Putting people in the map: anthropogenic biomes of the world

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Humans have fundamentally altered global patterns of biodiversity and ecosystem processes. Surprisingly, existing systems for representing these global patterns, including biome classifications, either ignore humans altogether or simplify human influence into, at most, four categories. Here, we present the first characterization of terrestrial biomes based on global patterns of sustained, direct human interaction with ecosystems. Eighteen "anthropogenic biomes" were identified through empirical analysis of global population, land use, and land cover. More than 75% of Earth's ice-free land showed evidence of alteration as a result of human residence and land use, with less than a quarter remaining as wildlands, supporting just 11% of terrestrial net primary production. Anthropogenic biomes offer a new way forward by acknowledging human influence on global ecosystems and moving us toward models and investigations of the terrestrial biosphere that integrate human and ecological systems.

Humans have long distinguished themselves from other species by shaping ecosystem form and process using tools and technologies, such as fire, that are beyond the capacity of other organisms (Smith 2007). This exceptional ability for ecosystem engineering has helped to sustain unprecedented human population growth over the past half century, to such an extent that humans now consume about one-third of all terrestrial net primary production (NPP; Vitousek *et al.* 1986; Imhoff *et al.* 2004) and move more earth and produce more reactive nitrogen than all other terrestrial processes combined (Galloway 2005; Wilkinson and McElroy 2007). Humans are also causing global extinctions (Novacek and Cleland 2001) and changes in climate that are comparable to any observed in the natural record (Ruddiman 2003; IPCC 2007). Clearly, *Homo sapiens* has emerged as a force of nature rivaling climatic and geologic forces in shaping the terrestrial biosphere and its processes.

Biomes are the most basic units that ecologists use to describe global patterns of ecosystem form, process, and biodiversity. Historically, biomes have been identified and mapped based on general differences in vegetation type associated with regional variations in climate (Udvardy 1975; Matthews 1983; Prentice *et al.* 1992; Olson *et al.* 2001; Bailey 2004). Now that humans have restructured the terrestrial biosphere for agriculture, forestry, and other uses, global patterns of species composition and abundance, primary productivity, land-surface hydrology, and the biogeochemical cycles of carbon, nitrogen, and phosphorus, have all been substantially altered (Matson *et al.* 1997; Vitousek *et al.* 1997; Foley *et al.* 2005). Indeed, recent studies indicate that human-dominated ecosystems now cover more of Earth's land surface than do "wild" ecosystems (McCloskey and Spalding 1989; Vitousek *et al.* 1997; Sanderson *et al.* 2002, Mittermeier *et al.* 2003; Foley *et al.* 2005).

It is therefore surprising that existing descriptions of biome systems either ignore human influence altogether or describe it using at most four anthropogenic ecosystem classes (urban/built-up, cropland, and one or two cropland/natural vegetation mosaic(s); classification systems include IGBP, Loveland *et al.* 2000; "Olson Biomes", Olson *et al.* 2001; GLC 2000, Bartholome and Belward 2005; and GLOBCOVER, Defourny *et al.* 2006). Here, we present an alternate view of the terrestrial biosphere, based on an empirical analysis of global patterns of sustained direct human interaction with ecosystems, yielding a global map of "anthropogenic biomes". We then examine the potential of anthropogenic biomes to serve as a new global framework for ecology, complete with

In a nutshell:

- Anthropogenic biomes offer a new view of the terrestrial biosphere in its contemporary, human-altered form
- Most of the terrestrial biosphere has been altered by human residence and agriculture
- Less than a quarter of Earth's ice-free land is wild; only 20% of this is forests and > 36% is barren
- More than 80% of all people live in densely populated urban and village biomes
- Agricultural villages are the most extensive of all densely populated biomes and one in four people lives in them

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testable hypotheses, that can advance research, education, and conservation of the terrestrial biosphere as it exists today – the product of intensive reshaping by direct interactions with humans.

■ Human interactions with ecosystems

Human interactions with ecosystems are inherently dynamic and complex (Folke *et al.* 1996; DeFries *et al.* 2004; Rindfuss *et al.* 2004); any categorization of these is a gross oversimplification. Yet there is little hope of understanding and modeling these interactions at a global scale without such simplification. Most global models of primary productivity, species diversity, and even climate depend on stratifying the terrestrial surface into a limited number of functional types, land-cover types, biomes, or vegetation classes (Haxeltine and Prentice 1996; Thomas *et al.* 2004; Feddema *et al.* 2005).

Human interactions with ecosystems range from the relatively light impacts of mobile bands of hunter-gatherers to the complete replacement of pre-existing ecosystems with built structures (Smil 1991). Population density is a useful indicator of the form and intensity of these interactions, as increasing populations have long been considered both a cause and a consequence of ecosystem modification to produce food and other necessities (Boserup 1965, 1981; Smil 1991; Netting 1993). Indeed, most basic historical forms of human–ecosystem interaction are associated with major differences in population density, including foraging (< 1 person km^{-2}), shifting (> 10 persons km^{-2}), and continuous cultivation (> 100 persons km^{-2}); populations denser than 2500 persons km^{-2} are believed to be unsupportable by traditional subsistence agriculture (Smil 1991; Netting 1993).

In recent decades, industrial agriculture and modern transportation have created new forms of human–ecosystem interaction across the full range of population densities, from low-density exurban developments to vast conurbations that combine high-density cities, low-density suburbs, agriculture, and even forested areas (Smil 1991; Qadeer 2000; Theobald 2004). 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. Such major differences in population density help to distinguish situations in which humans may be considered merely agents of ecosystem transformation (ecosystem engineers), from situations in which human populations have grown dense enough that their local resource consumption and waste production form a substantial component of local biogeochemical cycles and other ecosystem processes. To begin our analysis, we therefore categorize human–ecosystem interactions into four classes, based on major differences in population density: high population intensity ("dense", >100 persons km^{-2}), substantial population intensity ("residential", 10 to 100 persons km^{-2}), minor population

("populated", 1 to 10 persons km^{-2}), and inconsequential population ("remote", < 1 person km^{-2}). Population class names are defined only in the context of this study.

■ Identifying anthropogenic biomes: an empirical approach

We identified and mapped anthropogenic biomes using the multi-stage empirical procedure detailed in WebPanel 1 and outlined below, based on global data for *population* (urban, non-urban), *land use* (percent area of pasture, crops, irrigation, rice, urban land), and *land cover* (percent area of trees and bare earth); data for NPP, IGBP land cover, and Olson biomes were obtained for later analysis (WebPanel 1 includes references for all data sources). Biome analysis was conducted at 5 arc minute resolution (5' grid cells cover ~ 86 km^2 at the equator), a spatial resolution selected as the finest allowing direct use of high-quality land-use area estimates. First, "anthropogenic" 5' cells were separated from "wild" cells, based on the presence of human populations, crops, or pastures. Anthropogenic cells were then stratified into the population density classes described above ("dense", "residential", "populated", and "remote"), based on the density of their non-urban population. We then used cluster analysis, a statistical procedure designed to identify an optimal number of distinct natural groupings (clusters) within a dataset (using SPSS 15.01), to identify natural groupings within the cells of each population density class and within the wild class, based on non-urban population density and percent urban area, pasture, crops, irrigated, rice, trees, and bare earth. Finally, the strata derived above were described, labeled, and organized into broad logical groupings, based on their populations, land-use and land-cover characteristics, and their regional distribution, yielding the 18 anthropogenic biome classes and three wild biome classes illustrated in Figure 1 and described in Table 1. (WebTables 1 and 2 provide more detailed statistics; WebPanel 2 provides maps viewable in Google Earth, Google Maps, and Microsoft Virtual Earth, a printable wall map, and map data in GIS format.)

■ A tour of the anthropogenic biomes

When viewed globally, anthropogenic biomes clearly dominate the terrestrial biosphere, covering more than three-quarters of Earth's ice-free land and incorporating nearly 90% of terrestrial NPP and 80% of global tree cover (Figures 1 and 2a; WebTable 2). About half of terrestrial NPP and land were present in the forested and rangeland biomes, which have relatively low population densities and potentially low impacts from land use (excluding residential rangelands; Figures 1 and 2a). However, one-third of Earth's ice-free land and about 45% of terrestrial NPP occurred within cultivated and substantially populated biomes (dense settlements, villages, croplands, and residential rangelands; Figures 1 and 2a).
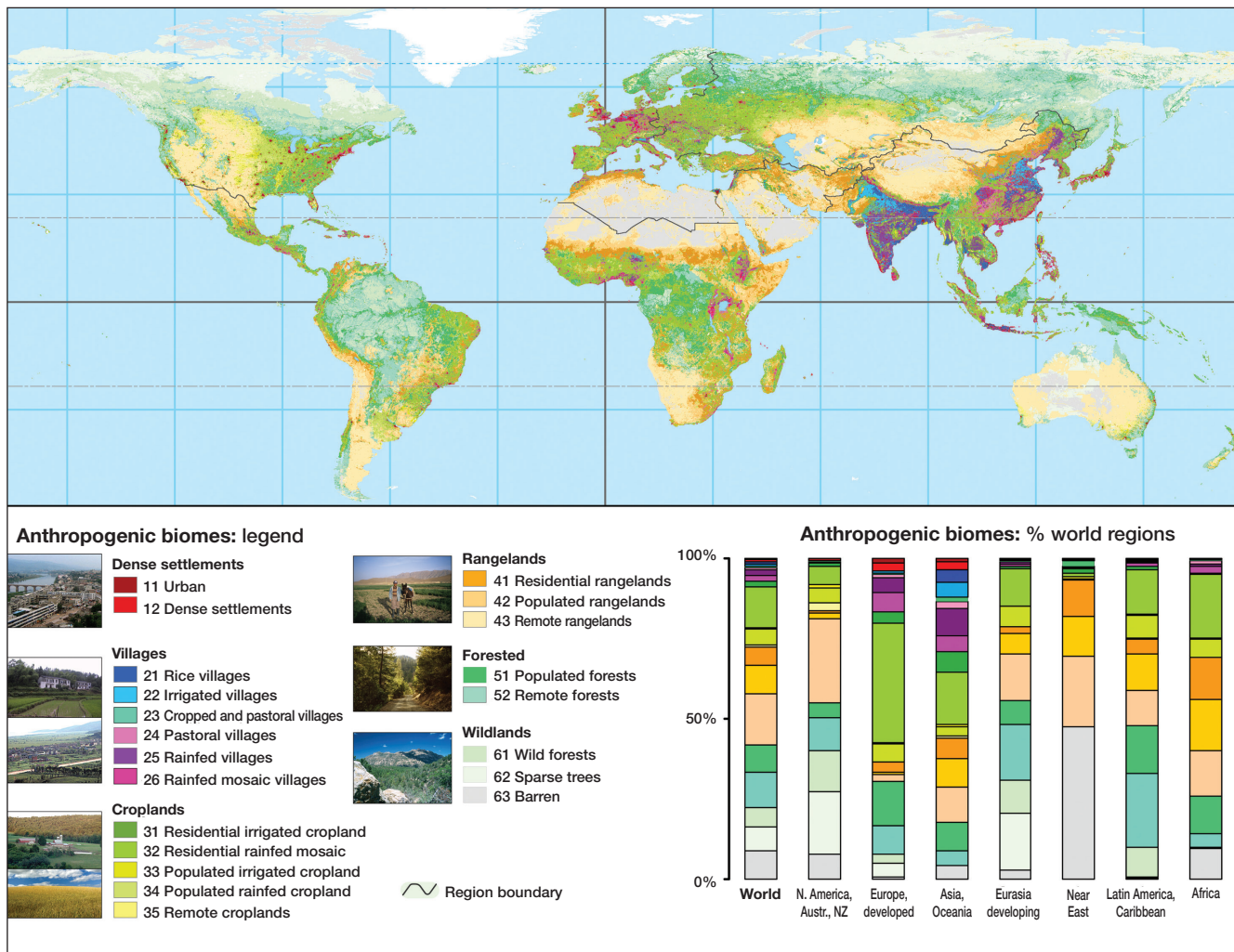
Figure 1. *Anthropogenic biomes: world map and regional areas. Biomes are organized into groups (Table 1), and sorted in order of population density. Map scale = 1:160 000 000, Plate Carrée projection (geographic), 5 arc minute resolution (5' = 0.0833°). Regional biome areas are detailed in WebTable 3; WebPanel 2 provides interactive versions of this map.*

Of Earth's 6.4 billion human inhabitants, 40% live in dense settlements biomes (82% urban population), 40% live in village biomes (38% urban), 15% live in cropland biomes (7% urban), and 5% live in rangeland biomes (5% urban; forested biomes had 0.6% of global population; Figure 2a). Though most people live in dense settlements and villages, these cover just 7% of Earth's ice-free land, and about 60% of this population is urban, living in the cities and towns embedded within these biomes, which also include almost all of the land we have classified as urban (94% of 0.5 million km², although this is probably a substantial underestimate; Salvatore *et al.* 2005; Figure 2a).

Village biomes, representing dense agricultural populations, were by far the most extensive of the densely populated biomes, covering 7.7 million km², compared with 1.5 million km² for the urban and dense settlements biomes. Moreover, village biomes house about one-half of the world's non-urban population (1.6 of ~ 3.2 billion persons). Though about one-third of global urban area is also embedded within these biomes, urban areas accounted for

just 2% of their total extent, while agricultural land (crops and pasture) averaged > 60% of their area. More than 39% of densely populated biomes were located in Asia, which also incorporated more than 60% of that continent's total global area, even though this region was the fifth largest of seven regions (Figure 1; WebTable 3). Village biomes were most common in Asia, where they covered more than a quarter of all land. Africa was second, with 13% of village biome area, though these covered just 6% of Africa's land. The most intensive land-use practices were also disproportionately located in the village biomes, including about half the world's irrigated land (1.4 of 2.7 million km²) and two-thirds of global rice land (1.1 of 1.7 million km²; Figure 2a).

After rangelands, cropland biomes were the second most extensive of the anthropogenic biomes, covering about 20% of Earth's ice-free land. Far from being simple, crop-covered landscapes, cropland biomes were mostly mosaics of cultivated land mixed with trees and pastures (Figure 3c). As a result, cropland biomes constituted only slightly more than half of the world's total crop-covered

Table 1. Anthropogenic biome descriptions

Group	Biome	Description
Dense settlements		*Dense settlements with substantial urban area*
11	Urban	Dense built environments with very high populations
12	Dense settlements	Dense mix of rural and urban populations, including both suburbs and villages
Villages		*Dense agricultural settlements*
21	Rice villages	Villages dominated by paddy rice
22	Irrigated villages	Villages dominated by irrigated crops
23	Cropped and pastoral villages	Villages with a mix of crops and pasture
24	Pastoral villages	Villages dominated by rangeland
25	Rainfed villages	Villages dominated by rainfed agriculture
26	Rainfed mosaic villages	Villages with a mix of trees and crops
Croplands		*Annual crops mixed with other land uses and land covers*
31	Residential irrigated cropland	Irrigated cropland with substantial human populations
32	Residential rainfed mosaic	Mix of trees and rainfed cropland with substantial human populations
33	Populated irrigated cropland	Irrigated cropland with minor human populations
34	Populated rainfed cropland	Rainfed cropland with minor human populations
35	Remote croplands	Cropland with inconsequential human populations
Rangeland		*Livestock grazing; minimal crops and forests*
41	Residential rangelands	Rangelands with substantial human populations
42	Populated rangelands	Rangelands with minor human populations
43	Remote rangelands	Rangelands with inconsequential human populations
Forested		*Forests with human populations and agriculture*
51	Populated forests	Forests with minor human populations
52	Remote forests	Forests with inconsequential human populations
Wildlands		*Land without human populations or agriculture*
61	Wild forests	High tree cover, mostly boreal and tropical forests
62	Sparse trees	Low tree cover, mostly cold and arid lands
63	Barren	No tree cover, mostly deserts and frozen land

area (8 of 15 million km^2), with village biomes hosting nearly a quarter and rangeland biomes about 16%. The cropland biomes also included 17% of the world's pasture land, along with a quarter of global tree cover and nearly a third of terrestrial NPP. Most abundant in Africa and Asia, residential, rainfed mosaic was by far the most extensive cropland biome and the second most abundant biome overall (16.7 million km^2), providing a home to nearly 600 million people, 4 million km^2 of crops, and about 20% of the world's tree cover and NPP – a greater share than the entire wild forests biome.

Rangeland biomes were the most extensive, covering nearly a third of global ice-free land and incorporating 73% of global pasture (28 million km^2), but these were found primarily in arid and other low productivity regions with a high percentage of bare earth cover (around 50%; Figure 3c). As a result, rangelands accounted for less than 15% of terrestrial NPP, 6% of global tree cover, and 5% of global population.

Forested biomes covered an area similar to the cropland biomes (25 million km^2 versus 27 million km^2 for croplands), but incorporated a much greater tree-covered area (45% versus 25% of their global area). It is therefore surprising that the total NPP of the forested biomes was nearly the same as that of the cropland biomes (16.4 ver-

sus 16.0 billion tons per year). This may be explained by the lower productivity of boreal forests, which predominate in the forested biomes, while cropland biomes were located in some of the world's most productive climates and soils.

Wildlands without evidence of human occupation or land use occupied just 22% of Earth's ice-free land in this analysis. In general, these were located in the least productive regions of the world; more than two-thirds of their area occurred in barren and sparsely tree-covered regions. As a result, even though wildlands contained about 20% cover by wild forests (a mix of boreal and tropical forests; Figure 2c), wildlands as a whole contributed only about 11% of total terrestrial NPP.

■ **Anthropogenic biomes are mosaics**

It is clear from the biome descriptions above, from the land-use and land-cover patterns in Figure 3c, and most of all, by comparing our biome map against high-resolution satellite imagery (WebPanel 2), that anthropogenic biomes are best characterized as heterogeneous landscape mosaics, combining a variety of different land uses and land covers. Urban areas are embedded within agricultural areas, trees are interspersed with croplands and housing, and managed vegetation is mixed with semi-natural vegetation (eg croplands are embedded within rangelands and forests). Though some of this heterogeneity might be explained by the relatively coarse resolution of our analysis, we suggest a more basic explanation: that direct interactions between humans and ecosystems generally take place within heterogeneous landscape mosaics (Pickett and Cadenasso 1995; Daily 1999). Further, we propose that this heterogeneity has three causes, two of which are anthropogenic and all of which are fractal in nature (Levin 1992), producing similar patterns across spatial scales ranging from the land holdings of individual households to the global patterning of the anthropogenic biomes.

We hypothesize that even in the most densely populated biomes, most landscape heterogeneity is caused by natural variation in terrain, hydrology, soils, disturbance regimes (eg fire), and climate, as described by conventional models of ecosystems and the terrestrial biosphere (eg Levin 1992; Haxeltine and Prentice 1996; Olson *et*

al. 2001). Anthropogenic enhancement of natural landscape heterogeneity represents a secondary cause of heterogeneity within anthropogenic biomes, explained in part by the human tendency to seek out and use the most productive lands first and to work and populate these lands most intensively (Huston 1993). At a global scale, this process may explain why wildlands are most common in those parts of the biosphere with the least potential for agriculture (ie polar regions, mountains, low fertility tropical soils; Figure 1) and why, at a given percentage of tree cover, NPP appears higher in anthropogenic biomes with higher population densities (compare NPP with tree cover, especially in wild forests versus forested biomes; Figure 3c). It may also explain why most human populations, both urban and rural, appear to be associated with intensive agriculture (irrigated crops, rice), and not with pasture, forests, or other, less intensive land uses (Figure 3c). Finally, this hypothesis explains why most fertile valleys and floodplains in favorable climates are already in use as croplands, while neighboring hillslopes and mountains are often islands of semi-natural vegetation, left virtually undisturbed by local populations (Huston 1993; Daily 1999). The third cause of landscape heterogeneity in anthropogenic biomes is entirely anthropogenic: humans create landscape heterogeneity directly, as exemplified by the construction of settlements and transportation systems in patterns driven as much by cultural as by environmental constraints (Pickett and Cadenasso 1995).

All three of these drivers of heterogeneity undoubtedly interact in patterning the terrestrial biosphere, but their relative roles at global scales have yet to be studied and surely merit further investigation, considering the impacts of landscape fragmentation on biodiversity (Vitousek et al. 1997; Sanderson et al. 2002).

■ A conceptual model for anthropogenic biomes

Given that anthropogenic biomes are mosaics – mixtures of settlements, agriculture, forests and other land uses and land covers – how do we proceed to a general ecological understanding of human–ecosystem interactions within and across anthropogenic biomes? Before developing
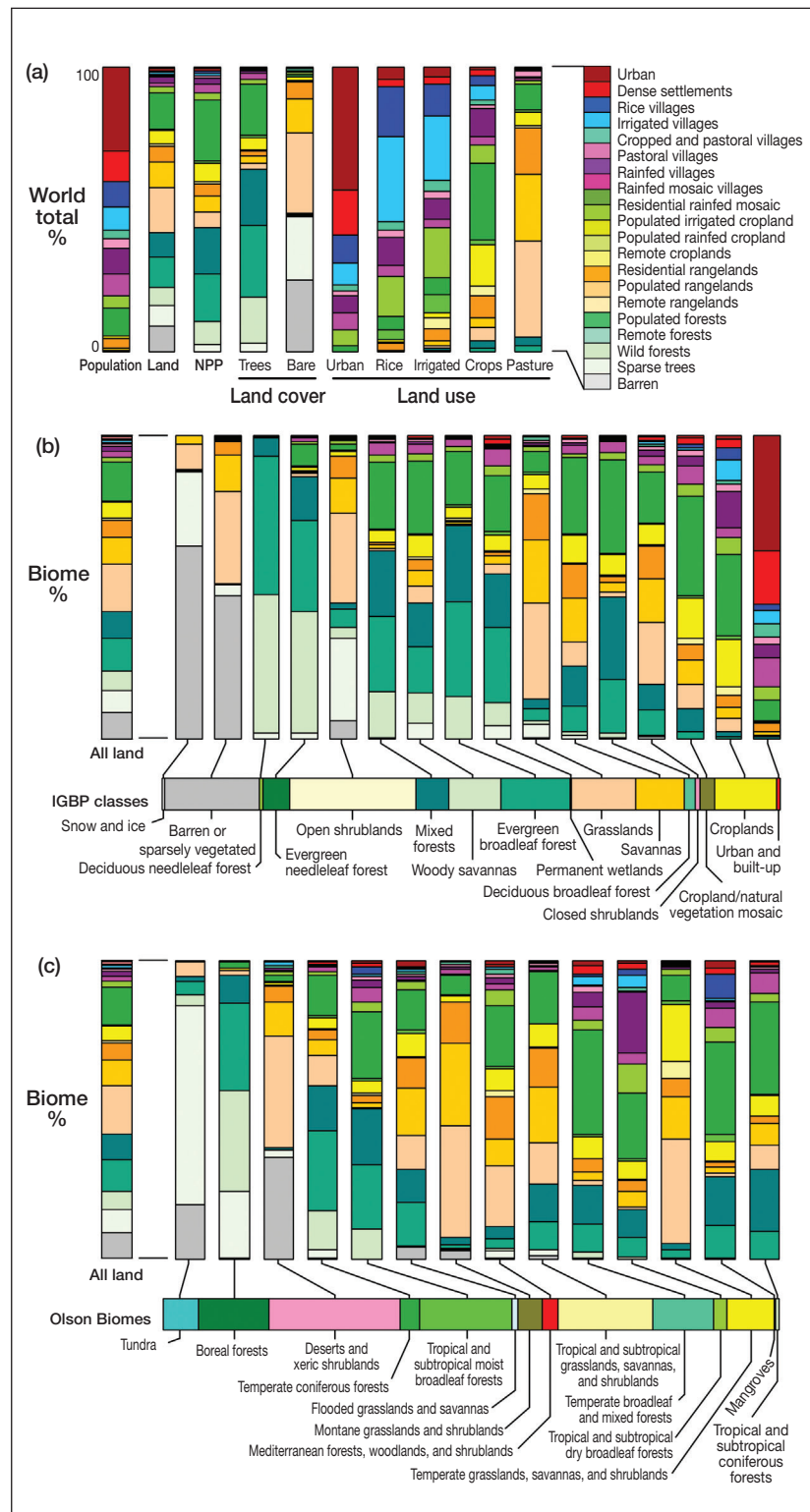
Figure 2. Anthropogenic biomes expressed as a percentage of (a) global population, ice-free land, NPP, land cover, and land use (WebTable 3), (b) IGBP land-cover classes (Friedl et al. 2002; WebTable 4), and (c) Olson biomes (Olson et al. 2001; WebTable 5). In (b) and (c), left columns show the anthropogenic biomes as a percentage of global ice-free land, horizontal bars show (b) IGBP land cover and (c) Olson biomes as a percentage of ice-free land, and columns in center illustrate the percent area of each anthropogenic biome within each IGBP and Olson class, sorted in order of decreasing total wild biome area, left to right. Color and order of anthropogenic biome classes are the same as in Figure 1.
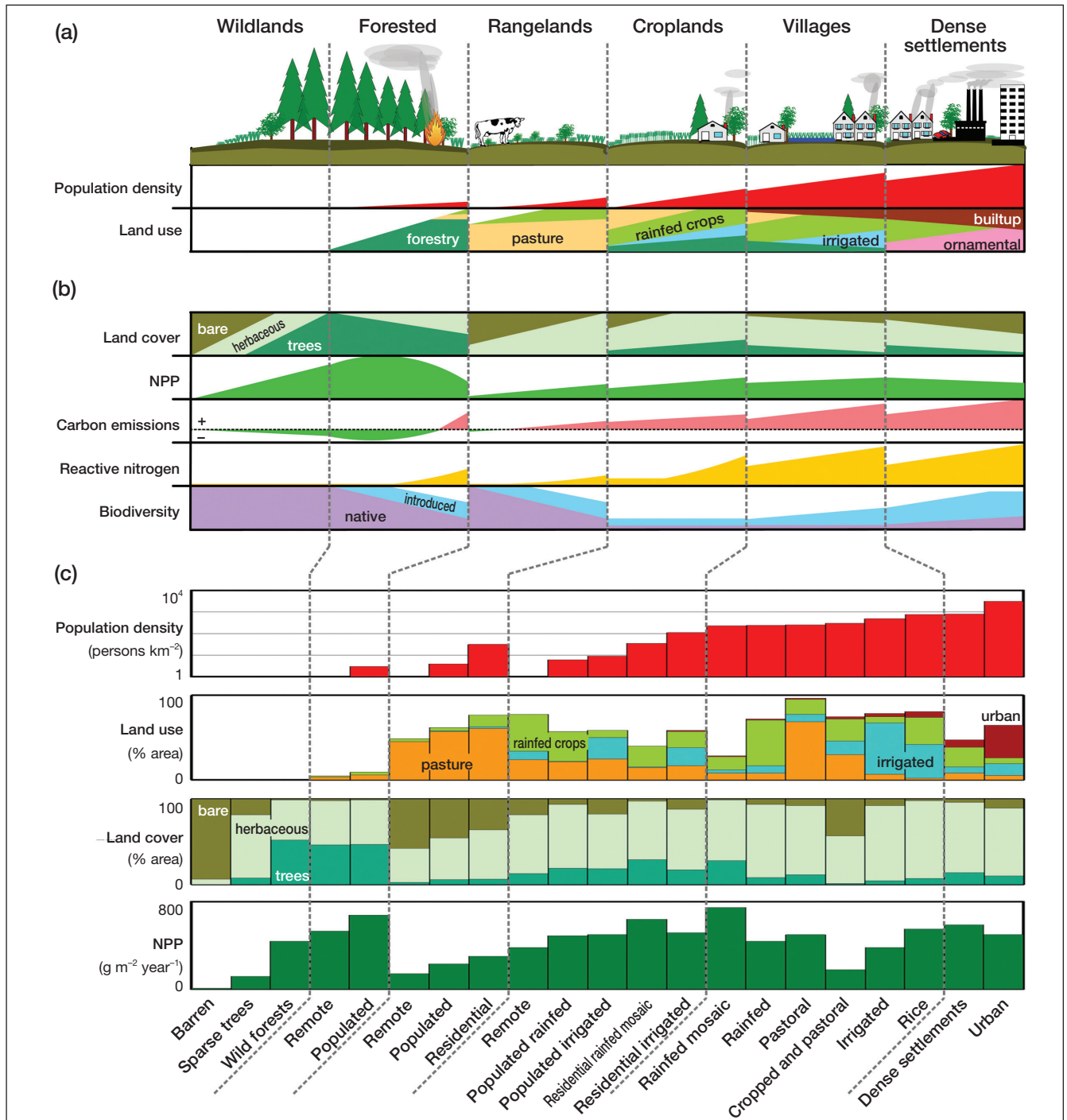
Figure 3. *Conceptual model of anthropogenic biomes compared with data. (a) Anthropogenic biomes structured by population density (logarithmic scale) and land use (percent land area), forming patterns of (b) ecosystem structure (percent land cover), process (NPP, carbon balance; red = emissions, reactive nitrogen), and biodiversity (native versus non-native + domestic biodiversity; indicated relative to pre-existing biodiversity; white space indicates net reduction of biodiversity) within broad groups of anthropogenic biomes. (c) Mean population density, land use, land cover, and NPP observed within anthropogenic biomes (Figure 1; WebTable 1). Biome labels at bottom omit names of broad groups, at top.*

a set of hypotheses and a strategy for testing them, we first summarize our current understanding of how these interactions pattern terrestrial ecosystem processes at a global scale using a simple equation:

$$Ecosystem\ processes = f(population\ density,\ land$$
$$use,\ biota,\ climate,\ terrain,\ geology)$$

Those familiar with conventional ecosystem-process models will recognize that ours is merely an expansion of these, adding human population density and land use as parameters to explain global patterns of ecosystem processes and their changes. With some modification, conventional land-use and ecosystem-process models should therefore be capable of modeling ecological

changes within and across anthropogenic biomes (Turner *et al.* 1995; DeFries *et al.* 2004; Foley *et al.* 2005). We include population density as a separate driver of ecosystem processes, based on the principle that increasing population densities can drive greater intensity of land use (Boserup 1965, 1981) and can also increase the direct contribution of humans to local ecosystem processes (eg resource consumption, combustion, excretion; Imhoff *et al.* 2004). For example, under the same environmental conditions, our model would predict greater fertilizer and water inputs to agricultural land in areas with higher population densities, together with greater emissions from the combustion of biomass and fossil fuel.

Some hypotheses and their tests

Based on our conceptual model of anthropogenic biomes, we propose some basic hypotheses concerning their utility as a model of the terrestrial biosphere. First, we hypothesize that anthropogenic biomes will differ substantially in terms of basic ecosystem processes (eg NPP, carbon emissions, reactive nitrogen; Figure 3b) and biodiversity (total, native) when measured across each biome in the field, and that these differences will be at least as great as those between the conventional biomes when observed using equivalent methods at the same spatial scale. Further, we hypothesize that these differences will be driven by differences in population density and land use between the biomes (Figure 3a), a trend already evident in the general tendency toward increasing cropped area, irrigation, and rice production with increasing population density (Figure 3c). Finally, we hypothesize that the degree to which anthropogenic biomes explain global patterns of ecosystem processes and biodiversity will increase over time, in tandem with anticipated future increases in human influence on ecosystems.

The testing of these and other hypotheses awaits improved data on human–ecosystem interactions obtained by observations made within and across the full range of anthropogenic landscapes. Observations within anthropogenic landscapes capable of resolving individually managed land-use features and built structures are critical, because this is the scale at which humans interact directly with ecosystems and is also the optimal scale for precise measurements of ecosystem parameters and their controls (Ellis *et al.* 2006). Given the considerable effort involved in making detailed measurements of ecological and human systems across heterogeneous anthropogenic landscapes, this will require development of statistically robust stratified-sampling designs that can support regional and global estimates based on relatively small landscape samples within and across anthropogenic biomes (eg Ellis 2004). This, in turn, will require improved global data, especially for human populations and land-use practices. Fortunately, development of these datasets would also pave the way toward a system of anthropogenic ecore-gions capable of serving the ecological monitoring needs of regional and local stakeholders, a role currently occupied by conventional ecoregion mapping and classification systems (Olson *et al.* 2001).

Are conventional biome systems obsolete?

We have portrayed the terrestrial biosphere as composed of anthropogenic biomes, which might also be termed "anthromes" or "human biomes" to distinguish them from conventional biome systems. This begs the question: are conventional biome systems obsolete? The answer is certainly "no". Although we have proposed a basic model of ecological processes within and across anthropogenic biomes, our model remains conceptual, while existing models of the terrestrial biomes, based on climate, terrain, and geology, are fully operational and are useful for predicting the future state of the biosphere in response to climate change (Melillo *et al.* 1993; Cox *et al.* 2000; Cramer *et al.* 2001).

On the other hand, anthropogenic biomes are in many ways a more accurate description of broad ecological patterns within the current terrestrial biosphere than are conventional biome systems that describe vegetation patterns based on variations in climate and geology. It is rare to find extensive areas of any of the basic vegetation forms depicted in conventional biome models outside of the areas we have defined as wild biomes. This is because most of the world's "natural" ecosystems are embedded within lands altered by land use and human populations, as is apparent when viewing the distribution of IGBP and Olson biomes within the anthropogenic biomes (Figure 2 b,c).

Ecologists go home!

Anthropogenic biomes point to a necessary turnaround in ecological science and education, especially for North Americans. Beginning with the first mention of ecology in school, the biosphere has long been depicted as being composed of natural biomes, perpetuating an outdated view of the world as "natural ecosystems with humans disturbing them". Although this model has long been challenged by ecologists (Odum 1969), especially in Europe and Asia (Golley 1993), and by those in other disciplines (Cronon 1983), it remains the mainstream view. Anthropogenic biomes tell a completely different story, one of "human systems, with natural ecosystems embedded within them". This is no minor change in the story we tell our children and each other. Yet it is necessary for sustainable management of the biosphere in the 21st century.

Anthropogenic biomes clearly show the inextricable intermingling of human and natural systems almost everywhere on Earth's terrestrial surface, demonstrating that interactions between these systems can no longer be avoided in any substantial way. Moreover, human interactions with ecosystems mediated through the atmosphere (eg climate change) are even more pervasive and are dis-

proportionately altering the areas least impacted by humans directly (polar and arid lands; IPCC 2007; Figure 1). Sustainable ecosystem management must therefore be directed toward developing and maintaining beneficial interactions between managed and natural systems, because avoiding these interactions is no longer a practical option (DeFries *et al.* 2004; Foley *et al.* 2005). Most importantly, though still at an early stage of development, anthropogenic biomes offer a framework for incorporating humans directly into global ecosystem models, a capability that is both urgently needed and as yet unavailable (Carpenter *et al.* 2006).

Ecologists have long been known as the scientists who travel to uninhabited lands to do their work. As a result, our understanding of anthropogenic ecosystems remains poor when compared with the rich literature on "natural" ecosystems. Though much recent effort has focused on integrating humans into ecological research (Pickett *et al.* 2001; Rindfuss *et al.* 2004; WebPanel 3 includes more citations) and support for this is increasingly available from the US National Science Foundation (www.nsf.gov; eg HERO, CNH, HSD programs), ecologists can and should do more to "come home" and work where most humans live. Building ecological science and education on a foundation of anthropogenic biomes will help scientists and society take ownership of a biosphere that we have already altered irreversibly, and moves us toward understanding how best to manage the anthropogenic biosphere we live in.

■ Conclusions

Human influence on the terrestrial biosphere is now pervasive. While climate and geology have shaped ecosystems and evolution in the past, our work contributes to the growing body of evidence demonstrating that human forces may now outweigh these across most of Earth's land surface today. Indeed, wildlands now constitute only a small fraction of Earth's land. For the foreseeable future, the fate of terrestrial ecosystems and the species they support will be intertwined with human systems: most of "nature" is now embedded within anthropogenic mosaics of land use and land cover. While not intended to replace existing biome systems based on climate, terrain, and geology, we hope that wide availability of an anthropogenic biome system will encourage a richer view of human–ecosystem interactions across the terrestrial biosphere, and that this will, in turn, guide our investigation, understanding, and management of ecosystem processes and their changes at global and regional scales.

■ Acknowledgements

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