European Commission

SCIENCE FOR POLICY BRIEFS

Sensing global patterns of inequality from space*

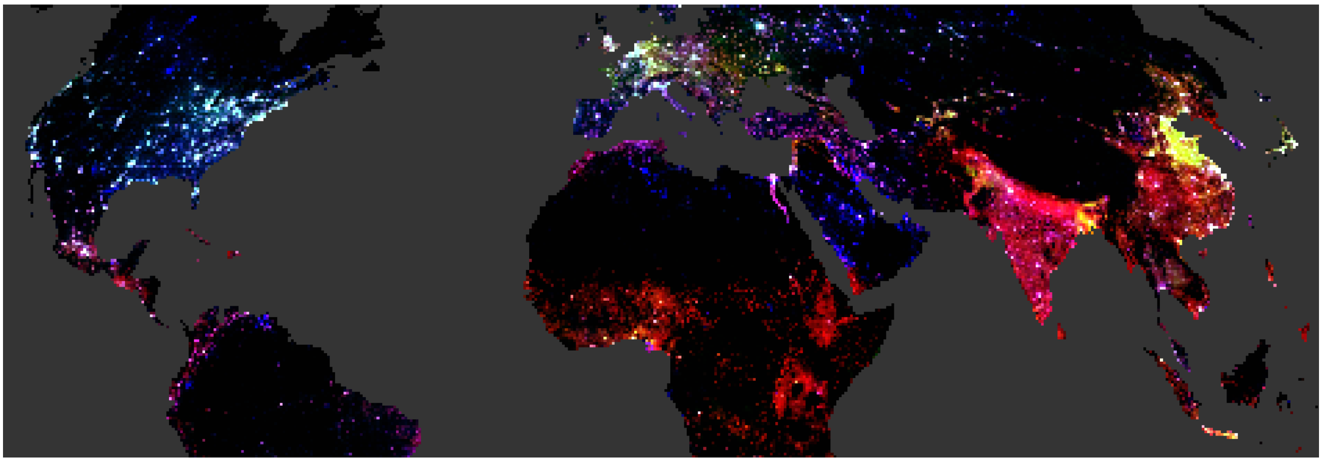
Headlines

- The combination of **Earth Observation and population data** produces new information that describes inequalities across the globe in an original, objective and spatially distinct way.
- The new information contributes to a better understanding of the **spatial distribution of wealth and poverty** around the globe.
- The approach has potential for the **monitoring** and **detection of changes** in spatial patterns of inequality.

Towards a new map of inequalities

Inequality is one of the greatest challenges for global development, with its corrosive effects on social cohesion and political stability. Recent **advances in space technologies and artificial intelligence**, applied to geo-spatial data processing, may contribute to a new understanding of inequality by helping to reveal **spatial patterns of inequalities**. New data technologies have allowed the JRC to draw maps of inequality **in much finer detail** than is possible with national or sub-national statistical data. This new approach merges physical measures of electromagnetic energy reflected and emitted by the Earth's surface and collected by an artificial orbiting platform (Earth Observation Data) with population data collected by national statistical offices (Census Data). Artificial intelligence techniques translate the physical measures into information about the presence of built, roofed structures and the level of light emissions generated by local night-time illumination practices. Using geo-spatial modelling techniques, this information is used to bring the Census Data to a finer level of detail, estimating seamlessly the number of people living on every square kilometre of the Earth's sur-

Figure 1. Global map of inequalities (2015)



Note: The map shows a colour composition of normalised population density (red), building density (green) and night-time light emissions (blue) for the year 2015 with a spatial resolution of 1 km2.

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This brief can be downloaded from: https://ec.europa.eu/jrc/en/research/crosscutting-activities/fairness.

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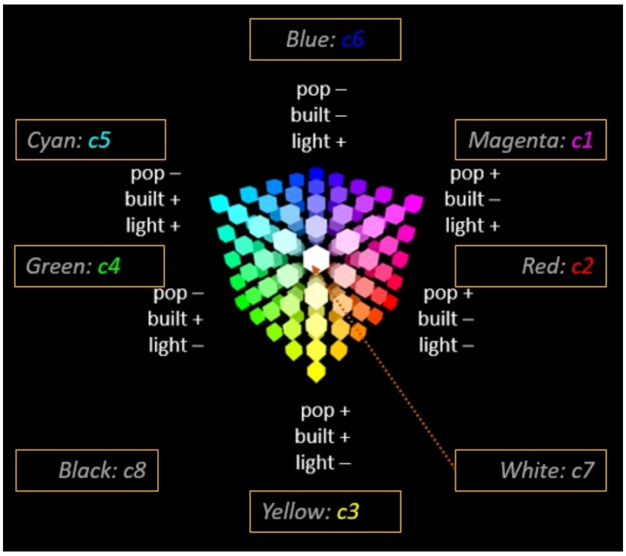
face. By **combining** the information on i) the **density of people**, ii) the **density of buildings**, and iii) **night-time illumination** practices at the same place and time, it is possible to discern **distinct, statistically significant data clusters**. They describe locally specific configurations of economic development, peace and political stability for each square kilometre of the Earth's surface.

Reading the map of inequalities

The white (C7) and black (C8) data clusters show the norm of the global distribution. C7 shows the normal signal of **urban areas, connoting high density of people and buildings and intense night-time light emissions**. C8 shows the normal signal of uninhabited areas, connoting the absence of people, buildings and night-time light emissions. All the other clusters (C1-C6) represent patterns in the data that can be linked to specific **spatial patterns of inequalities** on the Earth's surface:

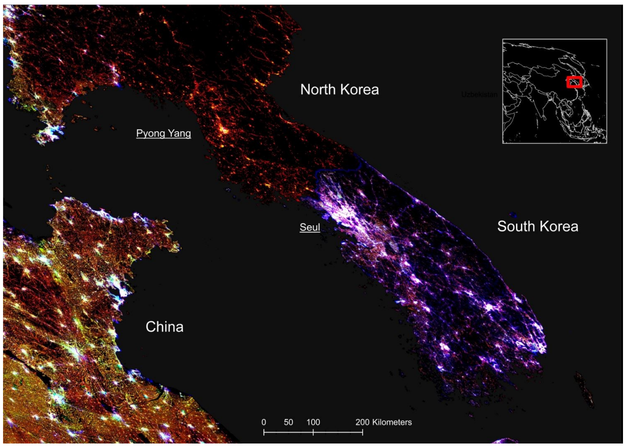
- Magenta (C1) indicates **deprived areas**: either historic, dense urban centres with limited illumination infrastructure, or densely inhabited rural areas with presence of electrification (see parts of rural India).
- Red (C2) indicates poor areas such as **large slums** (dense population, no public illumination), conflict-affected areas (see Yemen in Figure 1), or disaster-affected areas (see parts of Central America, the Caribbean and Asia in Figure 1).
- Yellow (C3) indicates poor areas of **historic towns** and rural areas with diffuse but densely inhabited settlement infrastructure and scarce public illumination (see parts of rural China on Figure 1). Rapid onset destruction of the settlements and their electrical infrastructure, not yet reported by the input population data, also fall into this cluster.
- Green (C4) indicates the presence of second homes, over-built rural or **touristic areas** (see parts of France on Figure 4), or abandoned villages.
- Cyan (C5) indicates the presence of rich areas, such as **suburbs in developed countries** with large land consumption, intense public illumination, and sparse population density (see the USA and parts of the EU in Figure 1 and Figure 4).
- Blue (C6) indicates large **industrial installations** (see Figure 3 and Figure 4), security infrastructures (military installations, border fences), and large oil and gas extraction sites.

Figure 2. Colour cube representation of possible combinations of the three input data sets: population, buildings, and night-time light emissions



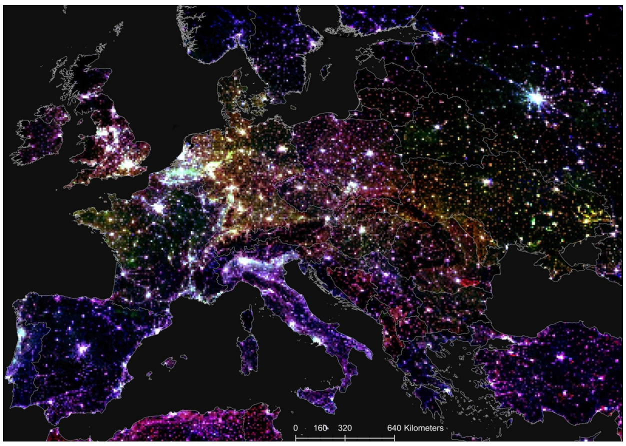
Note: The corners of the colour cube represent an ideal-typical or 'pure' data cluster as determined by the geo-spatial input data (population, buildings, night-time light emissions) in comparison to the global norm. The flags '+' and '-' indicate that they are significantly above or below that norm. All the other colours represent intermediate combinations of data parameters, proportionally to the distance to the closest colour cube corner.

Figure 3. Inequalities on the Korean peninsula



Note: The map shows the strong contrast between North and South Korea as captured by the model.

Figure 4. Inequalities in Europe



Note: The map shows rather diverse spatial settlement patterns, and some seem to coincide with administrative boundaries, but spatial patterns also diverge within countries. Germany is largely represented by yellowish tones, which usually marks poorer settlements with scarce public illumination. However, in Germany this can be attributed to the efforts to reduce light pollution.

Quick Guide

Inequality is usually measured through the analysis of socio-economic statistics from censuses or other surveys. To overcome the limitations of these data sets (large time intervals between surveys, limited spatial detail, lack of global coverage), the JRC has developed a new approach to mapping spatial patterns of inequalities using geospatial data derived from Earth Observation.

The three basic geo-spatial information layers (people, buildings and light) are compared to the normal distribution of the same information at the global level, and statistically significant cut-off values of the measured quantities are determined. After this normalisation step, the degree of agreement with the global normal combination of the considered parameters is measured for each spatial sample of the Earth's landmass: the density of people, buildings and night-time light emissions. Those three normalised parameters are input to a red-green-blue (RGB) digital colour composition model, by associating each parameter to one colour channel (Figure 1; see Figure 2 for the colour legend). Through a Red-Green-Blue (RGB) colour composition of normalised population density (red), building density (green) and night-time light emissions (blue), for the year 2015, it is possible to describe living conditions all around the globe. The selected colour composition model allows for human perception of the different geo-spatial data clusters by using natural colour vision. In this model, the perceived colours are pointers to the presence of varying geo-spatial data clusters on the ground, regrouping statistically significant combinations of the considered parameters, as compared to their global normal distribution. The schema summarises the association between the statistical data clusters and their representation in the digital colour composition model. The selected visualisation model supports more than 16 million data combinations, which can be represented as a cube in the RGB digital colour space.

A new approach to addressing fairness

The issue of inequality has risen in importance in recent years. The effects of the economic crisis, in Europe and globally, have been profound, reversing years of convergence in living standards and putting considerable strain on social protection systems. **Inequality has risen** in a **majority of Member States**, triggering concerns both about the sustainability of growth and about social cohesion. Building a more inclusive and fairer Union is a key priority for this European Commission COM(2017) 250. Shared knowledge and **understanding of inequality** are fundamental to addressing the challenges of inclusivity and fairness. New data technologies may provide a novel view of inequalities. These new technologies have the potential to generate novel pictures with a unique set of characteristics: i) they are based on **objective data** and concrete facts rather than on abstract, top-down classifications or arbitrary schemas; ii) they are strongly **linked to the local place and communities**; iii) they are **globally comparable**; and iv) they are dynamic and can be **continuously updated**. These unique characteristics may improve our capacity to assess local populations' living standards in an open and inclusive way, and to compare them with national and international standards.

Related and future JRC work

The JRC continues to conduct research on inequality at global scale. This includes research on the collection of socio-economic variables through the combination of global geospatial information layers, including Earth Observation data.

This brief is one of a **series of science for policy briefs** reporting on recent JRC research on various aspects of fairness. A **comprehensive report on fairness** will be published in 2019.

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