1. NIGHTTIME LIGHTS

2. GLOBAL HUMAN FOOTPRINT

3. LAST OF THE WILD

4. ANTHROMES
   (ANTHROPOGENIC BIOMES)

CLASSIC:
Natural systems with humans disturbing them

ANTHROMES:
Human systems, with natural systems embedded within them
INPUT DATA

Suomi NPP
Satellite Imagery

IMAGING DATA

PRODUCT

NIGHTTIME LIGHTS

Fires

Clouds

Smoke

IMAGE PROCESSING

NASA
NOAA
to be recorded as polygons in the NIMA database, although this definition most likely underestimates the extent of access along rivers, since any river wide enough to float a dugout canoe is a potential access point. We did not include the effects of waterfalls or dams, which limit access upriver, because data were inadequate. Thus, access along some waterways may be overestimated.

Power infrastructure. Many of the dramatic changes in human influence that are due to land use change and access during the 20th century have literally been fueled by fossil energy. Before the industrial revolution, the human capacity to modify the environment was limited by human and animal muscle power, what McNeill (2000) called the “somatic energy regime.” Today one human being with a bulldozer can apply the power of 300 horses to modify the environment. Electrical power provides an excellent estimate of the technological development of a local area (Elvidge et al. 1997a) and the use of fossil fuels. In the United States, where electrical power is available nearly everywhere, the lights visible at night from satellites provide a proxy of population distribution and have been correlated with human settlements (Sutton et al. 1997, Elvidge et al. 1997b). We assigned a score of 10 to areas that have lights visible more than 89% of nights, 8 to areas with lights visible 40% to 88% of nights, 4 to areas with lights visible less than 40% of nights, and 0 to areas where no lights were visible.

Summing the scores. We summed the human influence scores for each of the nine datasets to create the human influence index (HII) on the land’s surface (figure 1). Overall, 83% of the land’s surface, and 98% of the area where it is possible to grow rice, wheat, or maize (FAO 2000), is directly influenced by human beings (HII > 0). The theoretical maximum (72) is reached in only one area, Brownsville, Texas, USA, but the top 10% of the highest scoring areas looks like a list of the world’s largest cities: New York, Mexico City, Calcutta, Beijing, Durban, São Paulo, London, and so on. The minimum score (0) is found in large tracts of land in the boreal forests of Canada and Russia, in the desert regions of Africa and Central Australia, in the Arctic tundra, and in the Amazon Basin. The majority of the world (about 60%), however, lies along the continuum between these two extremes, in areas of moderate but variable human influence.

The human influence index, like the GLOBIO methodology or the human disturbance index, treats the land surface as if it were a blank slate on which human influence is written, but we know this is not the case. The distribution of major ecosystem types and the human histories of different regions modify the biological outcomes of human influence (cf.
INPUT DATA

Suomi NPP Satellite Imagery → NASA NOAA → IMAGE PROCESSING → NIGHTTIME LIGHTS

PRODUCT

CITY / NON-CITY

CLASSIFICATION

Population Density

Land Transformation

Accessibility

Electrical Power

SANDERSON, 2002

LOVELAND ET AL., 2002

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Finally, there are many issues that require further investigation. Recommendations for future research areas include the following.

- Strategies for dealing with the uneven distribution of land cover and vegetation reference data. The dearth of data from developing countries is problematic. Achieving globally consistent land cover data may be difficult until appropriate reference data become available.
- Methods for pre-processing remotely sensed data, including atmospheric corrections, radiometric calibration, compositing techniques and image registration, in order to improve the overall quality of the data products.
- The role of MODIS data for both detailed and routine repetitive mapping.
- An improved approach to urban land cover characterization. The DCW urban layer used in this research is inadequate. Strategies such as the recent work by Elvidge et al. (1997) with Defense Meteorological Satellite Program data should be explored.
- Methods for characterizing wetlands using coarse-resolution data. This problem may require approaches merging both coarse-and high-resolution data from both active microwave and optical sensors, and ancillary data.
- An approach for improving the consistency of forest cover classes is needed. The subjective determination of forest density classes and separating mixed from other forests is likely to be inconsistent due to the manual interpretation process. It would be quite useful to first derive measures of canopy density, leaf type and phenology for use in forest cover interpretation.
- Improved characterization of the attributes of agricultural lands. Agriculture and agriculture-impacted lands cover a significant portion of the Earth and...
Satellite inventory of human settlements using nocturnal radiation emissions: a contribution for the global toolchest

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Abstract

Time series data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) have been used to derive georeferenced inventories of human settlements for Europe, North and South America, and Asia. The visible band of the OLS is intensified at night, permitting detection of nocturnal visible-near infrared emissions from cities, towns, and villages. The time series analysis makes it possible to eliminate ephemeral VNIR emission sources such as fire and to normalize for differences in the number of cloud-free observations. An examination of the area lit (km²) for 52 countries indicates the OLS derived products may be used to perform the spatial apportionment of population and energy related greenhouse gas emissions.

Keywords: night-time lights, human settlements

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Introduction

Much of global change research is dedicated to discerning and documenting the impacts of human activities on natural systems (Houghton et al. 1995). Human population land cover changes under differing scenarios. Census data from individual countries are collected using different methods, timescales, and reporting units, making it difficult to compare and synthesize data from across the globe. Remote sensing techniques can be used to monitor major changes in the continuous surface conditions of the Earth.
direct mortality, and modification of hydrologic and geomorphic processes that shape aquatic and riparian systems (Trombulak and Frissell 2000). Lalo (1987) estimated that 1 million vertebrates a day are killed on roads in the United States. Forman and Deblinger (2000) estimated that the effects of American roads extend over a band approximately 600 meters (m) wide. The nominal spatial accuracy of all of the NIMA datasets (table 1) is 2 km. Therefore, we assigned a score (8) for the direct effect of roads and railways within a 2 km buffer to ensure that we captured the actual location of the road as mapped, although we may be overestimating the spatial extent of influence. While we recognized that road influence depends on the type of road and the amount of traffic passing along it, we were unable to include these factors in our analysis because of the imprecision of the datasets. The effect of overlapping influence from multiple roads on the same location was not included.

We also used the independently derived NIMA datasets on settlements (represented by points with 2 km buffers) and built-up areas. The settlement data include a large variety of settlement types, such as camps, buildings, and monuments, but the vast majority of features are of unknown type. We assigned each point a score of 8. The built-up areas, which typically represent the largest cities as polygons in the NIMA database, were assigned a score of 10.

Human access. Roads, major rivers, and coastlines provide opportunities for hunting and extraction of other resources, pollution and waste disposal, and disruption of natural systems, as well as social and economic gain (Gucinski et al. 2001). As a result, designating areas of remoteness is a common element of many wilderness-mapping exercises (e.g., Lesslie and Malsen 1995, Aplet et al. 2000). Hunting of wildlife no longer supplies a significant source of food in the western world, but it does in most of the rest of the world. Such hunting, with its associated disruption of ecosystems, is of major concern (Robinson and Bennett 2000), because it could result in some forests ecosystems being "emptied" by overhunting (Redford 1992). In tropical ecosystems, access from rivers and the coast may be more important than access from roads (Peres and Terborgh 1995).

To measure the area affected by access, we estimated the distance a person could walk in one day in a difficult-to-traverse ecosystem (e.g., moist tropical forests) as 15 km (see, e.g., Wilkie et al. 2000). We acknowledge, however, that this approach oversimplifies the complex relationship between human beings and roads, a relationship that varies by ecosystem type and cultural context. All areas within 2 to 15 km of a road, major river, or coast were assigned a modest human influence score (4) that reflects intermittent use. Major rivers were defined roughly as those that reach the sea and are wide enough...
Figure 3. The human footprint, a quantitative evaluation of human influence on the land surface, based on geographic data describing human population density, land transformation, access, and electrical power infrastructure, and normalized to reflect the continuum of human influence across each terrestrial biome defined within biogeographic realms. Further views and additional information are available at “Atlas of the Human Footprint” Web site, www.wcs.org/humanfootprint.

Data are available at www.ciesin.columbia.edu/wild_areas. National boundaries are not authoritative.
Suomi NPP Satellite Imagery \rightarrow NASA, NOAA \rightarrow IMAGE PROCESSING \rightarrow NIGHTTIME LIGHTS \rightarrow CITY / NON-CITY

Population Density \rightarrow WCS, CIESIN \rightarrow ALGORITHM \rightarrow GLOBAL HUMAN INFLUENCE INDEX \rightarrow GRADIENT SCORE:

\[ \begin{array}{c}
\text{0} \\
\text{72} \\
\text{100%}
\end{array} \]

\[ \begin{array}{c}
\text{0} \\
\text{10% WILDEST AREAS}
\end{array} \]

GLOBAL HUMAN FOOTPRINT \rightarrow PERCENTAGE:

\[ \begin{array}{c}
\text{0} \\
\text{100%}
\end{array} \]

LAST OF THE WILD \rightarrow 15 CATEGORIES
ANTHROMES
ANTHROPOGENIC TRANSFORMATION OF THE BIOSPHERE, 2000

11: Urban
12: Mixed settlements
21: Rice villages
22: Irrigated villages
23: Rainfed villages
24: Pastoral villages
31: Residential irrigated croplands
32: Residential rainfed croplands
33: Populated croplands
34: Remote croplands
41: Residential rangelands
42: Populated rangelands
43: Remote rangelands
51: Residential woodlands
52: Populated woodlands
53: Remote woodlands
54: Inhabited treeless and barren lands
61: Wild woodlands
62: Wild treeless and barren lands

LAST OF THE WILD

01: Tropical Moist Forests
02: Tropical Dry Forests
03: Tropical Coniferous Forests
04: Temperate Broadleaf Forests
05: Temperate Coniferous Forests
06: Boreal Forests/Taiga
07: Tropical Grasslands
08: Temperate Grasslands
09: Flooded Grasslands
10: Montane Grasslands
11: Tundra
12: Mediterranean Forests
13: Deserts
14: Mangroves
15: Lakes
16: Rock and Ice
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12: Mediterranean Forests
13: Deserts
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15: Lakes
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Obtained for years 1700, 1800, 1900 and 2000:

HYDE 3.1 data model:
- human population density
- percentage cover by urban, crop and pasture lands
...

ANTHROME CLASSIFICATION ALGORITHM

ANTHROMES 19 CATEGORIES (2 LEVELS)
ANTHROMES

PACIFIC

ANTHROPOGENIC TRANSFORMATION OF THE BIOSPHERE, 2000

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ANTHROPOSIS
ANTHROPOGENIC TRANSFORMATION
OF THE BIOSPHERE, 2000

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31: Residential irrigated croplands
24: Pastoral villages
23: Rainfed villages
22: Irrigated villages
21: Rice villages
12: Mixed settlements
11: Urban
62: Wild treeless and barren lands
61: Wild woodlands
36: Inhabitants
29: Inhabited
28: Inhabitants
27: Inhabitants
26: Inhabitants
25: Inhabitants
24: Inhabitants
23: Inhabitants
22: Inhabitants
21: Inhabitants
20: Inhabitants
19: Inhabitants
18: Inhabitants
17: Inhabitants
16: Inhabitants
15: Inhabitants
14: Inhabitants
13: Inhabitants
12: Inhabitants
11: Inhabitants
10: Inhabitants
9: Inhabitants
8: Inhabitants
7: Inhabitants
6: Inhabitants
5: Inhabitants
4: Inhabitants
3: Inhabitants
2: Inhabitants
1: Inhabitants

ARCTIC

27: Arctic
26: Tundra
25: Tundra
24: Tundra
23: Tundra
22: Tundra
21: Tundra
20: Tundra
19: Tundra
18: Tundra
17: Tundra
16: Tundra
15: Tundra
14: Tundra
13: Tundra
12: Tundra
11: Tundra
10: Tundra
9: Tundra
8: Tundra
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5: Tundra
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3: Tundra
2: Tundra
1: Tundra

ANTHROPOGENIC TRANSFORMATION
OF THE BIOSPHERE, 2000

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AMAZON
ANTHROGENIC TRANSFORMATION OF THE BIOSPHERE, 2000

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Suomi NPP
LAST OF THE WILD ANTHROMES
CIESIN
NOAA
ALGORITHM
GLOBAL HUMAN FOOTPRINT

05: Temperate Coniferous Forests
GRADIENT SCORE:
CITY / NON-CITY

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Amazon
HIMALAYAS
ARCTIC
PACIFIC
SAHARA
GOBI

[human population density]
Appropriated human impact through the lens of natural sciences
"Steam engines were not adopted by some natural-born deputies of the human species: by the nature of the social order of things, they could only be installed by the owners of the means of production".

Andreas Malm and Alf Hornborg

The geology of mankind? A critique of the Anthropocene narrative,
“In recent decades, industrial agriculture and modern transportation have created new forms of human–ecosystem interaction…Nevertheless, population density can still serve as a useful indicator of the form and intensity of human–ecosystem interactions within a specific locale, especially when populations differ by an order of magnitude or more”.

Erle Ellis & Navin Ramankutty

*Putting people in the map: anthropogenic biomes of the world*
Urban as more than 2500 persons per square km

Dense as less than 100 persons per square km

Residential as 10-100 persons per square km

Populated as 1-10 persons per square km

Remote as less than 1 person per km

Wild as 0 persons per square km.
Last of the Wild:
Reinterpret human impact by including geographical proxies of network through parameters of **accessibility and electrical power**
“To measure the area affected by access, we estimated the distance a person could walk in one day in a difficult to traverse ecosystem (e.g. moist tropical forests) as 15 km. We acknowledge, however, that this approach oversimplifies the complex relationship between human beings and roads, a relationship that varies by ecosystem type and cultural context”.

Sanderson

*The Human Footprint and the Last of the Wild*
“Simple mathematics suggests that the greater the number of people, the more resources that will be required for the land, as mediated by their consumption rate”.

Sanderson
The Human Footprint and the Last of the Wild
If infrastructure reflects human interaction with ecosystem, we should also consider the fact that social relations and political imaginations are partially animated by infrastructure. Thus, the question is how we can reduce all levels of totality to a physical derivative.