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# The Physical Vulnerability to Climate Change Index computed at the sub-national level*

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## Abstract

The Physical Vulnerability to Climate Change Index (Feindouno et al., 2020) is a composite indicator computed at country level (191 countries) that can be used for the identification of the most vulnerable countries and as a criterion for guiding the international allocation of resources for adaptation. In this paper we present the details of the computation of the PVCCI at the sub-national level (2nd sub-national administrative level in the GADM database), representing 47,138 administrative units in the World (covering all land but Antarctica). It aims at measuring vulnerability to climate change at a finer geographic level, which is particularly relevant for countries that are characterized by high geoclimatic diversity. It would help identify the most vulnerable subnational administrative units and could be used as an instrument of adaptation planning.

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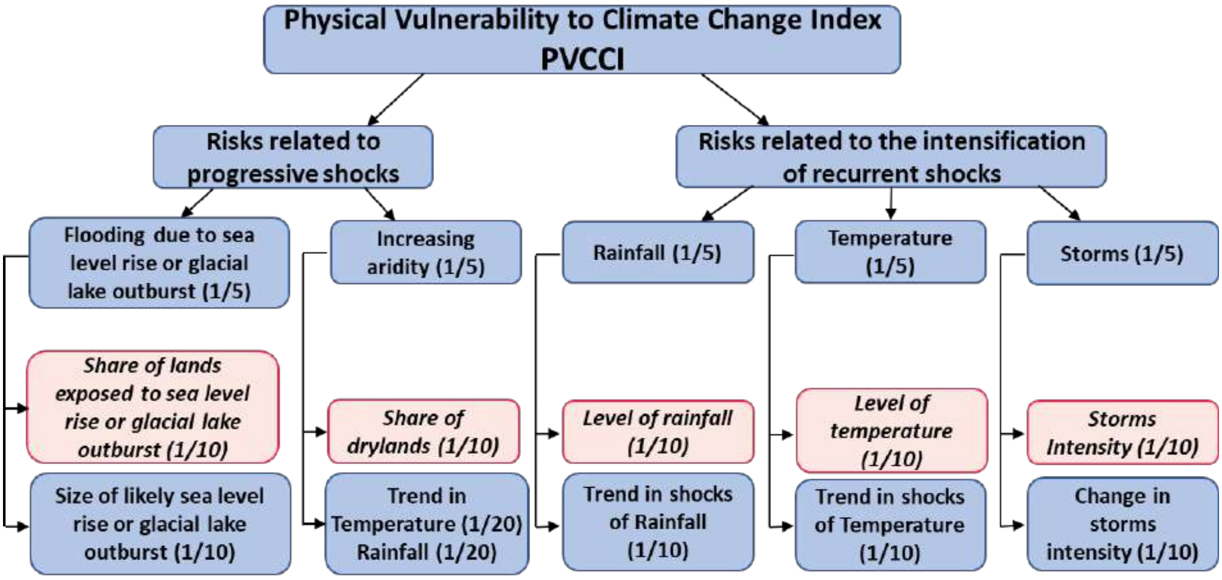
## Introduction

The Physical Vulnerability to Climate Change Index (PVCCI) (Guillaumont and Simonet 2011a and 2011b; Goujon *et al.* 2015; Closset *et al.* 2018; Feindouno *et al.* 2020) measures the main structural or physical consequences of climate change that may affect the well-being and activity of populations, as laid out in the literature on the subject. As argued by Feindouno *et al*. (2020), the PVCCI can be used for the identification of the most vulnerable countries and as a criterion for guiding the international allocation of resources for adaptation. The aim of the PVCCI is to assess aspects of vulnerability that are outside the active influence of countries and are due to long-term exogenous factors. It uses only geographical and climatic variables, geolocalized and published in international databases. Although based on past trends, it is also forward-looking as far as we consider that the past trends induced by climate change are likely to continue.

The PVCCI is a composite indicator that measures both exposure to shocks and the size of shocks. In its current version, it is composed of five dimensions (Figure 3) that refer to the risks of flooding, aridity, temperature shocks, rainfall shocks, and cyclones. For each of these different risks, measurements are taken of the degree of exposure to these shocks and their likely magnitude. The PVCCI components were then normalized on a scale of 0–100 using a standard min-max formula. The progressive aggregation of the different components combines an equal weighting scheme with a quadratic formula that amplifies the weight or impact of components with the highest value, with a partial compensation effect or limited substitutability between components (Noting the arbitrary nature of the weighting scheme adopted, Closset *et al.* (2018) and Feindouno *et al.* (2020) propose alternative schemes that result in no major changes in results).

**Figure 1: The PVCCI**




Notes: The boxes corresponding to last rows of the graph respectively refer to exposure components (red boxes, in italics) and to size of the shocks components

Examples of initial uses of the PVCCI include studies about the vulnerability of Asian LDCs for the Asian Development Bank (Guillaumont, 2017), vulnerability of small islands at the request of the French Development Agency (Goujon *et al.*, 2015). Several studies have considered the PVCCI as a positive factor for concessional resource allocation, either Guillaumont (2015) and Weiler *et al.* (2018) for aid to adaptation or Guillaumont *et al.* (2020) for the African Development Fund. Furthermore, the PVCCI has been introduced as one of the components of the new Commonwealth Secretariat's Universal Vulnerability Index (Kattumuri and Mitchell, 2021).

In the latest studies by Closset *et al.* (2018) and Feindouno *et al.* (2020), the PVCCI was calculated for 191 UN member countries. Goujon and Hoarau (2020) presented the computation of the PVCCI to an expanded global sample by including 59 mostly island and affiliated (non-UN member) territories, thus covering a total of 250 countries and territories.

In this paper we present the details of the computation of the PVCCI at the sub-national level (2nd sub-national administrative level in the GADM database). It aims at measuring vulnerability to climate change at a finer geographic level, which is particularly relevant for countries that are characterized by high geoclimatic diversity. It would help identify the most vulnerable subnational administrative units and could be used as an instrument of adaptation planning.

First, we define the subnational level that is used. Second, we present computation methods by component and aggregation. Third, results are shown at the world level, then for Vietnam and Madagascar, two countries that are characterized by high geoclimatic diversity.

## I - Computation of the PVCCI at subnational level

For this update of PVCCI calculations for sub-national regions, we use the initial method explained in Closset *et al*. (2018) and Feindouno *et al.* (2020), using updated databases and a very few adaptations to compute the PVCCI at the subnational level. Moreover, while Feindouno *et al.* cover 191 UN member countries, we were able to compute the subnational PVCCI for additional subnational jurisdictions that are not UN member (such as Greenland and a number of small islands).

### 1. Perimeters of subnational units

The retained perimeters are those defined at the second sub-national administrative level in the Database of Global Administrative Areas GADM v3.6 (adm2). For small countries or territories with no second administrative level, we selected the first level GADM (adm1), or the entire perimeter for very small countries and territories with no administrative division (specifically small islands). All emerged lands are covered except Antarctica.

**Table 1: The world at the administrative level**

| GADM level | Number of administrative units | % | Number of countries and territories | % | Total Surface ($km^2$) | % |
|---|---|---|---|---|---|---|
| adm2 | 46311 | 98.25 | 164 | 64.57 | $127.63*10^6$ | 94.84 |
| adm1 | 800 | 1.70 | 63 | 24.80 | $6.92*10^6$ | 5.14 |
| adm0 | 27 | 0.06 | 27 | 10.63 | $20.5*10^3$ | 0.02 |
| Total | 47138 | 100.0 | 254 | 100.0 | $134.58*10^6$ | 100.0 |

## 2. Component calculation methods

*Flood risks*

This first component combines an index of the risk of flooding due to sea level rise and an index of the risk of flooding due to glacial lake outburst (melting glaciers).

*Flooding due to sea level rise: share of the territory below an altitude of 5 meters*

The method consists in fixing a critical and probable sea level rise and deducting the share of the territory affected using the share of the territory below a certain altitude corresponding to the chosen level of sea level rise. There is currently no estimate of sea-level rise specific to each territory, leading to the selection of a common level. According to recent end-of-century projections under unfavorable scenarios, incorporating Antarctic ice sheet dynamics, global mean sea level may rise or even could exceed 2 meters (Kulp and Strauss, 2019, Oppenheimer *et al.*, 2019). Considering the risks of submersion during extreme events, heavy swells or cyclones, and the risks of soil salinization and coastline erosion, vulnerable coastal territory can incorporate higher altitudes. To account for this uncertainty and the risk of more frequent extreme events, we select an elevation of 5 meters.[1] Last, pragmatically, we make use of finer zoning data by elevation than the ones used by Feindouno *et al.* (2020), resulting in a reduction of the part of the territory under 1 or 2 meters, specifically for small islands, while some administrative units in the World are at 100%. The choice of 5 meters is then made in order to preserve the specificity, and the rank, of small islands.

The data on the share of the administrative unit below a certain altitude are calculated from three digital elevation/surface models. In all cases, we counted the surfaces below 5 meters directly connected to the sea, i.e. the surface whose elevation is below the flooding threshold must be continuous from the coast. Surfaces not connected to the sea are not considered to be at risk of flooding in the event of sea level rise.

- For territories located between 60 degrees South and 60 degrees North, we first use the database CoastalDEM with 3 arc second (90m) resolution. This digital elevation model (of the land surface without overground items such as buildings or vegetation) is a derivative of the Shuttle Radar Topography Mission (SRTM) digital surface model. The SRTM, derived from a radar mission, does not differentiate between the ground surface, buildings and vegetation, which slightly raises the altitudes and therefore makes it more difficult to detect territories with

[1] Closset *et al.* (2018) used 1 meter but also tested 2 meters, and show that the results are similar, since the shares of coastal territories below 1m or 2m are nearly proportional and generate similar normalized indices when using corresponding min-max values.

an altitude of less than 5 meters. The CoastalDEM corrects these errors to get closer to the real land surface for coastal areas. For non-coastal areas, we continued to use the SRTM.

- territories at a latitude above 60 degrees North: since the SRTM and CoastalDEM models are not available, we use the ASTER numerical surface model with a resolution of 1 arc second.

In the cases of inland seas (Caspian Sea, Dead Sea), low-lying coastal territories are not taken into account as they are not affected by sea level rise.

*Flooding due to glacial lake outburst: size-adjusted number of glaciers*

The risk of flooding due to global warming is also associated to melting glaciers, not only Polar glaciers that contribute to sea level rise, but also the associated risk of glacier lakes sudden emptying or overflowing (Glacial Lake Outburst Floods, GLOFs), which is particularly important for small landlocked Himalayan states, such as Bhutan and Nepal. Each glacier represents a risk of flooding for the downstream valleys. Regarding this risk at the territory level, for a country or a subnational administrative unit, we consider that the higher the number of glaciers, the higher the number of potential floodings in a higher number of mountain valleys. We also consider that the intensity of potential floodings is an increasing function of the size of the glaciers. We then use the number of glaciers adjusted by the share of the country covered by these glaciers as an estimate of the share of the territory exposed to the risk of GLOF. Here we multiply the number of glaciers in the administrative unit by the share of the administrative unit covered by these glaciers using the glacier outlines from the Global Land Ice Measurements from Space database[2].

*Share of dry lands*

According to the definition of the United Nations Environment Program, drylands are areas, other than polar zones, where the ratio of annual precipitation to potential evapotranspiration is between 0.05 and 0.65. It aggregates arid, semi-arid and dry sub-humid zones (a ratio lower than 0.05 characterizes hyper-arid desert zones that are excluded). The share of territory in arid zones is expressed as the percentage of the total territory located in non-desert areas. Primary data on annual rainfall and potential evapotranspiration are taken from the Climate Research

[2] GLIMS and NSIDC (2005, updated 2018): Global Land Ice Measurements from Space glacier database. Compiled and made available by the international GLIMS community and the National Snow and Ice Data Center, Boulder CO, U.S.A. DOI:10.7265/N5V98602. http://glims.colorado.edu/glacierdata/

Unit CRU TS 4.03 - University of East Anglia for the period 1950-2018. They are geolocalized data with a 0.5x0.5 degree resolution grid of the earth's surface[3]. We follow the calculations used by Closset *et al.* (2018) and Feindouno *et al.* (2020) but using updated primary data.

*Precipitation and temperature levels, trends and instabilities*

Precipitation and temperature data are from the Climate Research Unit CRU TS version 4.03 - University of East Anglia (geolocalized data with a 0.5x0.5 degree resolution grid of the Earth's surface). They are monthly data covering the period 1901-2018. We follow the calculations used by Closset *et al.* (2018) and Feindouno *et al.* (2020). The average level of temperature and precipitation is the annual average level calculated from monthly data for the period 1950-2018, for each administrative unit.

Temperature and precipitation trends are calculated specifically for each month of the year and an average of the twelve trends is then calculated. For each administrative unit, the following regression is estimated for each month of the year, based on monthly data covering the period 1950-2018 (t = 1950, ..., 2018):

$$y_t = \alpha + \beta . trend + \varepsilon_t \qquad (1)$$

*Trend* being a deterministic trend (trend = 1, ... 68), $\varepsilon_t$ are the residuals.

For each administrative unit, we therefore have 12 estimated parameters $\widehat{\beta_\iota}$ (i = January, ..., December) for which the simple average is calculated for measuring the average temperature (or precipitation) trend:

$$\text{Trend} = \left( \sum_1^{12} \widehat{\beta_\iota} \right)/12 \qquad (2)$$

*The trend in shocks*

For temperature and precipitation series, and for each administrative unit, the calculation is carried out again firstly month by month. The shock series are calculated from the differences between the observed values and the expected values according to the trend previously estimated by equation (1):

$$\hat{\varepsilon}_t = y_t - \hat{y}_t \qquad (3)$$

In Feindouno *et al.* (2020), in the PVCCI only positive temperature shocks and only negative rainfall shocks are selected, considering that they better reflect the consequences of climate

[3] For a detailed explanation of these data and their processing see Feindouno *et al.* (2016). CRU is one of the most widely used database for research on climate change, including by the IPCC.

change (particularly if we focus on problems of aridity or simply rainfall deficits)[4]. In order to consider that the higher the deviation from the trend, the more important the shock, shocks are defined as squared deviations:

$$E_t = (\hat{\varepsilon}_t)^2 \text{ if } \hat{\varepsilon}_t > 0 \text{ ; and equals 0 otherwise, for temperatures (4a)}$$

$$E_t = (\hat{\varepsilon}_t)^2 \text{ si } \hat{\varepsilon}_t < 0 \text{ ; and equals 0 otherwise, for precipitation (4b)}$$

The *trend in shocks* is the trend in the series of squared deviations $E_t$, following the regression:

$$E_t = \mu + \pi.trend + \epsilon_t \qquad (5)$$

With μ the constant, *trend* is the deterministic trend (trend = 1, ... 68), ϵ the error term. The trend in shocks is the estimated parameter $\widehat{\pi}$.

For each administrative unit, the calculation being carried out month by month, we therefore have 12 estimated parameters $\widehat{\pi}_i$ (i = January, ..., December), for which the simple average is calculated for measuring the average trend in shocks of temperature (or precipitation):

$$\text{Trend in shocks} = = (\textstyle\sum_1^{12} \widehat{\pi}_i)/12 \qquad (6)$$

*Cyclone activity and trend*

The component of the intensity of cyclone or storm activity is presented in detail in Feindouno *et al.* (2018). Primary data are from the National Oceanic and Atmospheric Administration (NOAA), and more specifically from the National Climatic Data Center - International Best Track Archive for Climate Stewardship (IBTrACS): http://www.ncdc.noaa.gov/oa/ibtracs/). We use the v03r07 version of the database, in its polygon version where every cyclone is registered for every affected territory through which it passes. This database is published by UNEP/GRID Geneva (http://preview.grid.unep.ch/). Data cover the period 1970-2014 and records a total of 3915 cyclonic episodes of categories 1 to 5 on the Saffir-Simpson scale and tropical storms ("category 0"). The IBTrACS - UNEP database provides the geolocalization of each cyclone-category, with the geographic breakdown of the affected territories, as well as the associated dates (days) and duration (hours).

The geolocalized polygons of cyclone-categories from UNEP database allows to compute the share of the territory that is affected by cyclone activity (as a percentage of the total country area) and the duration of the exposure, and this is that it is done for the computation of the PVCCI at country level. However, the sub-national administrative unit level is smaller than the

[4] However, they present a version 3 of the PVCCI where negative and positive shocks are selected for both temperature and rainfall series, resulting in small variations in the results, except for a few countries.

polygons in the UNEP database: if this is not a problem for detecting the affected administrative unit (and the share of the administrative unit that is affected, which then can be computed as a share of the total area of the administrative unit), this does not allow to directly compute the duration of the cyclone activity at the administrative unit level. In order to compute this duration at the administrative unit level, we then assign the total duration of the cyclone-category (at the polygon or country level) to affected administrative unit using the share of the administrative unit's affected surface in the territory's total affected surface (at the polygon level):

$$D_r = D_t * S_r / S_t$$

With $D_r$ the estimated duration of cyclone activity at the administrative unit level, $D_t$ the total duration of the cyclone activity (at the territory or polygon level), $S_r$ the affected area of the administrative unit, $S_t$ the total affected area at the polygon level.

For every administrative unit i at period t, the formula to estimate the intensity of cyclonic activity, considering the share of the affected area, the duration and the cyclone category, is then:

$$IIC_{it} = \sum_{j=1}^{n} \sum_{k=0}^{5} \propto_k \times D_{kjit} \times S_{kjit} \qquad (7)$$

With the event j (an administrative unit can be exposed to several events) and k the category of the event (6 possible categories from 0 to 5, the same cyclone can go through different categories), D the duration of the event-category (in hours), S the share of the administrative unit area affected by the event-category (in %). α is the relative weight of the category, which defines its relative power or intensity.

$$\propto_k = (v_k / v_0)^3 \qquad (8)$$

$v_k$ being the minimum wind speed defining the Saffir-Simpson category k and $v_0$ the minimum speed of category 0. The elevation to the cube is based on the non-linear Power Dissipation Index formula (see details and justification in Feindouno *et al.*, 2018).

The calculation is performed for every administrative unit every year over the period 1970-2014. The trend in storms activity intensity is based on the difference in average intensity levels between the periods 1970-1992 and 1993-2014.

*The aggregation of components*

The components are normalized on a scale of 0 to 100. For most of them, the following standard formula is used:

$$Index_i = (x_i - min)/(max-min)*100 \qquad (9a)$$

With $x_i$ the observed value for the administrative unit i, min and max the minimum and maximum values observed in the full (World) sample of administrative units (see Table 2, except for the share of LECZ under 5m whose maximum is set at 75%, and the change in storms intensity whose minimum is set at 0).

Three components are subject to a particular normalization. First, the rainfall trend component (vulnerability increases with a declining rainfall trend due to the risk of desertification), for which an inverse formula is used:

$$Index_i = (x_i - max)/(min-max)*100 \qquad (9b)$$

Second, the two components of size-adjusted number of glaciers and storms activity intensity, for which, following Closset *et al.* (2018) and Feindouno (2020), the normalization is performed by log-linearization (both showing very extreme values):

$$Index_i = (\ln(x_i +1) - 0)/(\ln(max +1) - 0)*100 \qquad (9c)$$

The resulting normalized components are therefore indices with a scale of 0 to 100, with the index increasing with vulnerability.

**Table 2: Min and max values of the components observed in the World sample of administrative units (used for normalization)**

| | Min | Cases | Max | Cases |
|---|---|---|---|---|
| Share of LECZ under 5 meters | 0 | Baharak (AFG) and 35,668 others | 100 (75) | Go Cong (VNM) and 1,499 others |
| Size-adjusted number of glaciers | 0 | Fujayrah (ARE) and 34,976 others | 12.3 | Northern Areas (PAK) |
| Share of drylands | 0 | Beratit (ALB) and 33,520 others | 100 | Al Hajjaylah (YEM) and 10,485 others |
| Trend in temperature | -0.006 | Pitcairn Islands (PCN) | 0.056 | Franz-Josef-Land (RUS) |
| Trend in rainfall | -0.984 | Buthidaung (MMR) | 1.116 | Dededo (GUM) |
| Level of rainfall | 0.288 | Akabli (DZA) | 7485 | Agat (GUM) |
| Trend in rainfall shocks | -830.1 | Buthidaung (MMR) | 477.0 | Mumbai Suburban (IND) |
| Level of temperature | -20.73 | Northeast Greenland National Park (GRL) | 29.90 | Gao (MLI) |
| Trend in temperature shocks | -0.188 | Phillips (USA) | 0.098 | Kargalinskiy (KAZ) |
| Storm intensity | 0 | Linxia Hui (CHN) and 33,540 others | 222.8 | Taketom (JAP) |
| Change in storms intensity | -168.8 (0) | Iles du vent (PYF) and 39,660 others | 242.5 | Taketom (JAP) |

The progressive aggregation of the different components uses a quadratic formula that amplifies the weight of the components with a high value, with a partial compensating effect or limited substitutability between the components. For each administrative unit, we have:

$$PVCCI_i = \sqrt{\frac{1}{n}\sum_{k=1}^{n} {index_{ki}}^2}$$

With $index_k$ the value of the component index k. Specifically, the aggregation follows three steps:

- the risk of flooding component consists in combining the normalized index of the risk of flooding due to sea level rise and the normalized index of flooding due to glacial lake outburst. We calculate the quadratic mean of the two normalized indices, that is a combined index. As the final risk of flooding index, we select the highest value between the combined index and the sea level rise index alone.

- the increasing aridity risk component aggregates the two subcomponents trends in temperature and trends in precipitation

- for the other 3 risk components, the two indexes of exposure and shocks are aggregated : the aridity risk index aggregates the dryland share index and the climate trend index (itself calculated by aggregating temperature and precipitation trends); the precipitation risk index aggregates the average precipitation level index and the trend in precipitation shocks index ; the temperature risk index aggregates the average temperature index and the temperature shock trend index; the cyclone risk index aggregates the average level of cyclone activity and the cyclone activity trend index.

- The five risk indexes are aggregated, again using the quadratic mean, to compute the PVCCI (by assigning identical "nominal" weights to the five components, but the quadratic mean giving more "effective" weight to components with high levels compared to those with low levels). Other weighting systems are discussed in Closset *et al.* (2018) and Feindouno *et al.* (2020).

## II – Results

### 1. The global PVCCI maps: from country-level to sub-national level an inversely

For the sake of comparing / contrasting the results from the subnational PVCCI with the existing results from the country-level PVCCI, we first recalculated the country-level PVCCI following Feindouno *et al.* (2020) but using updated primary data (for temperature, rainfall, altitudes and using LECZ under 5 meters), reported in Figure 2a. Second, the subnational PVCCI computed at the administrative unit level is presented in Figure 2b. Third, we recover country-level PVCCI by aggregating subnational PVCCI (using quadratic mean) weighting the administrative units' PVCCI by their share in the total surface of their country, in Figure 3c.

The recalculated PVCCI at the country level following Feindouno *et al.* (2020) generates the same conclusions than the original authors: two groups show the highest levels of physical vulnerability to climate change, for different reasons (and both groups being characterized by significant heterogeneity): Sahelian African countries suffering from aridity risk and increasing shocks of extreme temperature and lack of precipitation, and Small Islands Developing States suffering from flooding risk and storm activity (see Figure 2a). The subnational level PVCCI (Figure 2b) also reveals high levels of vulnerability in Sahel (from the West to the East-corn), South Africa, Central and South Asia; Middle East and North Africa, Australia, as revealed by country-level PVCCI, but also more localized parts in Far-Northern Canada and Greenland, West USA and Mexico, Western part of South America and North-Eastern Brazil.

However, while specific coastal risks (sea level rise and storm activity) are easily highlighted in the country-level PVCCI of SIDS due to their smallness, this is not the case for higher-sized coastal countries. Contrastingly, the subnational PVCCI is able to signal high vulnerability of coastal parts of larger countries.

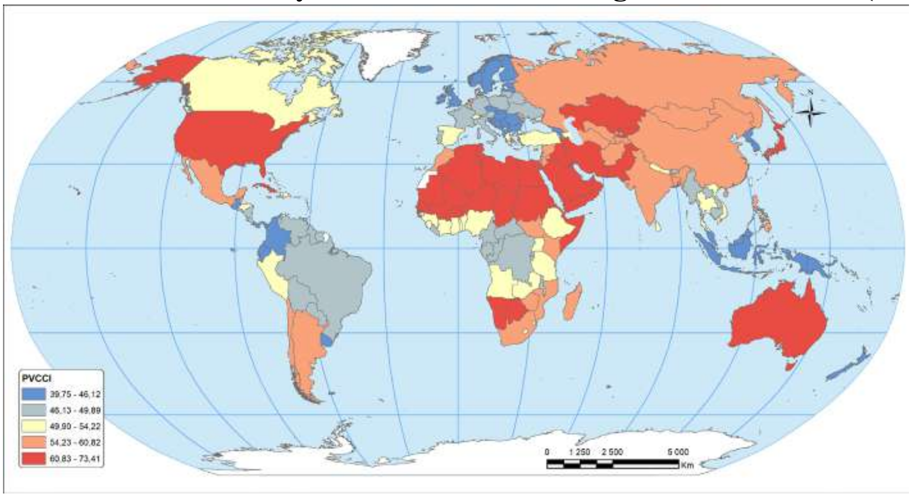
When we recombine subnational PVCCI to recover country-level PVCCI (Figure 2c), and compare it to the one computed following Feindouno *et al.* (Figure 2a), the main result is that large countries (even with highly vulnerable localized parts) appear less vulnerable with the former, while smaller countries maintain their level of vulnerability, which is an expected result given the characteristics of both. This is also a desirable output since it can be argued that larger countries, such as the USA or Russia, would have refuge areas (low vulnerability parts), contrarily to small islands for instance. China, India and Australia are large countries that show similar level of high vulnerability from both country-level PVCCI, since a large part of their territory (and a large number of their administrative units) is characterized by high subnational PVCCI.

A country by country comparison of the results from both country-level PVCCI, the recalculated PVCCI following Feindouno *et al.* (2020) and the PVCCI from the recombination of subnational PVCCI, is reported in Table A1 in appendix.

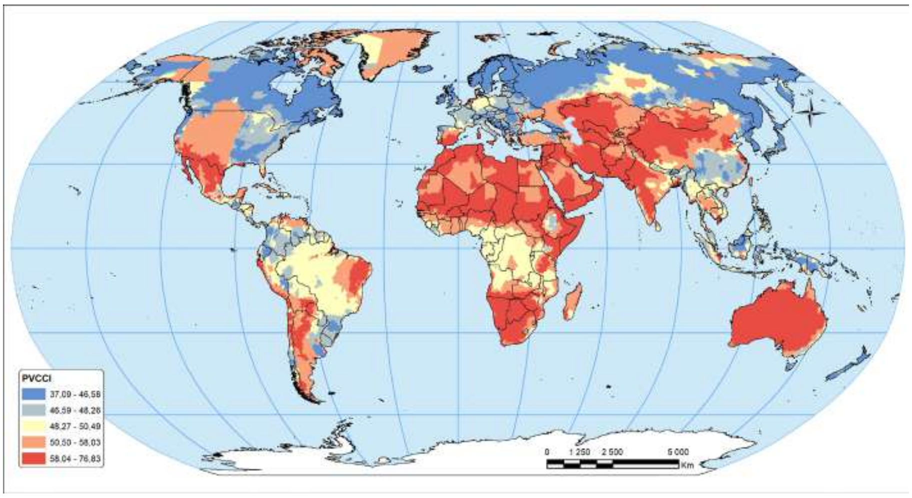
The figure 3 reports the results of the subnational PVCCI at the component level. The Flood risk index show high vulnerability of the low-lying coastal regions around the World, but also in Artic, and Himalayan and Andean regions. The Aridity risk index is high in Sahel (from the west to the east-corn) and south Africa, central and South-east Asia; middle east and north Africa; Australia; far-northern Canada and Greenland; and some part of west USA and Mexico and west of south America (and North-eastern Brazil). Rainfall (Negative) shocks risk is high everywhere except in the tropical regions and in the north-east America; Temperature (Positive) shocks risk index is high mostly in the tropical regions. Storm risk index is high in the Caribbean, Mexico and North West America; North Australia and the West Pacific rim; and the Bay of Bengal and the North of Arabian sea; and South-West of Indian ocean.

**Figure 2: The PVCCI, from country to subnational level**

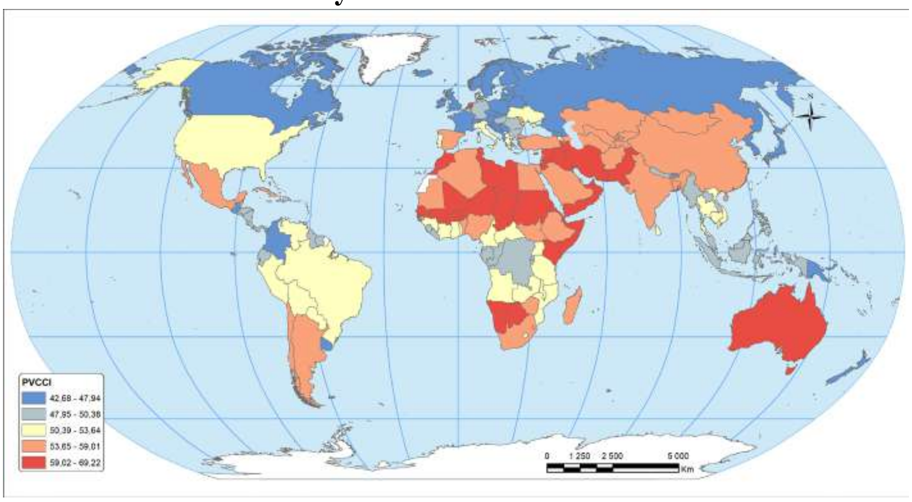
**2a. Recalculated Country-level PVCCI following Feindouno *et al.* (2020)**




**2b. Sub-national PVCCI**

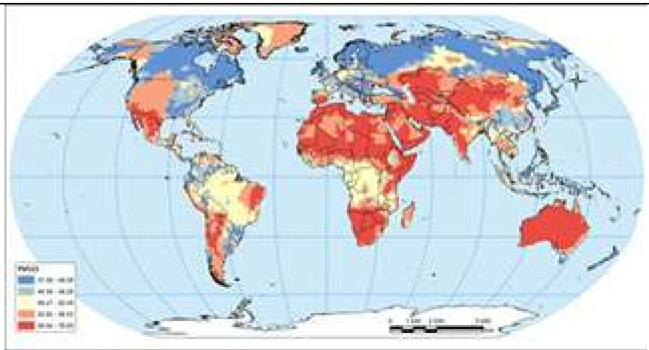
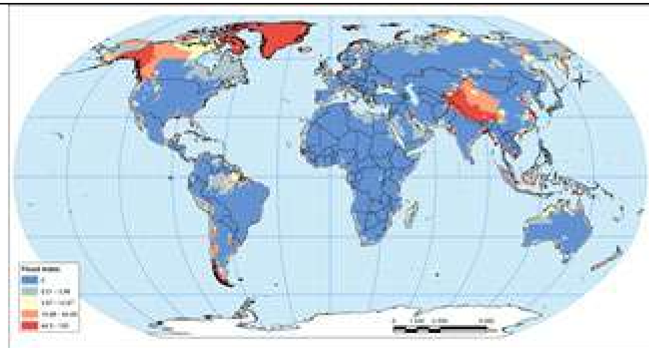
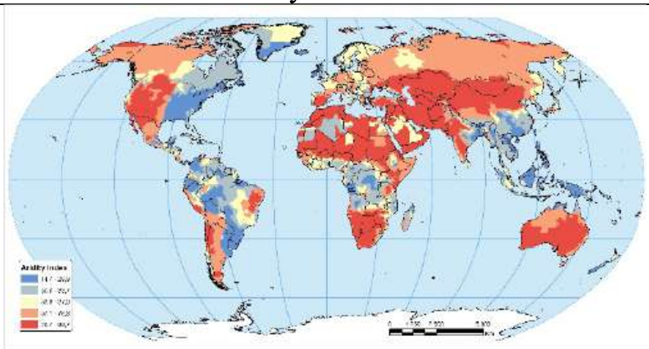
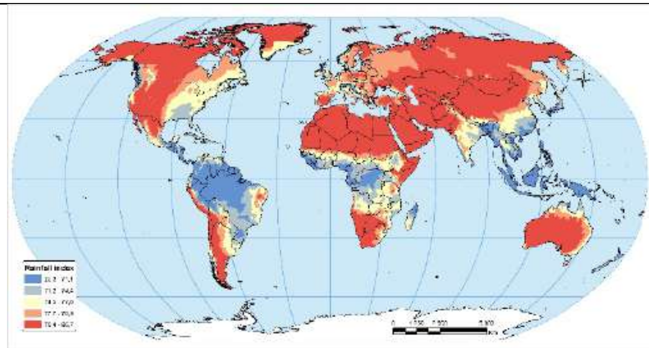
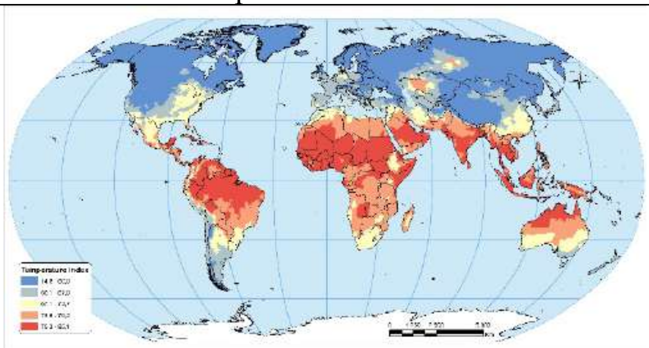
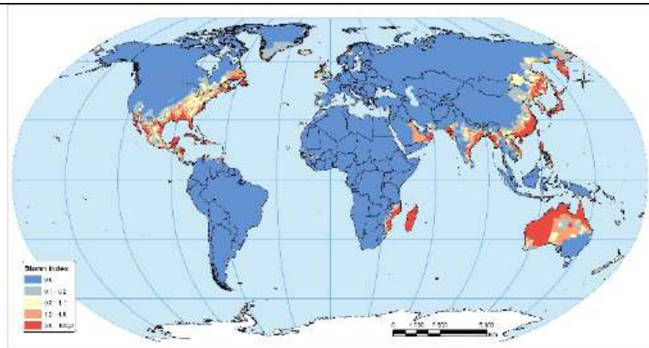



**2c. Recombined Country-level PVCCI from Sub-national PVCCI**




Notes: Large sub-national jurisdictions such as Greenland, Western Sahara of French Guyana are not covered in the recalculated country-level PVCCI following Feindouno *et al.*, 2020.

**Figure 3: The subnational PVCCI and its components**

| PVCCI | Flood risk index |
| --- | --- |
|  |  |
| Aridity risk index | Rainfall risk index |
|  |  |
| Temperature risk index | Storm risk index |
|  |  |

On the map, the interest of the subnational PVCCI is mainly observable for the cases of countries with a large territory characterized by geoclimatic diversity, such as the USA, Canada, Russia, China, Brazil but it can be also observed for countries with smaller territory. The subnational PVCCI also reveals that there are many pockets of high physical vulnerability to climate change in countries where the original country level of PVCCI is low to moderate. The subnational PVCCI also allows for a deeper analysis of territories and their vulnerability as well as their interactions with human activities, firstly where populations are concentrated. We illustrate this observation by the cases of Vietnam and Madagascar in the next sections.

## 2. The case of Vietnam

Vietnam is characterized by a very wide geographic diversity. 1,650 km long from North to South extremes, about 50 km wide East to West at its narrowest part, Vietnam is a coastal country (coastline is 3444 kms long). Usually known for its two large deltas, the Red River Delta in the North and the Mekong River Delta in the South, this is also a mountainous country (mountains account for 40% of the country's land area, mainly in the North-Western and Central regions). Climatic variety (from tropical to temperate) is due to differences in latitude and altitude, monsoon winds, and tropical storms. According to the Climate Change Knowledge Portal (CCKP) of the World Bank, Vietnam is one of the most vulnerable countries to climate change, characterized by high people exposition to natural disasters. However, according to the country-level PVCCI from Feindouno *et al.* (2020), physical vulnerability to climate change is moderate, as Vietnam belongs to the second lowest quintile of the PVCCI (about 120$^{th}$ rank out of 192 countries). Vietnam, at the country level and comparatively, shows moderate level of risk for flooding, aridity and cyclone activity. But, given its geographic and climatic diversity, this is likely to mask a number of vulnerability pockets, which would be amplified if Vietnamese population is concentrated in these pockets.

We are able to compute the subnational PVCCI for Vietnam at the level GDAMadm2, with a fine disaggregation of 678 administrative units or "districts".

The subnational PVCCI reveals highly heterogeneous levels of vulnerability between Vietnamese districts, since they belong from the (World) 2nd quintile to the 5th quintile, even if the 3rd quintile is the most prevalent. A large part of the extreme Southern region falls into the 5th quintile, together with a smaller part of the Red River delta region.

At the component level, flood index reflects the high risk in the two deltas and on the coastal line. Aridity is the weakest risk for Vietnam but affect some mountainous parts in the North, and in the South. Rainfall index show a low risk except in the two central coastal provinces of Quảng Bình and Quảng Trị. Temperature index show a high risk and a very high risk specifically in the South but also in some coastal provinces. Storm risk index is very heterogeneous, and is very high in the North and South coastal regions but also in the Northeast region.

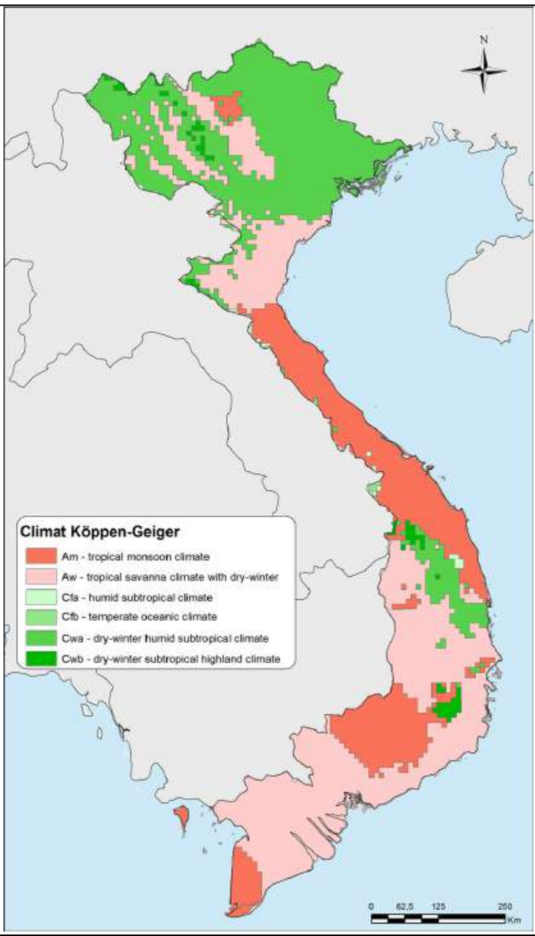
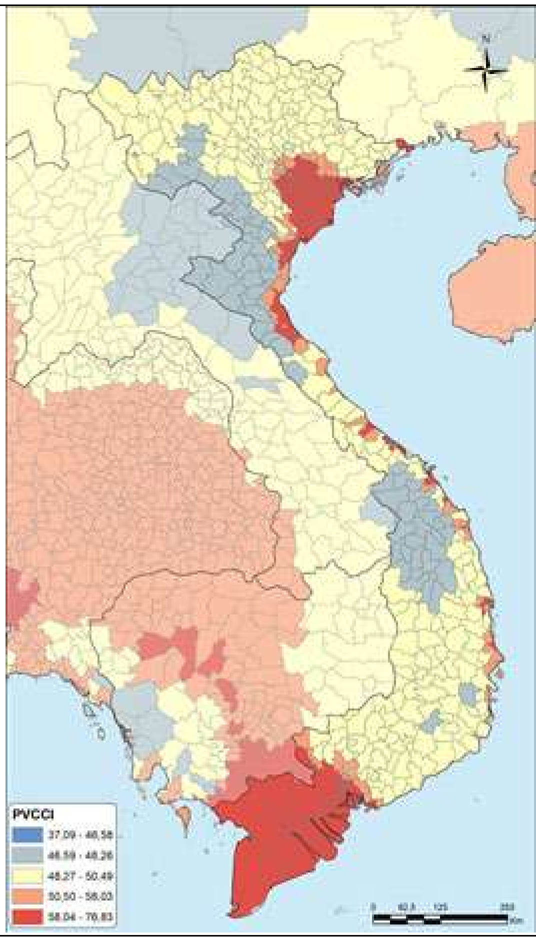
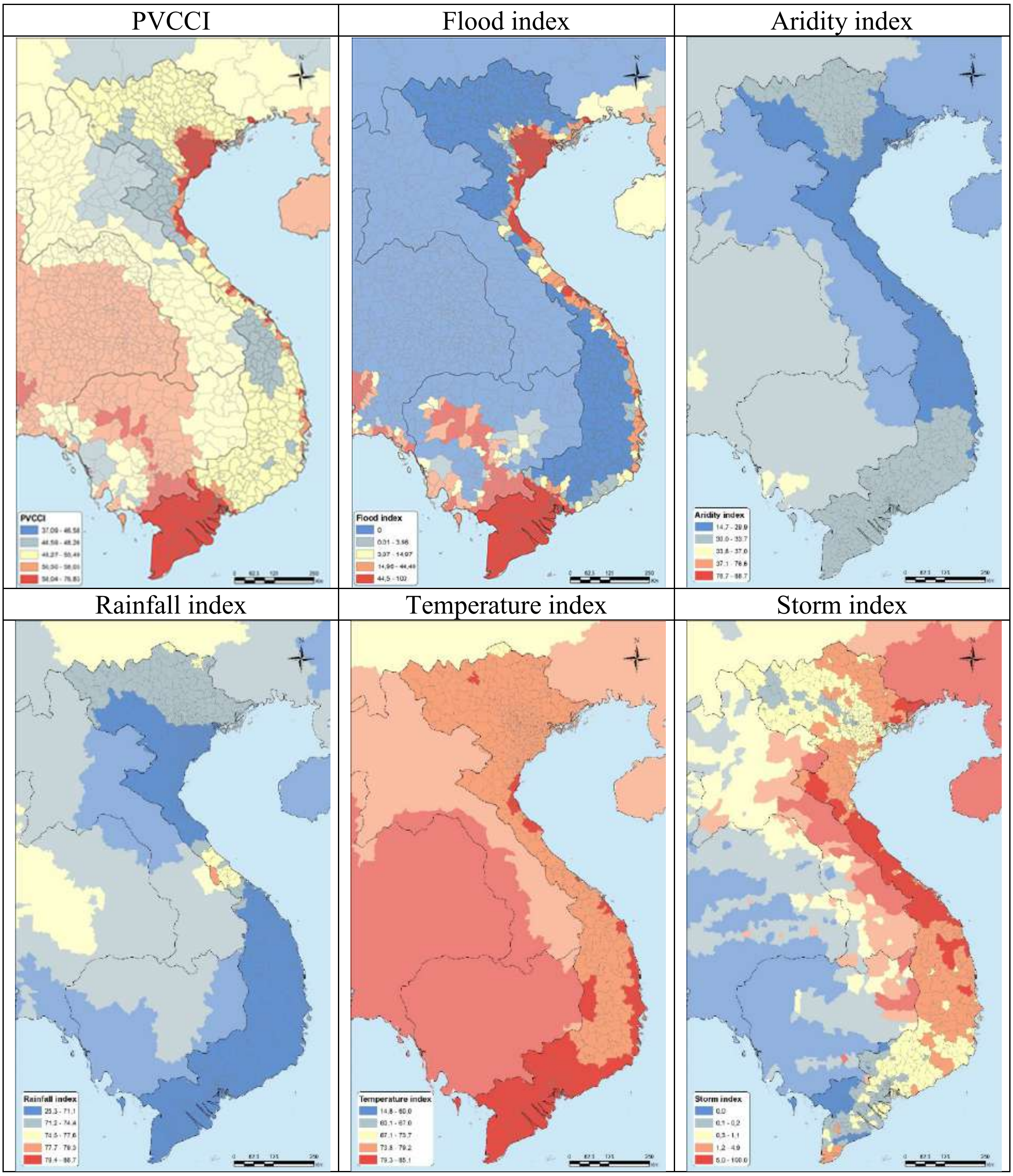
| **Figure 5: Climatic zones of Vietnam** | | **Figure 6: Vietnam's subnational PVCCI** |
|---|---|---|
|  | |  |

**Figure 4: The components of Vietnam's subnational PVCCI**



## 3. The case of Madagascar

Madagascar is a large island characterized by a diversity of ecosystems, from coasts to high plateau at the center. It is one of the most vulnerable countries mainly due to the increasing number of tropical storms the country faces every year. Sea level rise is also a concern for coastal regions. Finally, rainfall variability and increased temperatures affect staple crop production for a poor economy that is highly dependent on raw agricultural output. According to the country-level PVCCI of Feindouno *et al.* (2020), Madagascar is one of the most physically vulnerable country (about 10$^{th}$ rank out of 192 countries, belonging to the 5$^{th}$ quintile). It is also very specific in the SSA country group, being the 4$^{th}$ most vulnerable in the region, the 1$^{st}$ for storm risk with a very high level of risk, the 8$^{th}$ for flood risk, but showing low level of risk of aridity, temperature and rainfall compared to the other SSA countries.

However, Madagascar is characterized by a great geoclimatic diversity (Figure 5) that increases the interest to go further into a subnational analysis. This diversity encompasses several distinct ecosystems, with a mountainous plateau stretching across the center, where the capital city of Antananarivo is located, bordered on all sides by low-lying coastal areas. The climate within those zones is highly variable due to altitude and position relative to the prevailing trade winds and the movement of the intertropical convergence zone.[5]

At the level GDAMadm2, the country is divided into 22 regions, being both decentralized territorial communities and administrative districts, for which we have been able to build the subnational PVCCI (Figure 6).

It is immediately striking to note the relative homogeneity of the map, the regions belonging from the 3$^{rd}$ to the 5$^{th}$ world quintile, the 4$^{th}$ being the most represented. The whole country appears to be highly vulnerable to climate change with the regions of Atsimo Andrefana (South-East) and Atsinanana (West) being among the most vulnerable regions in the world.

Figure 7 below reproduces the vulnerability map of Madagascar's regions to climate change according to the five physical components. This exercise allows us to highlight more clearly the complex interaction between climate change on the one hand and the diversity of the island's climate zones on the other.

[5] There are two distinct seasons but that are specific by regions: a hot and rainy season from November to April, with maximum rainfall in December and January; and a cooler and drier season from May to October, with minimum rainfall in September and October, with rainfall that is limited to the southern and eastern coasts.

Here again, the vulnerability to the intensification of cyclones in Madagascar is to be highlighted[6]. With an average of three to four tropical storms affecting the country each year, the island as a whole appears to be extremely vulnerable and no region is spared. The damage is often very significant, including loss of crops, increased incidence of epidemics, degradation of coastal and marine ecosystems, disruption of essential urban services such as water and electricity, severe flooding, damage to infrastructure, and sometimes loss of life.[7] The progressive increase in temperature is also a significant factor of vulnerability. Rainfall variability and temperature increase will also aggravate the current problems of the agricultural sector characterized by a lack of capacity and low productivity. The southwestern regions of the island will suffer the most from increased aridity. Indeed, we observe that, apart from the more mountainous regions of the central plateau, the coastal regions are characterized by particularly worrying trends related to the increase in temperature shocks, particularly in the regions of Atsimo Andrefana (South-East) and Atsinanana (West).

**Figure 5: Climatic zones of Madagascar**

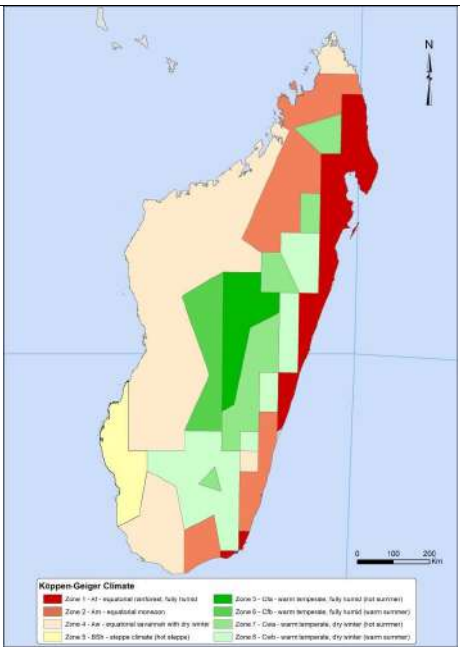
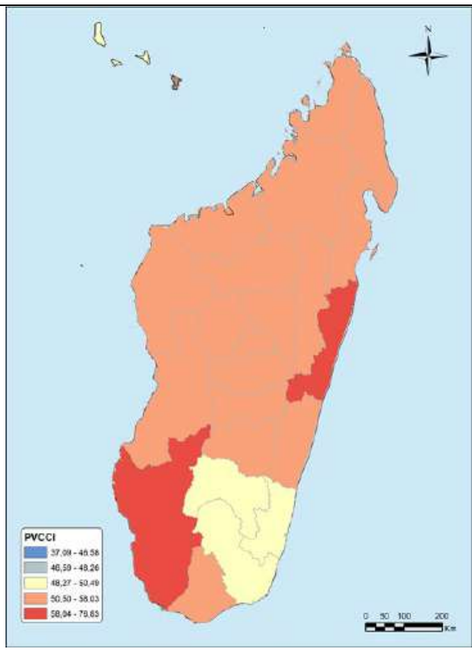


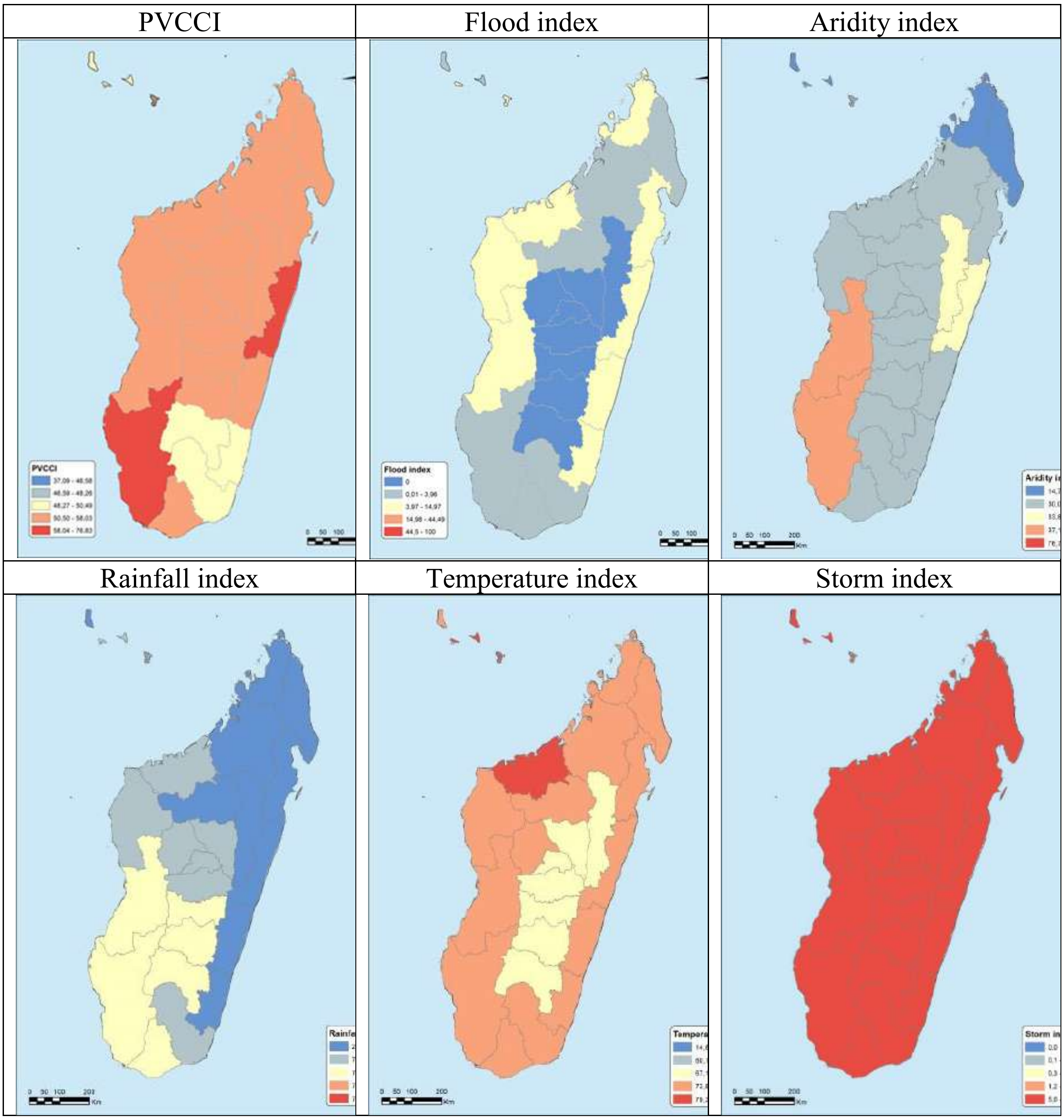

**Figure 6: Madagascar's subnational PVCCI**




[6] Since 1990 Madagascar has experienced 42 cyclones, 8 floods and seven periods of drought that are estimated to have caused $1 billion in damage (EM-Database). According to the World Bank (2020 p. 4), natural disasters cost the Malagasy economy an average of 1% of GDP each year and are particularly devastating for rural activities (as again demonstrated by the last one Batsirai at the beginning of Feb 2022 that caused approx. 100 deaths). This average rate masks the severity of major disasters: Tropical storm Enawo at the beginning of March 2017 that crossed the whole country, including richest mountainous central provinces, caused damage equivalent to 4% of GDP (IMF 2020 p. 68).

[7] Natural disasters disproportionately affect the poorest and most vulnerable people (IMF 2020, p.67). While in sub-Saharan Africa between 2000 and 2019 26% of the population was affected by natural disasters, in Madagascar 45% or 12 million people were affected.

**Figure 7: Madagascar's subnational PVCCI by component**

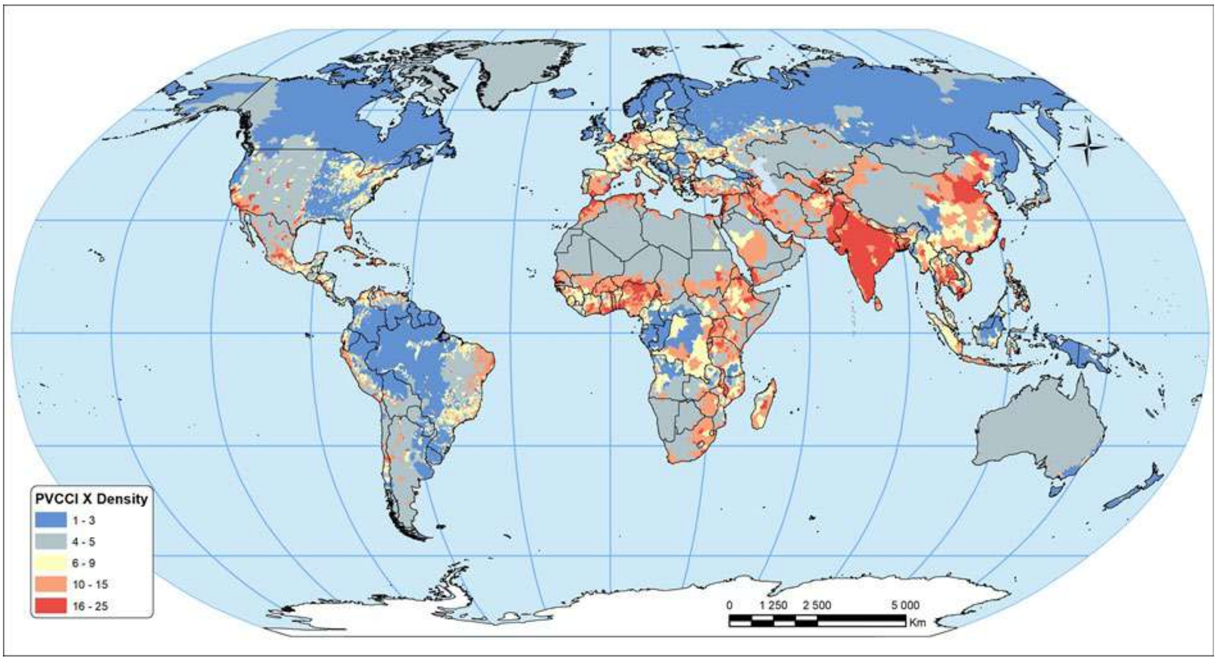



## 4. Crossing the PVCCI and population density

The PVCCI is built to measure a physical vulnerability of countries or territories, aggregating both physical exposure and increasing constraints or shocks characteristics. Vulnerability to climate change is understood here as a vulnerability to a specific global and progressive shock, likely to translate into country-specific shocks through various events. Physical exposure to climate change is a central challenge for many countries as it implies the diminution of the overall usable land surface either through desertification or sea-level rise or the intensification of adverse climatic shocks (more storms per year, more drought, etc.). The subnational PVCCI allows to highlight areas the most exposed to the effect of climate change. However, the extent of the physical vulnerability to climate change does always correlate to the economic, environmental or social consequences of climate change in the long-run. While some areas are more exposed to climate change, its impact might be less severe than in other areas once human factors are considered. In order to approximate the human or societal exposure to climate change, it is possible to cross the geolocalized PVCCI with non-physical factors of exposure, using different methods.

A very simple way is to rank every administrative unit by its PVCCI quintile and by its population density quintile; and by crossing both, with results being reclassified by quintile. Regarding the World results, the territories characterized by high human exposure (because they show jointly high levels of physical vulnerability and population density) are observable in the North-East China, most parts of India, in some regions in the Middle-East, North Africa (and Southern Spain) and tropical Africa (Nigeria), in the extreme South-Western part of the USA, California, the Brazilian Nordeste, and in Indochinese peninsula. Compared to the figure reporting the map of the sub-national PVCCI, territories that show low human exposure, despite high physical vulnerability, because they are sparsely populated, are mostly located in Sahelian and South-West African countries, Central Asia, Australia and most part of Western USA (The detailed map of Africa is provided in appendix).

**Figure 8: Crossing PVCCI with population density**



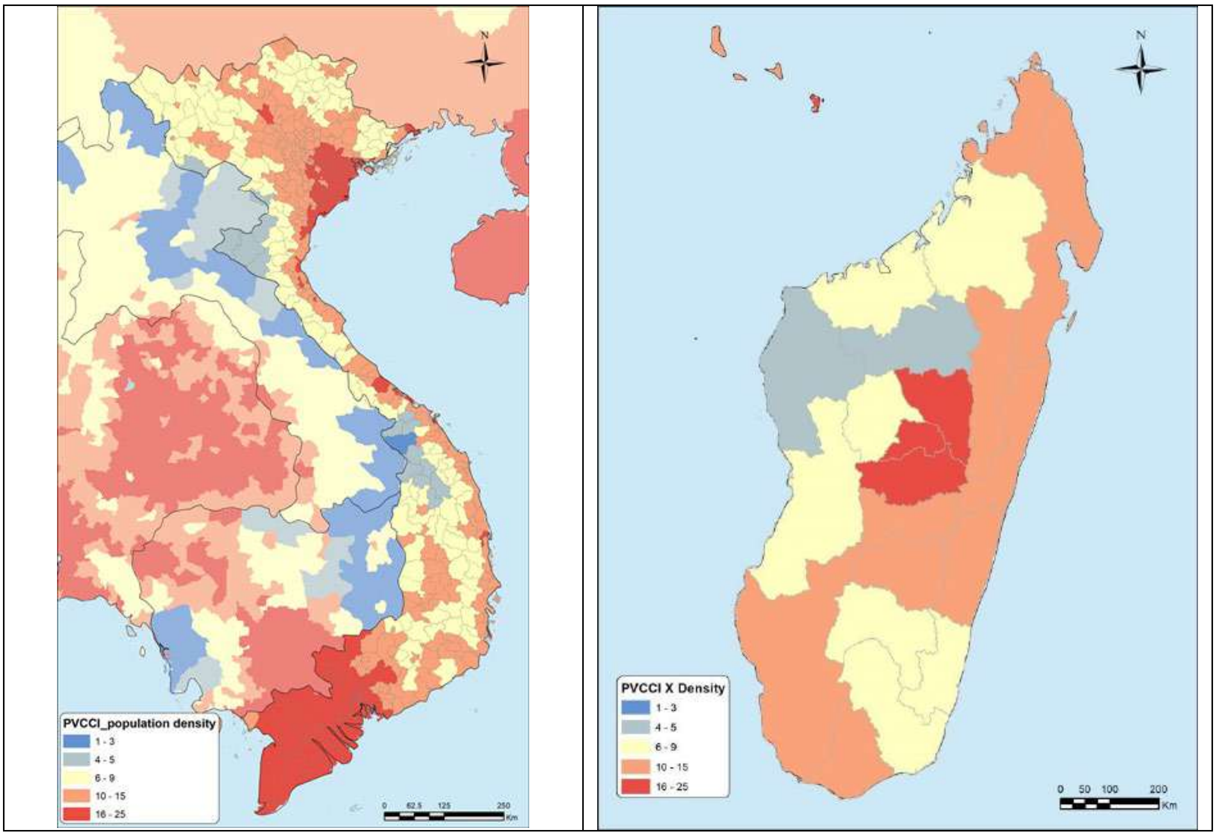
Notes: Every administrative unit are ranked by its PVCCI quintile and by its density quintile; and both are crossed (multiplied): results are reclassified by quintile

| | | Population density | | | | |
|---|---|---|---|---|---|---|
| | Quintiles | 1 | 2 | 3 | 4 | 5 |
| P | 1 | 1 | 2 | 3 | 4 | 5 |
| V | 2 | 2 | 4 | 6 | 8 | 10 |
| C | 3 | 3 | 6 | 9 | 12 | 15 |
| C | 4 | 4 | 8 | 12 | 16 | 20 |
| I | 5 | 5 | 10 | 15 | 20 | 25 |

Regarding Vietnam, considering population density amplifies the concern about climate change, since the two deltas and more generally coastal districts, that are physically vulnerable are also densely populated.  Specifically, a large part of South Vietnam belongs to the 5th quintile of the most exposed population in the World.

For Madagascar, the interaction between physical vulnerability and population density generates a significant heterogeneity between regions that was not clearly reflected before. In particular, the capital province of Antananarivo at the center, appears to belong to the most vulnerable world quintile because it concentrates Malagasy population while being physically vulnerable to climate change, contrasting with less densely populated Coastal regions.

**Figure 9: Crossing PVCCI with population density in Vietnam and Madagascar**



## Concluding remarks

Developing countries will not be able to achieve the 2030 Sustainable Development Goals (SDGs) if some regions at the sub-national level are left out. Emerging evidence suggests an important role of local, rather than national, factors in driving the behavior of SDG targets.[8] Areas that lag behind suffer from different forms of vulnerability that imperil their potential for growth and development. Those structural constraints impact both the life of the poorest populations but also the capabilities of the public and private sectors to operate. Factors such as recurrent climatic shocks, over which private actors have little to no control, that are unmitigated because of inexistent or unreliable infrastructure, make growth more volatile and investment risker. Indeed, initial cost and depreciation of public investment are (likely to be) higher in highly physically vulnerable areas. As vulnerabilities aren't homogeneously distributed across territories, the sustainable development challenge goes well beyond simple country average and the question shouldn't be which countries are on track to meet the SDGs targets but rather which regions. Furthermore, vulnerability to climate change is a multi-dimensional concept, even when taken at the national level, so it is more likely at the local level, as illustrated by the cases of Madagascar and Vietnam. For this reason, vulnerability calls for national and international actions, focused on the most vulnerable developing regions. Such actions require assessments of vulnerability, according to indicators which are comparable between countries and regions, reliable, and likely to be used for policy purposes, primarily for the international allocation of resources at the national and local levels.

An exercise such as the one described in this paper provide critical information to strengthen the relevance and targeting of policies toward a more inclusive development. Those policies will play a critical role to help developing countries face the challenge of climate change if and only if the limited amount of available resource for adaptation is allocated where the needs are the greatest. The PVCCI is a simple, precise, objective, transparent, relevant, measurable, and clear index. Due to these characteristics, it seems to be a suitable index to direct support to the countries and regions which are most vulnerable to climate change.

[8] Recently, Burke *et al.* (2016) exploring the contribution of within-country and between-country differences in explaining under-5 mortality show that within-country differences in under-5 mortality accounted for around 75% of overall variation in under-5 mortality in Africa over the period 1980-2000. According to their estimates, 23% of the eligible children in the study countries continue to live in areas where, if current trends continue, the SDG mortality targets will not be met. Similarly, according to the 2018 joint report from the UN and the World Bank on fragility and conflicts, inequalities across regions and populations within countries are fundamental factors explaining the rise of discontent, political instability and, ultimately, fragility and internal conflicts.

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APPENDIX

## Table A1: Individual country scores

| Country | Recalculated National PVCCI | | Recombined National PVCCI from subnational PVCCI | |
|---|---|---|---|---|
| | Score | Rank | Score | Rank |
| AFGHANISTAN | 57,47 | 57 | 58,29 | 45 |
| ANGOLA | 50,78 | 105 | 53,01 | 80 |
| ANGUILLA | 56,48 | 66 | 56,41 | 56 |
| ALBANIA | 41,98 | 184 | 46,78 | 167 |
| ANDORRA | 46,00 | 156 | 47,08 | 161 |
| UNITED ARAB EMIRATES | 64,49 | 9 | 62,57 | 8 |
| ARGENTINA | 54,75 | 74 | 55,12 | 65 |
| ARMENIA | 45,84 | 159 | 50,50 | 113 |
| ANTIGUA AND BARBUDA | 55,52 | 71 | 54,84 | 66 |
| AUSTRALIA | 63,71 | 15 | 60,23 | 29 |
| AUSTRIA | 47,70 | 147 | 46,47 | 176 |
| AZERBAIJAN | 51,57 | 97 | 55,12 | 64 |
| BURUNDI | 48,53 | 133 | 49,30 | 134 |
| BELGIUM | 49,05 | 127 | 49,46 | 127 |
| BENIN | 52,76 | 86 | 54,06 | 74 |
| BURKINA FASO | 61,18 | 34 | 60,72 | 23 |
| BANGLADESH | 54,75 | 75 | 57,64 | 50 |
| BULGARIA | 44,56 | 170 | 48,06 | 151 |
| BAHRAIN | 62,39 | 21 | 64,03 | 5 |
| BAHAMAS | 73,41 | 1 | 69,22 | 1 |
| BOSNIA AND HERZEGOVINA | 41,33 | 186 | 45,6 | 183 |
| BELARUS | 47,78 | 145 | 46,75 | 168 |
| BELIZE | 55,19 | 73 | 54,71 | 70 |
| BOLIVIA | 49,68 | 119 | 52,71 | 83 |
| BRAZIL | 48,39 | 136 | 50,72 | 109 |
| BARBADOS | 49,36 | 123 | 49,41 | 129 |
| BRUNEI DARUSSALAM | 44,94 | 168 | 47,24 | 159 |
| BHUTAN | 48,13 | 140 | 45,77 | 181 |
| BOTSWANA | 61,02 | 36 | 60,53 | 26 |
| CENTRAL AFRICAN REPUBLIC | 49,44 | 122 | 50,81 | 106 |
| CANADA | 54,20 | 78 | 46,51 | 175 |
| SWITZERLAND | 52,07 | 89 | 46,53 | 174 |
| CHILE | 56,93 | 61 | 53,88 | 76 |
| CHINA | 57,55 | 56 | 54,22 | 73 |
| COTE D'IVOIRE | 51,03 | 102 | 50,96 | 102 |
| CAMEROON | 48,85 | 130 | 50,81 | 107 |
| CONGO, DR OF | 48,28 | 138 | 49,81 | 123 |
| CONGO | 48,11 | 142 | 49,33 | 132 |
| COLOMBIA | 45,67 | 162 | 47,88 | 154 |
| COMOROS | 48,48 | 134 | 49,32 | 133 |
| CAPE VERDE | 61,41 | 30 | 60,80 | 22 |
| COSTA RICA | 48,79 | 131 | 48,13 | 148 |
| CUBA | 61,38 | 31 | 53,99 | 75 |
| CYPRUS | 59,68 | 45 | 59,67 | 35 |
| CZECH REPUBLIC | 46,12 | 154 | 47,88 | 155 |
| GERMANY | 49,88 | 116 | 49,38 | 131 |

| Country | Recalculated National PVCCI | | Recombined National PVCCI from subnational PVCCI | |
|---|---|---|---|---|
| | Score | Rank | Score | Rank |
| DJIBOUTI | 63,38 | 17 | 62,33 | 11 |
| DENMARK | 49,89 | 115 | 50,38 | 115 |
| DOMINICAN REPUBLIC | 51,65 | 95 | 50,36 | 116 |
| ALGERIA | 62,18 | 23 | 56,69 | 55 |
| ECUADOR | 44,12 | 173 | 48,67 | 145 |
| EGYPT | 62,56 | 18 | 57,27 | 53 |
| ERITREA | 64,01 | 13 | 62,46 | 10 |
| SPAIN | 53,63 | 82 | 55,61 | 62 |
| ESTONIA | 44,54 | 171 | 46,59 | 173 |
| ETHIOPIA | 53,02 | 85 | 55,66 | 61 |
| FINLAND | 39,75 | 192 | 44,18 | 189 |
| FIJI | 56,54 | 65 | 51,41 | 98 |
| FRANCE | 47,77 | 146 | 47,94 | 153 |
| MICRONESIA, FS OF | 53,63 | 81 | 51,81 | 90 |
| GABON | 48,14 | 139 | 49,46 | 128 |
| UNITED KINGDOM | 40,99 | 188 | 45,75 | 182 |
| GEORGIA | 41,97 | 185 | 45,16 | 185 |
| GHANA | 51,64 | 96 | 51,92 | 89 |
| GUINEA | 51,23 | 101 | 50,79 | 108 |
| GAMBIA | 64,09 | 12 | 63,83 | 6 |
| GUINEA-BISSAU | 54,22 | 77 | 54,77 | 68 |
| EQUATORIAL GUINEA | 48,44 | 135 | 48,93 | 141 |
| GREECE | 49,89 | 114 | 52,75 | 82 |
| GRENADA | 52,70 | 87 | 51,32 | 99 |
| GUATEMALA | 46,07 | 155 | 47,42 | 158 |
| GUYANA | 46,83 | 150 | 49,04 | 138 |
| HONDURAS | 52,17 | 88 | 50,05 | 119 |
| CROATIA | 43,01 | 180 | 46,65 | 169 |
| HAITI | 53,29 | 83 | 50,92 | 103 |
| HUNGARY | 45,58 | 163 | 48,89 | 143 |
| INDONESIA | 45,74 | 161 | 48,79 | 144 |
| INDIA | 58,97 | 47 | 56,06 | 57 |
| IRELAND | 40,88 | 189 | 45,02 | 186 |
| IRAN, ISLAMIC REP OF | 61,20 | 33 | 60,15 | 31 |
| IRAQ | 62,07 | 25 | 60,93 | 20 |
| ICELAND | 41,07 | 187 | 42,93 | 191 |
| ISRAEL | 60,38 | 42 | 60,22 | 30 |
| ITALY | 48,92 | 128 | 50,54 | 112 |
| JAMAICA | 58,70 | 50 | 52,56 | 86 |
| JORDAN | 60,82 | 39 | 59,79 | 33 |
| JAPAN | 62,23 | 22 | 46,82 | 166 |
| KAZAKHSTAN | 60,92 | 37 | 58,81 | 42 |
| KENYA | 57,60 | 55 | 59,02 | 38 |
| KYRGYZSTAN | 61,50 | 29 | 57,82 | 48 |
| CAMBODIA | 49,58 | 121 | 52,23 | 87 |
| KIRIBATI | 64,14 | 10 | 67,63 | 2 |
| SAINT KITTS AND NEVIS | 50,52 | 109 | 49,40 | 130 |
| KOREA, REPUBLIC OF | 44,79 | 169 | 45,78 | 180 |
| KUWAIT | 64,79 | 7 | 62,86 | 7 |

| Country | Recalculated National PVCCI | | Recombined National PVCCI from subnational PVCCI | |
|---|---|---|---|---|
| | Score | Rank | Score | Rank |
| LAO PDR | 48,35 | 137 | 48,91 | 142 |
| LEBANON | 57,04 | 59 | 58,38 | 44 |
| LIBERIA | 47,00 | 149 | 48,15 | 147 |
| LIBYAN ARAB JAMAHIRIYA | 62,43 | 20 | 60,50 | 27 |
| SAINT LUCIA | 48,88 | 129 | 49,04 | 139 |
| LIECHTENSTEIN | 42,44 | 182 | 45,01 | 187 |
| SRI LANKA | 50,39 | 111 | 51,44 | 97 |
| LESOTHO | 50,81 | 104 | 52,68 | 85 |
| LITHUANIA | 46,40 | 153 | 47,02 | 164 |
| LUXEMBOURG | 46,68 | 152 | 47,60 | 157 |
| LATVIA | 45,97 | 157 | 46,63 | 171 |
| MOROCCO | 58,54 | 52 | 59,29 | 37 |
| MOLDOVA, REPUBLIC OF | 55,39 | 72 | 54,79 | 67 |
| MADAGASCAR | 59,98 | 43 | 54,54 | 71 |
| MALDIVES | 65,29 | 5 | 66,83 | 3 |
| MEXICO | 58,63 | 51 | 57,00 | 54 |
| MARSHALL ISLANDS | 64,12 | 11 | 66,52 | 4 |
| NORTH MACEDONIA | 45,35 | 165 | 50,83 | 105 |
| MALI | 62,16 | 24 | 61,94 | 13 |
| MALTA | 59,97 | 44 | 59,94 | 32 |
| MYANMAR | 49,11 | 126 | 49,57 | 126 |
| MONTENEGRO | 40,63 | 190 | 45,00 | 188 |
| MONGOLIA | 60,64 | 40 | 57,63 | 51 |
| MOZAMBIQUE | 54,46 | 76 | 53,64 | 77 |
| MAURITANIA | 64,62 | 8 | 58,83 | 41 |
| MAURITIUS | 61,85 | 27 | 55,30 | 63 |
| MALAWI | 49,65 | 120 | 51,23 | 100 |
| MALAYSIA | 45,44 | 164 | 48,12 | 149 |
| NAMIBIA | 61,07 | 35 | 60,55 | 25 |
| NIGER | 65,05 | 6 | 60,93 | 21 |
| NIGERIA | 53,75 | 79 | 56,00 | 58 |
| NICARAGUA | 49,79 | 118 | 50,01 | 121 |
| NETHERLANDS | 60,45 | 41 | 61,08 | 19 |
| NORWAY | 43,43 | 176 | 42,68 | 192 |
| NEPAL | 53,21 | 84 | 49,10 | 136 |
| NAURU | 42,37 | 183 | 46,43 | 177 |
| NEW ZEALAND | 45,75 | 160 | 45,25 | 184 |
| OMAN | 65,62 | 3 | 62,48 | 9 |
| PAKISTAN | 65,36 | 4 | 60,49 | 28 |
| PANAMA | 45,34 | 166 | 48,12 | 150 |
| PERU | 50,13 | 113 | 51,68 | 92 |
| PHILIPPINES | 56,02 | 70 | 49,19 | 135 |
| PALAU | 51,81 | 93 | 50,25 | 118 |
| PAPUA NEW GUINEA | 43,62 | 175 | 46,64 | 170 |
| POLAND | 47,61 | 148 | 47,76 | 156 |
| KOREA, DPR OF | 43,04 | 179 | 45,86 | 179 |
| PORTUGAL | 47,85 | 144 | 52,00 | 88 |
| PARAGUAY | 49,82 | 117 | 52,87 | 81 |
| QATAR | 56,96 | 60 | 55,82 | 59 |

| Country | Recalculated National PVCCI | | Recombined National PVCCI from subnational PVCCI | |
|---|---|---|---|---|
| | Score | Rank | Score | Rank |
| ROMANIA | 43,42 | 177 | 48,93 | 140 |
| RUSSIAN FEDERATION | 56,05 | 68 | 47,05 | 163 |
| RWANDA | 48,12 | 141 | 49,05 | 137 |
| SAUDI ARABIA | 63,83 | 14 | 57,78 | 49 |
| SUDAN | 66,62 | 2 | 61,48 | 15 |
| SENEGAL | 61,82 | 28 | 61,31 | 16 |
| SINGAPORE | 48,62 | 132 | 50,55 | 111 |
| SOLOMON ISLANDS | 53,73 | 80 | 50,01 | 120 |
| SIERRA LEONE | 50,72 | 106 | 49,86 | 122 |
| EL SALVADOR | 49,14 | 125 | 50,36 | 117 |
| SAN MARINO | 45,18 | 167 | 47,08 | 162 |
| SOMALIA | 62,53 | 19 | 61,70 | 14 |
| SERBIA | 43,20 | 178 | 46,91 | 165 |
| SOUTH SUDAN | 58,89 | 48 | 58,04 | 47 |
| SAO TOME AND PRINCIPE | 45,85 | 158 | 47,97 | 152 |
| SURINAME | 46,77 | 151 | 49,68 | 124 |
| SLOVAKIA | 44,03 | 174 | 46,60 | 172 |
| SLOVENIA | 42,69 | 181 | 46,03 | 178 |
| SWEDEN | 40,43 | 191 | 44,15 | 190 |
| SWAZILAND | 52,00 | 91 | 54,76 | 69 |
| SEYCHELLES | 56,63 | 64 | 61,19 | 17 |
| SYRIAN ARAB REPUBLIC | 59,42 | 46 | 59,71 | 34 |
| CHAD | 63,56 | 16 | 62,33 | 12 |
| TOGO | 51,29 | 99 | 51,50 | 95 |
| THAILAND | 50,38 | 112 | 51,73 | 91 |
| TAJIKISTAN | 57,28 | 58 | 55,78 | 60 |
| TURKMENISTAN | 56,86 | 62 | 58,72 | 43 |
| TIMOR-LESTE | 52,05 | 90 | 49,63 | 125 |
| TONGA | 56,04 | 69 | 57,31 | 52 |
| TRINIDAD AND TOBAGO | 50,52 | 110 | 50,62 | 110 |
| TUNISIA | 60,83 | 38 | 60,61 | 24 |
| TURKEY | 51,69 | 94 | 54,38 | 72 |
| TUVALU | 56,18 | 67 | 59,49 | 36 |
| TANZANIA, UNITED REP OF | 50,94 | 103 | 53,61 | 78 |
| UGANDA | 50,56 | 108 | 51,50 | 96 |
| UKRAINE | 49,27 | 124 | 51,04 | 101 |
| URUGUAY | 44,37 | 172 | 47,15 | 160 |
| UNITED STATES | 61,22 | 32 | 51,60 | 93 |
| UZBEKISTAN | 56,81 | 63 | 59,01 | 39 |
| ST VINCENT & THE GRENADINES | 51,24 | 100 | 50,87 | 104 |
| VENEZUELA | 48,08 | 143 | 50,48 | 114 |
| VIET NAM | 50,71 | 107 | 52,69 | 84 |
| VANUATU | 58,28 | 53 | 51,59 | 94 |
| SAMOA | 51,34 | 98 | 48,57 | 146 |
| YEMEN | 62,04 | 26 | 61,11 | 18 |
| SOUTH AFRICA | 58,74 | 49 | 58,23 | 46 |
| ZAMBIA | 51,83 | 92 | 53,23 | 79 |
| ZIMBABWE | 58,28 | 54 | 58,84 | 40 |

**Figure A1: The subnational PVCCI in Africa**

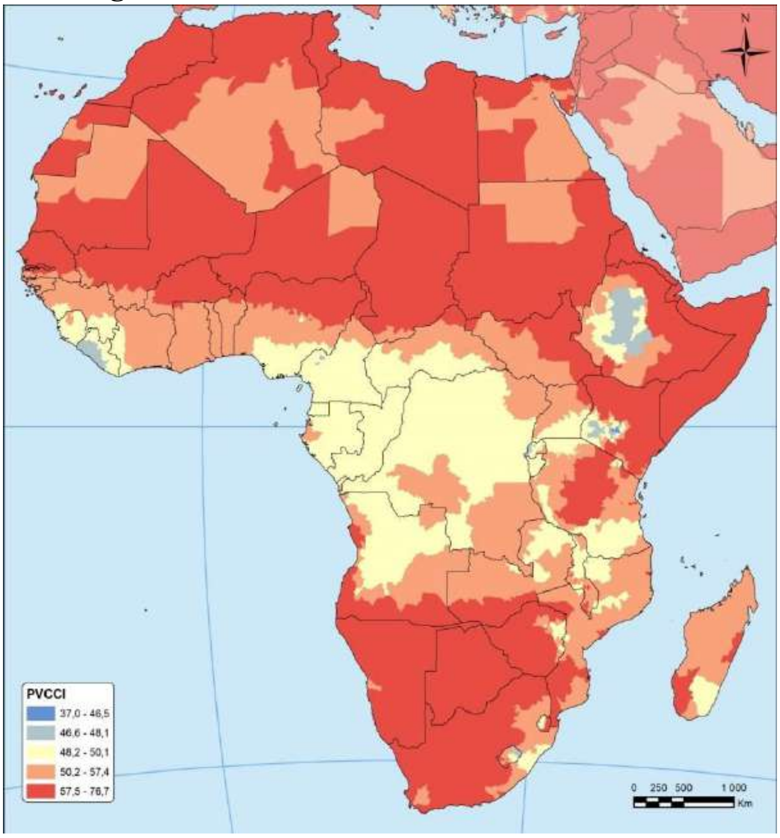
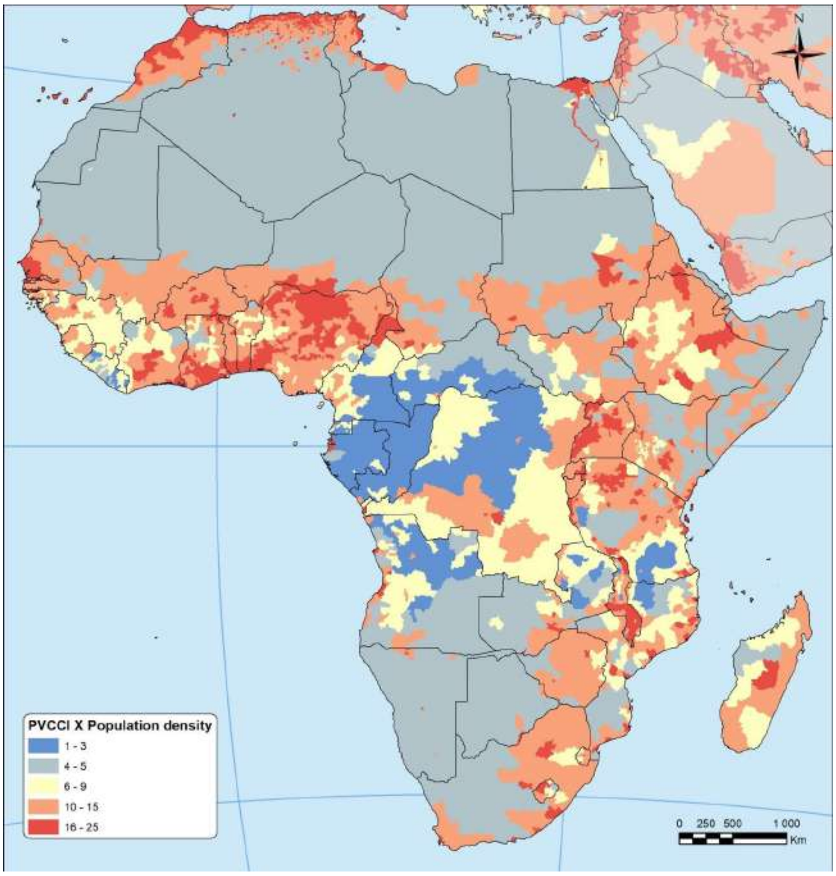



**Figure A2: Crossing PVCCI with population density in Africa**



*"Sur quoi la fondera-t-il l'économie du monde qu'il veut gouverner? Sera-ce sur le caprice de chaque particulier? Quelle confusion! Sera-ce sur la justice? Il l'ignore."*

Pascal

Created in 2003 , the **Fondation pour les études et recherches sur le développement international** aims to promote a fuller understanding of international economic development and the factors that influence it.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