  - 'restor' which displays only Eco-DRR restoration categories
  - 'protect' which displays only Eco-DRR protection categories

Figure 16: Selection of a pre-defined style in QGIS WMS tool

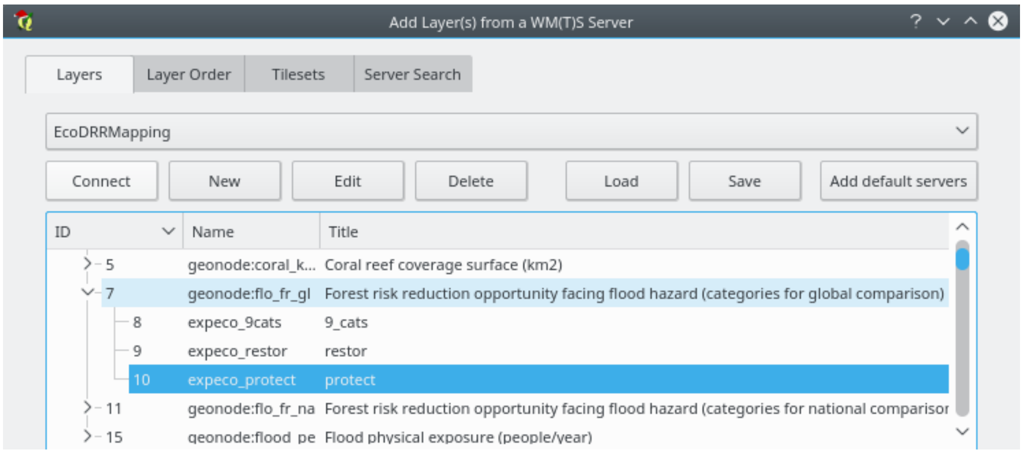
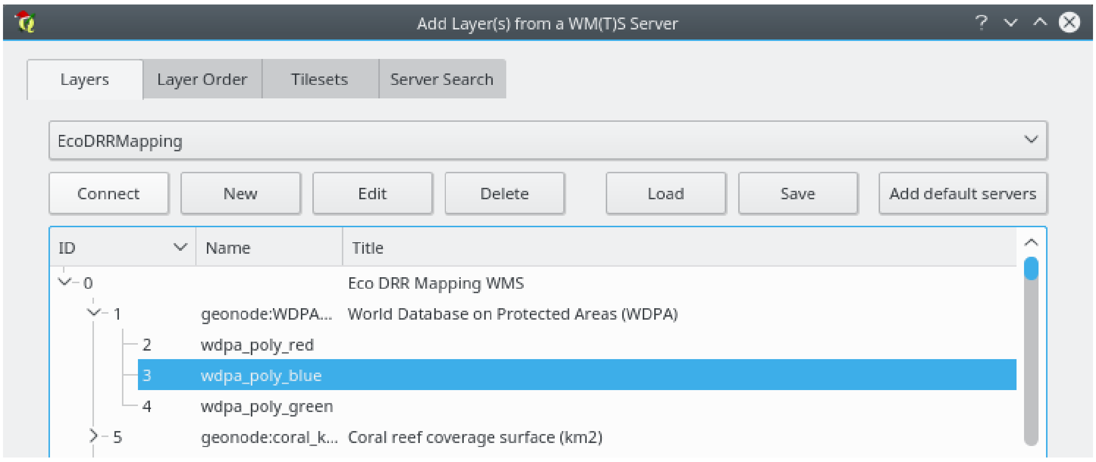


Figure 17: Selection of a pre-defined style in QGIS WMS tool



For instance the protection categories shown in **Error! Reference source not found.** for the combination flood exposure / forest coverage (comparison at a global scale), were isolated simply by selecting a specifically defined style (expeco_protect, **Error! Reference source not found.**).Figure 9 simply adds the World Database on Protected Areas (WDPA) data layer to the previous map, using the default red style. In order to facilitate the overlaying of WDPA layer with other layers users can apply some transparency to WDPA layer an if necessary switch default red style to a green or blue one (**Error! Reference source not found.**9).

Next steps

Field validations through countries' feedback and interaction between stakeholders could help to specify the accuracy and useability of the present dataset. Afterward, a second version could be generated, integrating these comments as well as an open population dataset.

As mentioned above, the tool does not include an analysis on the feasibity of Eco-DRR actions. However this could be easily done by adding additional map layer such as the percentage of urbanized land in each cell, additional topographical information (slope, topographical position[12],...), and socio-economic information which could help further define areas where protection or restoration of ecosystems is feasible.

Currently the analysis focuses on each cell as an isolated element, however neighbouring cells possibly have an influence on each other's exposure level to hazards (depending on topography, type of hazard and ecosystem). Future iterations of the tool could explore an analysis of the influence of neighbouring pixels on exposure and ecosystem coverage.

Next steps could also explore using open population datasets which are homogeneous at the global scale. The population data currently used in the model is acquired and therefore restricts the possibilities of output dissemination (in the present case dissemination of population attribute is allowed as it was aggregated into 10 km cells). Due to the high cost, it was also not possible to use the most recent population dataset. Using a open population dataset could solve the above issues. The new Global Human Settlement Layer[13] computed by JRC would be a good candidate and could be easily used to create a second version of Eco-DRR opportunity mapping after a thorough quality check.

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[12] http://www.jennessent.com/arcview/tpi.htm

[13] http://ghsl.jrc.ec.europa.eu/index.php

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