Myanmar national ecosystem service assessment technical report

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Introduction

This document provides information on the data and technical methods used for producing the report *Natural Connections: How natural capital supports Myanmar's people and economy* (Mandle *et al.* 2016). It is assumed that readers have a basic understanding of ecosystem services modeling and geoprocessing. The document provides details on the workflow, data inputs, model outputs, and post-processing conducted to produce the results shown in the main report.

Sections are organized by ecosystem service model, and within each section the following information is provided:

- A brief overview of the model
- Model inputs and outputs, including the source data used
- How the model results were translated into maps used in the report
- How beneficiaries were defined and combined with model results
- How climate change data was incorporated

The ecosystem service assessments were conducted using the Natural Capital Project's InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) suite of models (Sharp *et al.* 2016). The following models were used in Myanmar:

- Sediment Delivery Ratio model to evaluate the contribution of vegetation to sediment retention for water quality (page 3)
- Seasonal Water Yield model to evaluate the contribution of vegetation to dry season water availability and flood risk reduction (page 8)
- Coastal Vulnerability model to evaluate the role of coastal habitats in reducing the vulnerability of coastal populations to storms (page 13)

The Center for Climate Systems Research (CCSR), based at Columbia University's Earth Institute, produced information on both baseline climate conditions and projected climate. Climate projections were derived from the NASA Earth Exchange Global Daily Downscaled Projections gridded dataset, an ensemble of 21 global climate models (GCMs) at quarter-degree spatial resolution run from 1980-2070 under the RCP4.5 (low-medium) and RCP8.5 (high) emissions scenarios. Three climate variables were used directly from the dataset (precipitation, maximum and minimum temperature) and one additional variable (rainy days) was derived, computed as the sum of days per month with precipitation >0.2mm.

The global grids were first subset to the Myanmar bounding box. For each grid cell, the daily temperature data were averaged into monthly average time series, while precipitation data were summed into monthly total time series. These data were then averaged by month over two 20-year time slices, 2020s (2011-2030) and 2040s (2031-2050) for each of the two emission scenarios, as well as over the 1980-2006 period to yield a historical climatology. Variability across the 21 model results was summarized in terms of the 10th, 25th, 75th, and 90th percentiles as well as the multi-model mean for each grid cell, time slice, emissions scenario, and climate variable.

CCSR also provided projections of sea-level rise for the 2020 (2020-2029) and 2050 (2050-2059) time periods based on 10-year averages. These projections cover the whole coast of Myanmar and take into account various global and regional components that contribute to changes in sea level. These include thermal expansion and local ocean height (ocean component), loss of ice, and land water storage. The results do not take into account land subsidence. For each of these three components of sea level change, set percentiles of the distribution were estimated (10th, 25th, 75th, and 90th percentiles). The sum of all components at each percentile is assumed to give the aggregate model-outcome range of sea level rise projections. Decadal projections were generated by averaging over ten-year intervals and subtracting average values for 2000-2004.

Contact

For questions about the material included in this document, including methods and underlying data, please contact Stacie Wolny – swolny@stanford.edu.

Technical Methods

Sediment Delivery Ratio Model

Overview

The InVEST Sediment Delivery Ratio (SDR) model is a simplified method for estimating the amount of soil that is eroded from the landscape, the amount that reaches a waterway, and the areas on the landscape that provide the service of retaining sediment. The model is fully distributed and GIS-based, accepting inputs of rasters of climate, soil, topography, and land use and land cover (LULC) data. The outputs represent average annual sediment delivery and retention per subcatchment, and also include maps representing the per-pixel contribution to sediment yield. For each pixel, the algorithm first computes the average annual amount of eroded sediment, or soil loss, and then the sediment delivery ratio (SDR), which corresponds to the proportion of soil loss actually reaching the stream. See the InVEST User Guide and Hamel et al. (2015) for more details.

Data

SDR requires the following inputs:

- Land use/land cover: Used to indicate erosion and conservation practice potential per land cover type
- Digital elevation model (DEM): Used to generate the stream network and trace the path of sediment as it travels downslope to a stream
- Rainfall erosivity: A measure of the intensity of rainfall, such that harder rainfall is more likely to cause soil to detach and become erosion
- Soil erodibility: A soil property that indicates how easily different types of soil detach and become erosion
- Threshold flow accumulation: An integer value indicating the amount of upstream area that must flow into a pixel before it is considered part of a stream, used with the DEM to generate a stream map
- USLE crop (C) and practice (P) coefficients, based on each land use/land cover type

The following datasets were used as inputs to the model:

SDR Input	Dataset source
Land use/land cover	Custom map made by WWF from Google Earth Engine, where agriculture is defined by administrative district, 150m resolution
Digital elevation model	SRTM, 90m resolution
Rainfall erosivity	Derived from precipitation data using the equation $R = 38.5 + 0.35 P$ where R is rainfall erosivity and P is annual mean precipitation (mm/year); from Thang et al. (2005). Historical and future climate scenario precipitation data from CCSR climate modeling.
Soil erodibility	Derived from the FAO Harmonized World Soil Database using information on sand/silt/clay/organic carbon
Threshold flow accumulation	Value: 10000 (to define more major streams)

USLE coefficients	Based on a variety of literature sources, primarily Merritt, W. (2002). USLE P was kept constant, as no information on erosion control practices was available nationally.

USLE crop (C) and practice (P) coefficients are associated with each land use/land cover type. The coefficients used are as follows:

lucode	LULC description	usle_c	usle_p
1	Forest	0.02	1
2	Open forest	0.02	1
3	Scrubland	0.048	1
4	Mangrove	0	1
6	Water	0	1
7	Snow	0	1
101-1705	Agriculture, defined by district	Varies	1

To derive agriculture values by district crop type, the original single "Agriculture" LULC class was divided by district boundaries. This produces one distinct Agriculture LULC class per district. Crop information for each district came from the FAO Digital Agricultural Atlas for the Union of Myanmar, which provides district boundaries, the types of crops grown in each district, and the amount of area in the district that the crop is grown on. For each crop type grown in a district, a USLE C value was assigned, then weighted by the percent of the total agricultural area that crop is grown in. The resulting weighted USLE C values were added together for all crops grown in the district to calculate the final value used in the coefficient table. This provides differentiation across the country, based on differences in agriculture, that a single Agriculture LULC class for the whole country does not.

A second, hypothetical, LULC map was also created, where all land in the country was converted to agriculture. This was done according to district, as described above.

Results

One result from the SDR model is used in this analysis:

- *sed_export*: Sediment export, the amount of sediment that erodes from the landscape and does not get retained by the landscape but makes it to the stream. This is produced using the USLE and SDR methods described above. Units are in tons/year.

The "sediment retention" maps included in the report show the difference in sediment export between the all-agriculture and baseline LULC maps. An example of this is given in Figure 1.

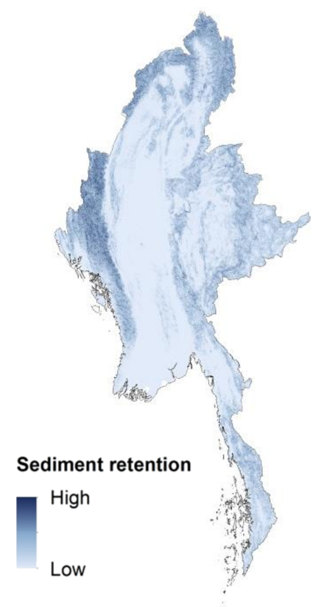

Fig 1. Sediment retention map, for historical climate

Including Beneficiaries

Model results show a biophysical measure of ecological functions like sediment retention. In order to link these ecosystem functions to human well-being, we need to consider where people and/or infrastructure, such as dams, are located that benefit from these services.

Dams

The GRanD database provides a shapefile with the location of dams globally, and those located within Myanmar were used to evaluate the impact of erosion on these facilities.

Once the facilities are located, the next step is to delineate the watersheds that drain into these points. The area within these watersheds is critical for providing water supply and sediment retention services that allow for proper functioning of the facilities. We used the InVEST tool DelineateIt to generate the watersheds that flow into each facility. DelineateIt requires the following inputs:

DelineateIt input	Data source
Digital elevation model (DEM)	SRTM, 90m resolution
Outlet points shapefile	GRanD database dam points
Threshold flow accumulation	Value: 1000 (to capture smaller rivers that the dams might be located on)

The main result from DelineateIt is a shapefile of the watersheds that are associated with the outlet points. To look at the sediment retention service provided by each watershed for each facility, the raster showing the difference in sediment export between the current landscape and the all-agriculture landscape was simply clipped by the watershed boundary. It is important to note that where multiple watersheds overlap, the overlapping area is providing a service to multiple downstream facilities. Figure 2 shows four dam locations, the associated watersheds created by DelineateIt, and sediment retention within those watersheds.

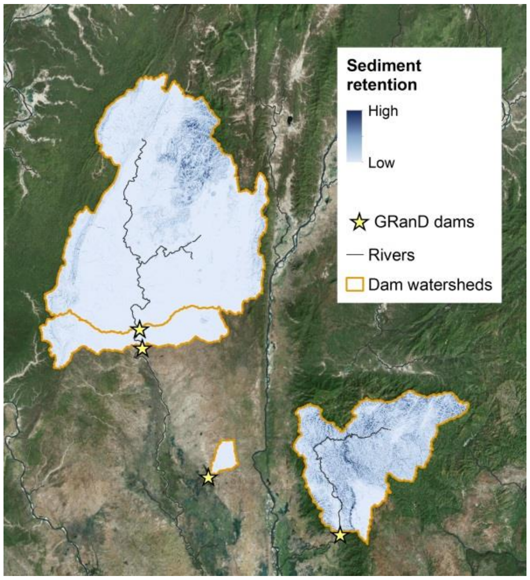

Fig 2. Example of watersheds created for dams

To look at the total change in sediment flowing to each dam if the dam watersheds lost their native vegetation, the values of sediment retention were aggregated by summing pixel values within the watersheds, thus providing the absolute amount of sediment retention service benefiting the dams.

Drinking water

To evaluate the ecosystem services provided directly to people in the form of cleaner water, 2014 Myanmar Population and Housing Census data was used, available from the Myanmar Information Management Unit (MIMU). This dataset provides township-level information on the number of people who rely on surface water for drinking water. Households that were categorized as using either “Pool/Pond/Lake” or “River/Stream/Canal” were considered in this assessment as relying directly on surface water for their drinking water source, and so potentially affected by changes in sediment levels in nearby water bodies.

MIMU point data on the location of towns and villages was also used, with the assumption that people who rely on surface water take that water from streams near their town or village. Using DelineateIt, the watershed draining to each village and town in Myanmar was created, using the following inputs:

DelineateIt input	Data source
Digital elevation model (DEM)	SRTM, 90m resolution
Outlet points shapefile	MIMU shapefiles for towns and villages
Threshold flow accumulation	Value: 1000 (to capture smaller rivers that the villages and towns might be located on)

All watersheds draining into a township were considered together, because only township-level census data is currently available. Population data was assigned to these "clusters" of watersheds, based on the total number of people in the township who use surface water for drinking, and divided by the watershed area. Dividing by watershed area is necessary to account for the fact that the SDR model estimates sediment loads (in terms of mass of sediments), rather than sediment concentration (mass per volume of water). Sediment concentration is more relevant to drinking water quality. Larger watersheds will generally have greater water yields, resulting in lower sediment concentrations relative to sediment loads, and this weighting accounts for that. As noted previously, where such service-oriented watersheds overlap, the overlapping area is providing a service to multiple townships. So where these township-level watersheds overlap, their populations were added together, to create the final beneficiary map for surface drinking water (Figure 3.)

Fig 3. Beneficiary map for surface drinking water

This beneficiary map was used both for the Sediment and Water Yield analyses, in relation to drinking water (it was not used to analyze dams.) For Sediment, the beneficiary map was multiplied by the "sediment retention" map described in the Results section above to create the total service map for drinking water. This service map shows where natural vegetation provides the greatest benefit to the largest number of people in terms of keeping sediment out of rivers, where it reduces water quality for people downstream who rely on surface water for drinking. Beneficiary information for Water Yield is described in the Seasonal Water Yield section of this document.

Climate change

Climate is included in the SDR model via the rainfall erosivity input, which can be calculated using precipitation information, as described in the Data section above. Historical and modeled future rainfall was provided by CCSR as a table of latitude/longitude point locations with corresponding values of monthly precipitation. For each data point, monthly values were added together to calculate annual rainfall, as required by the equation for rainfall erosivity in Thang *et al.* (2005). To turn the point data into the raster format required for SDR, Thiessen polygons were first created around each point, so that the value for each point was assigned to the whole polygon around it. The resulting polygons were then converted into an annual precipitation raster.

Finally, the Thang *et al.* (2005) equation was applied to the annual precipitation raster to derive the final rainfall erosivity input used in the SDR model.

Along with historical climate, four future climate scenarios were used in the report: RCP 4.5, 25th percentile of model values, time period 2011-2030, RCP 4.5, 25th percentile of model values, time period 2031-2050, RCP 8.5, 75th percentile of model values, time period 2011-2030 and RCP 8.5, 75th percentile of model values, time period 2031-2050.

SDR was run once for historical conditions with the current land use/land cover map and once for historical conditions with the all-agriculture LULC. Similarly, each future climate scenario was run once with current LULC and once with the all-agriculture LULC. For all climate scenarios, the “sediment retention” maps included in the report are the difference between results from the all-agriculture LULC and results from the current LULC, within a single climate scenario. “Sediment export % change” maps in the report are the difference between historical climate and one of the climate scenarios.

It is important to note that the intensity of rainfall events within a year is expected to increase under future climate scenarios, contributing to increased erosion, in addition to changes in total annual precipitation. Because calculations of rainfall erosivity used here are based only on annual precipitation, and do not capture with-in year variation, our results likely underestimate the increase in erosion that can be expected under future climate scenarios.

Seasonal Water Yield Model

Overview

The InVEST Seasonal Water Yield (SWY) model computes three main indices: quickflow (QF), local recharge (R), and baseflow (B), which are all based on monthly climate values. In this analysis, both quickflow and baseflow are used. Quickflow represents the amount of precipitation that is converted to direct runoff, entering streams soon after a rain event, and is computed based on the Curve Number approach. Baseflow represents the amount of precipitation that enters streams through subsurface flow, both during and in-between rain events. This approach requires monthly precipitation values to be disaggregated on an event basis. Event contributions are then summed up to provide an annual average, expressed in mm. See the InVEST User Guide for more details.

Data

The following Seasonal Water Yield parameters were used for this analysis:

- Monthly precipitation
- Monthly reference evapotranspiration
- Digital elevation model: To trace how water flows on the landscape, and define streams
- Land use/land cover: Used to map land cover classes to crop coefficient (Kc) values
- Soil group: SCS soil hydrologic groups (A, B, C or D), used in combination with the LULC map to compute Curve Number values.
- Climate zones: Polygons defining zones where the climate can be defined the same. In this case, used along with a Climate Zone Table of the number of rain events per month, per climate zone.
- Biophysical table: Contains crop evapotranspiration coefficients and curve number coefficients that map to land use/land cover classes.

The following datasets were used as inputs to the model:

Model Input	Dataset source
Precipitation	Historical and future climate scenario precipitation data from CCSR climate modeling.
Reference evapotranspiration	Derived from CCSR historical and future climate scenarios of precipitation and temperature data, using the Modified Hargreaves method.
Digital Elevation model	SRTM 90m DEM, resampled to 150m
Land use/land cover	Custom map made by WWF from Google Earth Engine, where agriculture is defined by administrative district, 150m resolution
Soil group	HiHydro dataset. Boer, F. de, (2015). HiHydroSoil: A High Resolution Soil Map of Hydraulic Properties. Report 134; www.futurewater.nl.
AOI/Watershed	Polygon outline of the country of Myanmar (Note that this is not hydrologically complete where watersheds cross the country border.)

Climate zones	Created Thiessen polygons around the climate data points (latitude/longitude values) provided with CCSR's climate modeling
Climate zone table	Number of rainy days per month, for historical and future climate scenarios, from CCSR's climate modeling
Biophysical table	Values from a variety of literature sources. Crop coefficients (Kc) primarily from FAO Irrigation and Drainage paper 56. Curve number (CN) values primarily from USDA Part 630 Hydrology National Engineering Handbook, chapter 9.
α, β, γ	Default parameters

Crop evapotranspiration and curve number coefficients are associated with each land use/land cover type. The coefficients used are as follows:

lucode	LULC description	Kc_1*	CN_A	CN_B	CN_C	CN_D
1	Forest	1	36	60	73	79
2	Open forest	0.9	43	65	76	82
3	Scrubland	0.43	35	56	70	77
4	Mangrove	1.1	98	98	98	98
6	Water	1.05	1	1	1	1
7	Snow	0.4	1	1	1	1
101-1705	Agriculture, defined by district	Varies	Varies	Varies	Varies	Varies

*This is the crop factor for month 1 (January.) Kc is constant across the year except for crops.

As with the USLE C coefficients, Kc and CN were calculated for each district's mix of agriculture, using a similar method. Kc is given monthly values in the SWY model, so it is useful that the FAO Digital Agricultural Atlas for the Union of Myanmar provides information on which season each crop is grown in - monsoon, summer and/or winter. For this analysis, monsoon months were taken as May through October, summer months March and April, and winter months November through February. This seasonal information was used, along with the percent area that the crop is grown in per district, and Kc(ini), Kc(mid) and Kc(end) values from the FAO Irrigation and Drainage paper 56. Similar to USLE C, Kc and CN values per crop were weighted by the percent of the district's agricultural area that crop is grown in, and the weighted values added together, to produce the final coefficient values for each district. For full data tables and more information about this process, contact the report authors.

Results

Two results from the Seasonal Water Yield model were incorporated into this analysis:

- Quick flow, for the main months in the monsoon season, when flooding is most likely to occur (June through September.) This represents the amount of precipitation that is converted to direct runoff, entering streams soon after a rain event, possibly contributing to flooding. Units in millimeters.
- Baseflow, which represents the amount of precipitation that enters streams through subsurface flow and sustaining streamflow between events, contributing to dry-season water availability. Units in millimeters.

Quick flow results were not used directly. Instead, they were combined with precipitation to calculate a “quick flow retention” or “flood risk reduction” index, as follows:

$$flow\ retention = 1 - QF/P$$

where *QF* is the sum of quick flow over the monsoon months (June –September) and *P* is total precipitation over those same months. The index ranges between 0 and 1; a value of 0 corresponds to no retention by the pixel, a value of 1 corresponds to total retention (no direct runoff is produced to contribute to flooding).

Maps in the report (such as Figure 4) show the difference in flow retention between the current LULC and all-agriculture LULC, which indicates where natural vegetation plays the greatest role in reducing flood risk. They show a reduction in the flow retention index from current LULC to the all-agriculture scenario, except for the mangrove areas (which were assumed to have less retention, since CN = 98). The reduction in the index is generally stronger in the high precipitation areas, where peak flow is higher (reduction is proportional to peak flow).

Fig 4. Example flow retention (flood risk reduction) result for historical climate

Baseflow results, like Sediment, were presented as the difference between the baseflow provided by the current LULC and the all-agriculture LULC (described in the Sediment Delivery Ratio model section.) This shows how natural vegetation contributes to providing baseflow during the dry season (Figure 5.)

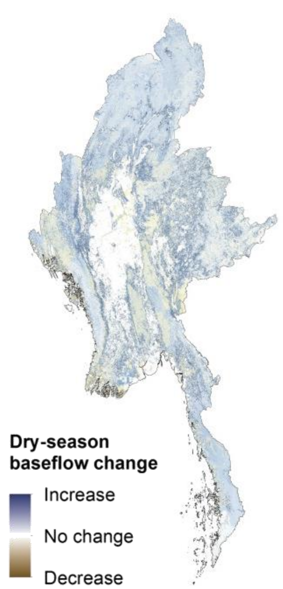

Fig 5. Example baseflow result for historical climate

When converting from the current landscape to the all agriculture scenario, the baseflow index increases in some areas and decreases in others. Baseflow contribution depends on two processes: infiltration of precipitation for slow release, and evapotranspiration, which are influenced by LULC parameters (CN and Kc.) Our results suggest that forested areas may provide more baseflow than a landscape converted to agriculture, due to deep soils and higher infiltration rates. Conversely, open forests, which were assumed to have more shallow soils or lower infiltration rates may not provide a high baseflow contribution: B values typically decreased in those regions compared to agricultural landscape, which is due to a balance between evapotranspiration and infiltration in favor of Agriculture. These results are preliminary and need to be confirmed through an uncertainty assessment.

Caveats and future work

The index of flow retention simplifies hydrologic processes since areas with high runoff production can be attenuated before reaching the stream. More detailed analyses based on information about past floods and a more sophisticated modeling approach could be performed for areas of interest. McCartney *et al*. (2013) conducted flood frequency analyses for two main rivers that could be used for economic analyses.

To improve the accuracy of the peak flow reduction index, CN values may be taken for wet conditions (Antecedent Runoff Conditions III). This is more representative of the wet periods during which flooding occurs, although the impact is deemed minimal.

For baseflow, in the absence of detailed hydrogeological information (see review by Mc Cartney *et al*. 2013), we set the model parameters to their default values. This assumes that upslope contribution is available for evapotranspiration for each pixel. Further work is needed to ascertain the robustness of these results, for example through sensitivity analyses of the seasonal water yield model, or use of a more sophisticated hydrologic model.

Including Beneficiaries

Drinking water

Dry-season baseflow is a valuable service to people who rely on surface water for drinking. Therefore, the same drinking water beneficiary map described in the Sediment section of this report (Figure 3) was used in a similar way as it was used with the Sediment Delivery Ratio model. The final beneficiary map for surface drinking water was multiplied by the Baseflow results to create the final service map, showing where natural vegetation plays the greatest role in providing dry-season baseflow to the largest number of people who rely on surface water for drinking.

Flood risk reduction

MIMU provides information on the villages that were affected by flooding in 2015. This was used to create a beneficiary map in a similar way to how the drinking water beneficiary map was made. Flood-affected village locations were used with the InVEST tool DelineateIt to create the watersheds that supply flood water to these villages. The inputs to DelineateIt are as follows:

DelineateIt input	Data source
Digital elevation model (DEM)	SRTM, 90m resolution
Outlet points shapefile	Points selected from the MIMU village shapefiles, for the villages affected by flooding in 2015
Threshold flow accumulation	Value: 1000 (to capture smaller rivers that the villages and towns might be located on)

Where these watersheds overlap, the overlapping area provides a service to multiple villages, so the total beneficiary map (Figure 6) is the total number of overlapping watersheds, which corresponds to the number of villages downstream that benefit. This total beneficiary map was multiplied by the "flow retention" map described in the Results section above to create the total service map. This service map shows where natural vegetation provides the greatest benefit to the largest number of people in terms of slowing down rainfall runoff so that it does not contribute to flooding for villages downstream.

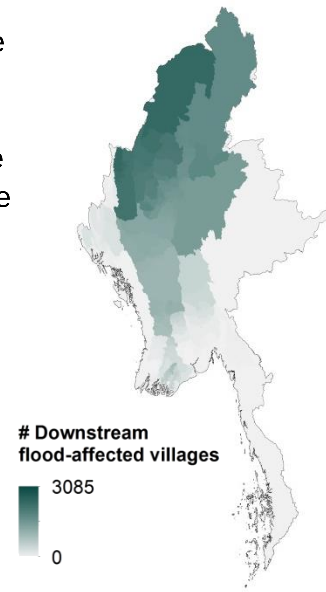

Fig 6. Beneficiary map for flood risk reduction

Climate change

Climate change data was used in the SWY model in several ways – as monthly precipitation, monthly reference evapotranspiration, and the number of monthly rainfall events. CCSR provided data for both historical and modeled future monthly precipitation, monthly temperature and number of rainfall events, each as a table of latitude/longitude point locations with corresponding values.

The model requires a precipitation raster for each month, and these were created by bringing the latitude/longitude locations into a GIS as points, then creating Thiessen polygons around each point. The precipitation value for each point was assigned to the whole polygon around it, which represents the resolution of the climate data. The resulting polygons were then converted into raster format.

Monthly reference evapotranspiration was calculated from monthly precipitation and temperature using the Modified Hargreaves method. This method also requires information on monthly solar radiation, which was obtained from the FAO Irrigation and Drainage Paper 56, Annex 2, Table 2.6 and assumed not to vary across climate scenarios. Calculations were done within a spreadsheet for each month, and the final ETo values converted into Thiessen polygons then raster in the same way monthly precipitation was done, using the latitude/longitude values provided.

The Seasonal Water Yield model has two ways of specifying rainfall events – one where a single number of monthly rainfall events is used over the whole area of interest, and a second where the number of events can vary across the area of interest. Because CCSR supplied a table of rainfall event information for latitude/longitude points across the country, the second method was used. This method requires two inputs: a raster defining "climate zones", where each climate zone is assigned a number of rainfall events in the corresponding "climate zone table." Climate zones were created by assigning a unique integer identifier to each latitude/longitude value in CCSR's rainfall events table, importing them into a GIS as points, creating Thiessen polygons, then converting to raster, such that the final rasters retained the unique integer identifier. The "climate zone table" then contains the same unique integer identifiers, mapped to the number of rainfall events provided for each point.

As with SDR, SWY was run once for historical conditions with current land use/land cover map and once for historical conditions with the all-agriculture LULC. Similarly, each future climate scenario was run once with current LULC and once with the all-agriculture LULC. For all climate scenarios, the "Dry-season baseflow change" maps included in the report show the difference between Baseflow results from the all-agriculture LULC and the current LULC, within a single climate scenario. "Flood risk reduction" maps are the difference in quick flow results between the all-agriculture LULC and the current LULC, within a single climate scenario.

Coastal Vulnerability Model

Overview

The InVEST Coastal Vulnerability (CV) model produces a qualitative estimate of how changes to natural habitats can affect coastal communities' exposure to storm-induced erosion and flooding. By considering biological and geophysical factors along the coastline, the model differentiates areas with relatively high or low exposure to erosion and inundation during storms, and indicates the role that natural habitats play in helping reduce that exposure. Combining these results with global population information can show areas along a given coastline where humans are most vulnerable to storm waves and surge, and where natural habitats play the greatest role in protecting people. See the InVEST User Guide for more details.

Data

The following CV parameters were used for this analysis:

- Area of Interest
- Land Polygon: Provides the location of the shoreline
- Bathymetry Layer: Depth information below water
- Relief: Land elevation on shore
- Natural Habitats: Location of coastal natural habitats
- Climatic Forcing Grid: Wind and wave information
- Continental Shelf: Location of the edges of the continental shelf
- Sea Level Rise: Points or polygons showing the trend in sea level rise
- Population Layer: Population density along the coast

The following datasets were used as inputs to the model:

Coastal Vulnerability Input	Dataset source
Area of Interest	Drawn by hand to include the coast of Myanmar and Sea Level Rise point data from CCSR
Land Polygon	Global land polygon provided in the InVEST sample data
Bathymetry Layer	GEBCO Bathymetry
Relief	USGS HydroSheds
Natural Habitats	Locations of coral reefs, sea grass and mangroves from UNEP-WCMC. Continental mangrove data for Tanintharyi was updated with forest mapping data from MOECAF. The associated Natural Habitats Table is shown below.
Climatic Forcing Grid	NOAA WaveWatch III
Continental Shelf	Continental Shelf polygon provided in the InVEST sample data

Sea Level Rise	Generated from latitude/longitude and sea level rise data provided by CCSR, for future climate scenarios
Population layer	WorldPop

Additional information is required about the Natural Habitats, which is provided in the Natural Habitats Table. The RANK field gives a relative ranking of how much protection each habitat provides for the coast – a value of 1 indicates highest protection, 4 lowest. PROTECTION DISTANCE indicates the distance over which the habitat has a protective influence, given in meters. The values assigned were based on general global guidelines and would benefit from more detailed study.

HABITAT	ID	RANK	PROTECTION DISTANCE
mangroves	1	1	2000
coralreefs	2	1	2000
seagrass	3	4	2000

Results

One result from the Coastal Vulnerability model was used in this report:

- coastal_exposure.shp: Shapefile of points, where each point corresponds to a shoreline segment and each segment has output values calculated by the model. The output value used for this report is “habitat_ro” (for “habitat role”) which is an index indicating how much protection coastal natural habitat provides to that shoreline segment, relative to all other segments (Figure 7.).

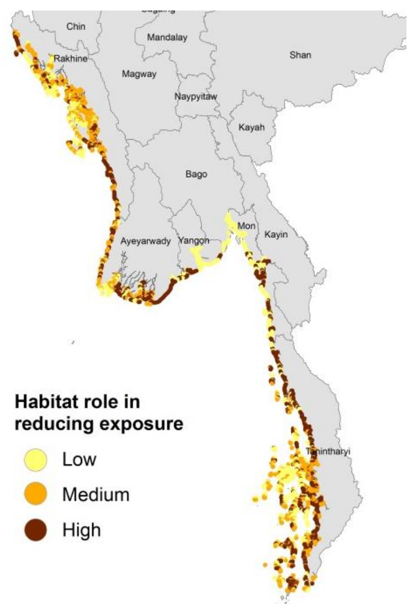

Fig 7. Habitat role in reducing coastal exposure to storms

Including Beneficiaries

Information about population density along the coast came from WorldPop. To capture the population in the vicinity of each point in the coastal_exposure.shp model output, the number of people per pixel from the WorldPop data set was summed across a 3 km x 3 km focal area, and then this population was associated with the nearest shoreline segment point.

To create the final service map, population density for each shoreline point was multiplied by the “habitat_ro” index. This provides an indication of where coastal natural habitats provide the greatest protection to the greatest number of people.

The total population data was also adjusted to account for groups within the population that are especially vulnerable to coastal storms, specifically the young and elderly, as well as households living in less structurally sound building. The proportion of the population below 10 years of age or 65 years and older was calculated from township-level data from the 2014 Myanmar Population and Housing Census, available from the Myanmar Information Management Unit (MIMU), along with the proportion of households living in buildings constructed of materials other than tile, brick or concrete. The total population size associated with each shoreline segment, as described above, was then multiplied by the vulnerable fraction of the population for each dimension (age, household building material). The relative results did not change substantively using either metric of vulnerability, and so the maps were not included in the final report.

Climate change

One of the inputs to the Coastal Vulnerability model is Sea Level Rise (SLR), which shows the trend in SLR for points or polygons along the coast. CCSR provided SLR data in the form of offshore latitude/longitude points, each of which has SLR values for a selection of time periods and future climate model percentiles. These lat/long values were turned into a shapefile of points, with associated SLR values, and used as scenario inputs to the Coastal Vulnerability model.

It is important to note that the results of the CV model cannot be directly compared between scenarios, as the high/low values are relative within each scenario. Post-processing of the results (using custom geoprocessing scripts) was done to allow comparison, which showed that the same places along the coast where habitats play the greatest role now, also play the greatest role later, and are even more important.

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