climada module[1] advanced 23 Jun 2018

https://github.com/davidnbresch/climada_advanced
David N. Bresch, david.bresch@gmail.com

This module implements additional features to extend the capabilities of (core) CLIMADA. This is currently work in progress, as we are currently extracting selected code from core CLIMADA.

In order to run properly, it needs at least https://github.com/davidnbresch/climada

Since this module is in it's making, currently just selected routines described – as the module grows, there will be more structure.

[1] Before reading further, please make sure you are familiar with the basics of CLIMADA, see climada manual https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf

Table of Contents

1. MRIO economics

http://github.com/davidnbresch/climada_advanced/tree/master/code/mrio_economics
with contributions from (in alphabetical order)
Ediz Herms, ediz.herms@outlook.com
Kaspar Tobler

This module contains a risk assessment method which allows businesses from all industries to analyze their supply chain risk and it further provides valuable insights on societal impacts of natural catastrophes.

This method combines the core CLIMADA functionality with Input-Output (IO) economics. We have made an effort to be compatible with major Multi-Regional Input-Output (MRIO) tables that are freely available.

This sub-module was initially developed in the course of the master theses 'Assessing TC weather and climate risk affecting global businesses' of Ediz Herms and Kaspar Tobler. For full details on the method and model details, reference is made to these works.

1.1. Getting started

1.1.1. Requirements

Before reading further, please make sure you are familiar with the basics of CLIMADA.

In order to run MRIO economics properly, it needs at least
https://github.com/davidnbresch/climada and
https://github.com/davidnbresch/climada_module_country_risk
https://github.com/davidnbresch/climada_module_isimip

1.1.2. Process on one page

1. Import Multi-Regional Input-Output table
- **i.** Obtain data from a Multi-Regional Input-Output table
- **ii.** Divide sub-sectors into a number of homogenous main sectors

2. Generate a hazard event set[2]
- **i.** Obtain historical events
- **ii.** Produce probabilistic events
- **iii.** Store intensities at centroids

3. Generate sectorial representation of assets (exposure)
- **i.** For each main sector, characterize their exposure by their geographical distribution (latitude, longitude) and monetary value.
- **ii.** Get NatID for each asset

[2] Provided for selected hazards by core climada and climada modules, see climada manual (p. 1) https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf

iii. Normalize asset values per country as specified in the MRIO table

4. *Generate (sectorial) damage functions – <u>not implemented yet</u>*

5. Calculate direct damages
   i. Calculate the direct damages for the (normalized) sectorial representation of assets, hazard and vulnerability.
   ii. Multiply the relative risk with the total sectorial production from the MRIO table to obtain the absolute damages in millions of dollars.

6. Calculate indirect damages using Input-Output methodology
   i. Choose between demand- and supply driven methodology (or environmental accounting)
   ii. Propagate risk

7. Display the results – e.g. in the form of a risk report

1.1.3. Step-by-step guide

First, read in a MRIO table, i.e. define the name and location of the raw file with the mrio table and flag the table type (cf. header of function `mrio_aggregate_table.m`).

```
climada_mriot = mrio_read_table('WIOT2014_Nov16_ROW.xlsx','wiod')
```

```
>> climada_mriot = mrio_read_table('WIOT2014_Nov16_ROW.xlsx','wiod')
climada_mriot =
  struct with fields:

           countries: [1×2464 categorical]
       countries_iso: [1×2464 categorical]
             sectors: [1×2464 categorical]
    climada_sect_name: [1×2464 categorical]
      climada_sect_id: [1×2464 double]
           mrio_data: [2464×2464 double]
          table_type: 'wiod'
            filename: '/Users/edizherms/Documents/MATLAB/climada_data/mrio/WIOT2014_Nov16_ROW.mat'
      no_of_countries: 44
        no_of_sectors: 56
                unit: '1e6USD'
     total_production: [2464×1 double]
      RoW_aggregation: 'None'
```

Next, aggregate MRIO table that only consists of the main sectors. It further can aggregate several different Rest of World (RoW) regions into one. It gives a climada aggregated_mriot struct that gives information on total production and trade flows on main sector level.

```
aggregated_mriot = mrio_aggregate_table(climada_mriot,1,0)
```

```
>> aggregated_mriot = mrio_aggregate_table(climada_mriot,1,0)
aggregated_mriot =
  struct with fields:

          countries: [1×264 categorical]
      countries_iso: [1×264 categorical]
            sectors: [1×264 categorical]
     climada_sect_id: [1×264 double]
    aggregation_info: [1×1 struct]
          mrio_data: [264×264 double]
         table_type: 'wiod'
           filename: '/Users/edizherms/Documents/MATLAB/climada_data/mrio/WIOT2014_Nov16_ROW.mat'
     no_of_countries: 44
      no_of_sectors: 6
     RoW_aggregation: 'None'
    total_production: [264×1 double]
               unit: '1e6USD'
```

The input parameters `full_aggregation_flag (=1)` and `RoW_flag (=0)` specify that we require a full aggregation that includes the trade flows and total production values, but excluding an aggregation of several RoW-region as the MRIO table provided by WIOD only has one RoW-region.

Next, we can calculate the direct damages for the countries specified in the MRIO table provided. They are saved in the so-called Input-Output Year Damage Set (IO_YDS):

```
IO_YDS = mrio_direct_risk_calc(climada_mriot, aggregated_mriot)
```

```
IO_YDS =
  struct with fields:

      direct: [1×1 struct]
    peril_ID: 'TC'
      hazard: [1×1 struct]
```

Let us now derive the indirect damages from the direct damages using Input-Output methodology:

```
[IO_YDS, leontief] = mrio_leontief_calc(IO_YDS, climada_mriot, 2);
```

```
IO_YDS =
  struct with fields:

      direct: [1×1 struct]
    peril_ID: 'TC'
      hazard: [1×1 struct]
    indirect: [1×1 struct]
```

The hyperparameter switch_io_approach (=2, Ghosh model in this example) specifies the Input-Output approach that is applied. The climada leontief struct contains useful information that can help to identify sources of risk.

It is now possible to return final results as a table. Therefore it is necessary to specifiy a set of countries (='ALL') and sectors (='ALL'). Moreover it may make sense to only read out data for a specific year (e.g. =2008), every year (='ALL') or only the average annual damage (=0) as is the case here.

```
[subsector_risk_tb, country_risk_tb] = mrio_get_risk_table(IO_YDS,
'ALL', 'ALL', 0);
```

The head of the table total_country_risk shows that it gives information on direct, indirect and total country risk (analogoues for subsector_risk_tb).

```
head(country_risk_tb)
```

```
>> head(country_risk_tb)
ans =
  8×7 table
```

Country	CountryISO	DirectCountryRisk	IndirectCountryRisk	TotalCountryRisk	RiskRatio	Value
Australia	AUS	558.46	761.72	1320.2	0.00048469	2.7237e+06
Austria	AUT	0	57.907	57.907	7.1523e-05	8.0963e+05
Belgium	BEL	1.781	179.34	181.12	0.00016306	1.1108e+06
Bulgaria	BGR	0	15.45	15.45	0.00012574	1.2287e+05
Brazil	BRA	2.1257	363.74	365.86	8.9159e-05	4.1035e+06
Canada	CAN	1081	1491.6	2572.6	0.00079104	3.2522e+06
Switzerland	CHE	0	112.36	112.36	8.0335e-05	1.3987e+06
China	CHN	10584	13447	24031	0.000757	3.1745e+07

1.1. Exposure

Currently, basic entities are provided for the main sectors as described in Table 1. These can be used for (direct) risk calculations. For this, it is assumed that the geographical distribution of the sub-sectors is sufficiently represented by that of the main sectors. However, the implementation in CLIMADA also enables the user to provide exposure data on a sub-sector level also.

Table 1. List of data providers that provide globally consistent and scientifically grounded data that is being used in the presented risk assessment method as a proxy for the geographical distribution of sectorial assets.

Main sector name	Source	Literature reference
Agriculture	https://doi.org/10.7910/DVN/DHXBJX	(Wood-Sichra, 2016)
Forestry	http://maps.elie.ucl.ac.be/CCI/viewer/index.php	(ESA, 2015)
Mining & Quarrying	https://mrdata.usgs.gov/mineplant/ https://mrdata.usgs.gov/mineral-operations/	(U.S. Geological Survey, 2005)
Utilities	http://enipedia.tudelft.nl/wiki/Portal:Power_Plants	(Davis, 2012)
Manufacturing	http://www.iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv5.html	(Amann, et al., 2011)
Services	https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html	(Henderson, Storeygard, & Weil, 2012)

1.1.1. Breakdown of economic sectors

In general, the breakdown of economic sectors is defined by the specifications given by the user in the process of reading an MRIO table (Section 1.4.1) where each sub-sector as defined by the MRIO table is assigned to a main sector.

It is possible to introduce new main sectors simply by assigning sub-sectors to them. However, it is then necessary to provide exposure data for that main sector also as described in Section 1.1.2.

1.1.2. Constructing your own entity

1.1.3. Provide entities on sub-sector level

As already mentioned, it is possible to provide entities on sub-sector level also. This is easily done by

1. Constructing an entity
2. Move it to .../climada_data/entity/
3. Give it a reasonable name following the mrio naming system (ISO3_MAINSECTOR_SUBSECTOR) corresponding to the MRIO table you are going to use

`mrio_direct_risk_calc` will automatically search for additional entities on sub-sector provided by the user. This is holds for data on exposure of mainsectors also. In such a case, the name should correspond to the structure ISO3_MAINSECTOR_XXX.

1.2. Vulnerability

At present, studies examining the sensitivity of economic sectors to climate hazards are lacking. For now, only region-specific damage functions have been employed for tropical cyclones. It may be promising to investigate on sectorial vulnerability using a combination of expert judgment and literature review as described in the Outlook (Section 1.5).

The damage function proposed by Emanuel has been employed for TCs (Emanuel, 2011). It has been calibrated using disaster loss records collected from EM-DAT CRED for TCs that occurred in the period from 1981 to 2010. For each country, Emanuel's damage function was adjusted so that the total reported damage best corresponds best to the total simulated damage. For the calibration, the combination of Vhalf and s was estimated using an optimization algorithm. The optimal parameter set is the one at which the annual mean squared error between the recorded damages in EM-DAT CRED and the damages simulated in CLIMADA is minimized.

It is notable that the world can be divided into two different regions that with different orders of magnitude in the calibrated parameters: the North West Pacific and the rest of the world. In the North West Pacific, the resulting damage functions are much lower (low scaling factor s) than in other countries. This could be because wind speeds in the hazard set are overestimated in this region.

1.3. Hazard

1.4. Risk propagation

In this method, IO models are employed to measure indirect inoperability effects. The core of IO models are IO tables that depict an economy's circular flow of goods and services.

1.4.1. MRIO tables

The presented risk propagation method makes use of MRIO tables displaying flows of goods according to industry outputs (industry-by-industry table). This decision is because the method evaluates global effects of natural catastrophes on the supply chain, which makes it necessary to map global trade flows of industries.

In general, the choice of the IO table will strongly depend on the specific application. It is desirable to use an up-to-date IO table covering a high number of economies with a fine breakdown of economic sectors. For reasons of comparability, it may also be worthwhile to use a table that is published on an annual basis. The model presented enables the use of the best-known and most renowned MRIO tables (Table 2).

Table 2. List of providers of MRIO tables that are currently supported in CLIMADA.

Name	Source	Literature Reference
EORA-MRIO	http://worldmirio.com/	(Lenzen, 2013)
EXIOBASE	http://www.exiobase.eu/	(Tukker, 2013)
WIOD	http://www.wiod.org/	(Timmer, 2015)

How to read data from a provided MRIO table into a climada mriot struct?
There are two options, one can either start with the function `mrio_read_table.m` to read in a MRIO table of the providers listed in **Table *1*.** List of data providers that provide globally consistent and scientifically grounded data that is being used in the presented risk assessment method as a proxy for the geographical distribution of sectorial assets.**Table *1*** or from scratch:

- If one starts from a table of the supported MRIO tables, download raw data. It further is necessary to set up a climada_mapping table (see climada_mapping tab) where each sub-sector needs to be assigned to a main sector. Once done, use mrio_read_table.m to read data from excel sheet.
- If one starts from scratch, populate the mandatory fields, see header section of `mrio_table_read.m`. Make sure all other fields have the same (corresponding) length.

1.4.2. Input-Output Methodology

Depending on the specific application it is necessary to either use a model that describes an economy that is dominated by scarce resources (supply-driven) or (demand-driven).

The standard Leontief model is implemented to describe a demand-driven economy.

The Ghosh model is implemented to describe a supply-driven economy.

1.5. Outlook

- Multi-hazard risk
- Impact analysis mode
- Year damage set
- Sub-sector mapping
- 1-A-C konsum
- Business perspective
- Vulnerability: seasonal risk

2. Function references

Bibliography

ESA. (2015). *Land Cover CCI: Product User Guide Version 2.0. [Data file].* Retrieved from https://maps.elie.ucl.ac.be/ CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

Lenzen, M. a. (2013). *BUILDING EORA: A GLOBAL MULTI-REGION INPUT-OUTPUT DATABASE AT HIGH COUNTRY AND SECTOR RESOLUTION.* Economic Systems Research.

Timmer, M. P. (2015). *An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production.* Review of International Economics.

Tukker, A. a.-C. (2013). *EXIOPOL - DEVELOPMENT AND ILLUSTRATIVE ANALYSES OF A DETAILED GLOBAL MR EE SUT/IO.* Economic Systems Research.

U.S. Geological Survey. (2005, 05 30). *Active Mines and Mineral Processing Plants in the United States in 2003 [Data file]*. Retrieved from https://mrdata. usgs.gov/mineplant/

Wood-Sichra, U. a. (2016). *Spatial Production Allocation Model (SPAM) 2005: Technical Documentation.* HarvestChoice Working Paper. Washington, D.C.: International Food Policy Research Institute (IFPRI) and St. Paul: International Science and Technology Practice and Policy (InSTePP) Center, University of Minnesota.