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Sustaining biodiversity and people in the world's anthropogenic biomes

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Humans have reshaped more than three quarters of the terrestrial biosphere into anthropogenic biomes (anthromes), embedding substantial areas of remnant and recovering novel ecosystems within the agricultural and settled landscapes that sustain human populations. The need to conserve biodiversity in anthromes is increasingly recognized as critical, as anthromes have largely replaced wildlands in Earth's most biodiverse and productive regions, and novel ecosystems now cover nearly twice the global area of wildlands. Extinction rates may still be increasing. Nevertheless, recent studies indicate that under appropriate conditions, most native taxa may be sustainable within anthromes while at the same time increasing anthrome productivity in support of human populations.

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Introduction

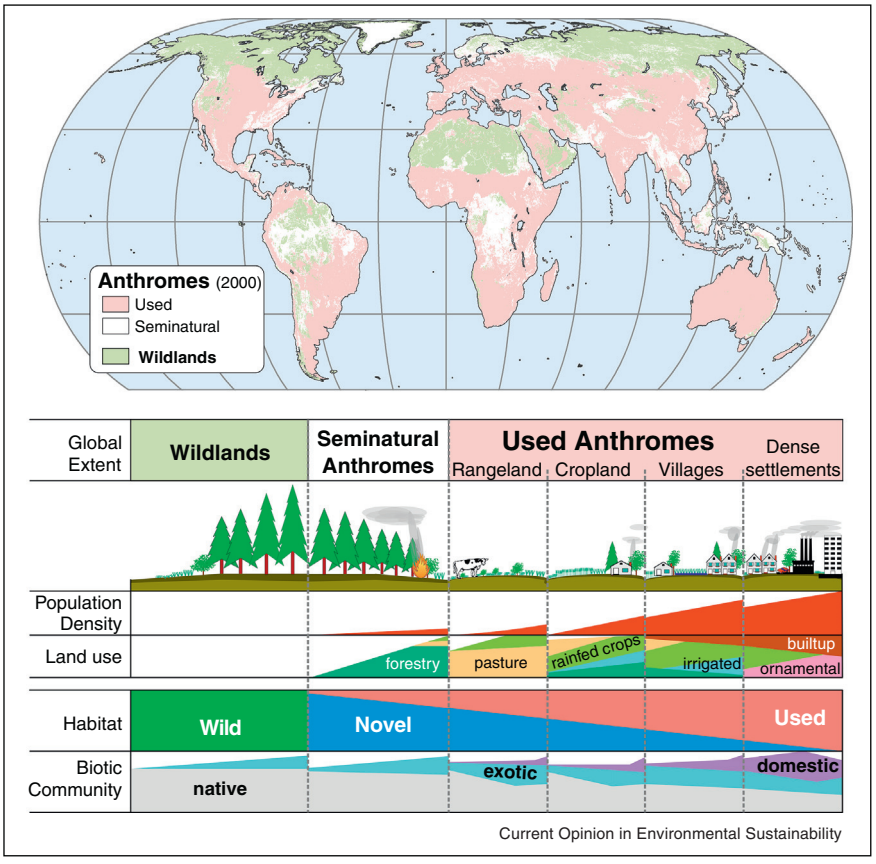
Human populations and their use of land have now transformed more than three quarters of the terrestrial biosphere into anthropogenic biomes (anthromes; [1]). Anthromes range from dense settlements, villages and croplands to rangelands and seminatural lands with only minor human populations and land use [2]. Emerging along with agriculture more than 8000 years ago, anthromes first covered more than half of the terrestrial biosphere as of 500–2000 years ago, mostly in the form of seminatural lands [3•]. Over the past century, anthrome extent and land use intensity increased rapidly together with growing human populations, leaving wildlands without human populations or land use in less than one quarter of the terrestrial biosphere [2]. This massive transformation of Earth's ecosystems for human use has occurred in parallel with enhanced rates of species extinctions, inspiring serious concerns that human use of the biosphere might not be sustainable [4,5,6••]. This review assesses recent studies on the prospects for sustaining both biodiversity and humanity in anthromes over the long-term.

Even within the most densely populated and intensively used anthromes, including urban areas and ancient village landscapes, humans rarely convert all land to agricultural and residential use because land use for crops and pastures tends to selectively concentrate in areas most productive for these uses and settlements tend to retain significant green spaces [1,3•,7–9]. As a result, anthromes generally take the form of multifunctional mosaics of used lands within which substantial remnant and less intensively managed ecosystems are often left embedded, especially where terrain is heterogeneous [1,3•,10]. It is also common for large areas of used lands to be abandoned and left to recover within anthromes, and for ecosystems never managed for production to become transformed by non-agricultural human activities ranging from informal harvests of timber, fuelwood and other natural resources, road-building, dams, habitat fragmentation, anthropogenic fire regimes, hunting, foraging, increased exposure to exotic species, and pollution [1,3•,6••,11,12]. As a result of these pervasive human influences, even the least disturbed areas of anthromes generally have biotic communities and ecosystem processes that differ substantially and potentially irreversibly from their prior historical state, broadly fitting the definition of novel ecosystems [2,10,11,13–15].

Biogeography and biodiversity of anthromes and novel ecosystems

A global map of contemporary anthromes and wildlands is presented in Figure 1, together with a conceptual diagram illustrating general patterns in human population densities and land use within and across anthromes and their relationships with the emergence of novel habitats and biotic communities. As indicated in Figure 1, human populations, land use, and anthromes tend to be concentrated in the more productive and biodiverse regions of the biosphere [16,17,18•,19]. Partly for this reason, human-induced habitat loss is considered the greatest current threat to terrestrial biodiversity [6••]. Humans have and are directly causing species extinctions, especially of megafauna, by reducing, fragmenting and transforming native habitats and by overexploiting individual species [4,6••,18•,20,21]. Yet current rates of terrestrial extinctions vary greatly by taxa, with mammals, reptiles and amphibians especially threatened [22], and the degree to which these types of extinctions are

Figure 1



Global extent of anthromes and wildlands (year 2000, on the basis of [2]) and conceptual diagram illustrating general relationships among anthrome population density, land use, habitats, and relative proportions of native, exotic and domestic species in biotic communities.

accelerating or inevitable under existing conditions, as implied by the concept of ''extinction debt'' [23], remains an area of active study [6••,18•,20–24].

Simultaneously with extinctions, humans drive major changes in biotic communities and ecosystems by intentionally and unintentionally introducing exotic species and domesticates [12,17,25••,26,27•]. Successful establishments of dominant exotic species (species invasions) have profound effects on almost every aspect of ecosystem form and function [6••,25••,26,27•,28]. However, their role in causing native species extinctions is inconsistent [26,27•,29,30]. Though local reductions are often observed in native populations, sometimes driving species towards threatened and endangered status, even highly dominant exotics are not generally known to cause regional extinctions of native species, at least in plants [29,30], though some fauna, especially those restricted to islands, appear more vulnerable [30]. The combination of high rates of invasion with lower rates of extinction has led to widespread observations of increasing biodiversity at regional scales, especially for plants, indicating that regional patterns of biodiversity may continue to increase without saturating [29,31], though risks of future extinction cannot be ruled out, even for plants [32].

Recently, trends in anthrome biodiversity have been hypothesized to follow processes of ''anthropogenic ecological succession'' [17] in which biotic communities accumulate exotics as human populations establish, grow, develop and become increasingly interconnected, as illustrated in Figure 1. Early human populations tend to be lower and often use land less intensively, by forestry or shifting cultivation in seminatural anthromes or grazing in rangelands, gradually shifting to croplands as populations increase. Land use later intensifies in more optimal environments, as anthromes support larger, denser, and better connected human populations, leaving marginal lands and remnant ecosystems to regenerate. The long-term result is a gradual but marked increase in total species richness in anthromes in parallel with growth in human populations [17], as exotic species adapted to anthropogenic habitats become established from regional and global pools of these species (biotic homogenization;