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Landscape Ecology in Asian Cultures



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Cultural landscapes are a product of the interactions between humans and natural settings. They are landscapes and seascapes that are shaped by human history and land use. Socioeconomic processes especially, but also environmental changes and natural disturbances, are some of the forces that make up landscape dynamics. To understand and manage such complex landscapes, interdisciplinary and transdisciplinary approaches are necessary, emphasizing the integration of natural and social sciences and considering multiple landscape functions. The spatial patterns of Asian landscapes are strongly related to human activities and their impacts. Anthropogenic patterns and processes have created numerous traditional cultural landscapes throughout the region, and understanding them requires indigenous knowledge. Cultural landscape ecology from a uniquely Asian perspective is explored in this book, as are the management of landscapes and land-use policies. Human-dominated landscapes with long traditions, such as those described herein, provide useful information for all ecologists, not only in Asia, to better understand the human–environmental relationship and landscape sustainability.

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Chapter 10

Have Ecological Human Rights Been Globally Lost? A Conflict of Ecological Spatial Requirements and Cultural Landscape Opportunities in Modern *Homo sapiens*

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10.1 Introduction

The mission of science, as of any other meaningful enterprise, is to contribute to the well-being of humanity. For a very long period of human history, this task has been predominantly understood in the utilitarian terms of finding the most efficient ways of exploiting the biosphere, to spend less time and labor to obtain more and better products (food, clothing, housing, transport, medicines). At present, amidst acute global and regional environmental and ecological problems, it has become clear that a conceptually novel scientific goal can be put forward: to understand what the inherent environmental requirements (rights) of our species are and how (whether) they are (can be) satisfied in the cultural landscape that substitutes for a natural environment for the majority of people in modern society. Here we outline the ecological problem of space use by large social mammals from that perspective.

All living organisms must consume energy from the environment and spend it within their bodies to sustain life processes. For a majority of species, their mass-specific metabolic rate falls within 1–10 W kg⁻¹ (Makariev et al. 2005a, 2008), with the metabolic rate of *Homo sapiens* falling close to the lower limit of this range. In physiological rest, the human body consumes about 10² W. Because the area that a human body projects on the Earth's surface is of the order of 0.5 m², the individual energetic requirements of a human being could in principle be covered by solar radiation, the power of which constitutes about 2 × 10² W m⁻² as a global average (Mitchell 1989). The area of the Earth's surface is 5 × 10¹⁴ m². The laws of physics do not prohibit a technology that would convert solar power to the power of an edible biomass with an efficiency close

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to unity. It follows that in principle it is possible to put two human beings per square meter over the entire planetary surface and to satisfy their energetic food requirements. This would correspond to a global population of 10^{15} individuals, which is over a hundred thousand times larger than the modern population. This simple estimate shows that there are no tangible *physical* limits to population growth.

At the same time, the biology of every species is correlated with the properties of the ecosystem to which the species belongs. With the characteristic time of the existence of a species being of the order of several million years (Stanley 1979), while the time-scale of the turnover of organic matter in most ecosystems does not exceed a hundred years (Whittaker and Likens 1975), it is obvious that the ecological and biological principles of ecosystem organization should include mechanisms which ensure ecosystem stability. These principles will impose *ecological* limits to the population density of any particular species, i.e., limits that are compatible with ecological and environmental sustainability. These principles should also be encoded in the biological design of the species.

The productivity of the biosphere does not exceed $p_{\max} = 2 \text{ W m}^{-2}$ (Gorshkov 1995), while a medium-sized mammal, as discussed above, can consume about $j \sim 10^2 \text{ W m}^{-2}$ on the area occupied by its body on the Earth's surface. This means that the presence of the larger organisms in the ecological community, with $j > p_{\max}$, introduces fluctuations in the plant biomass, because in any local area, such organisms must consume biomass at a rate greatly exceeding its production, thus disturbing the standing biomass store. To guard the ecosystem against the disturbing impact of large animals, their population density, and hence energy consumption per unit area of the ecosystem, declines with the increasing body size of the species in natural ecosystems (Makarieva et al. 2004). As a consequence, the individual territory controlled by the animal (home range) increases with the increasing body size of the species (Makarieva et al. 2005b and references therein). As we discuss below, this has profound implications for the physiological health and general well-being of the animals, with humans being no exception.

10.2 Quantifying the Natural Space Requirements of *Homo sapiens*

Our species originally belonged to a tropical ecosystem. It is a locomotive species. The encoded territorial requirements of human beings can be estimated from their physiological abilities related to movement. *Homo sapiens* is a relatively poor long-distance runner. The human world record speed for long-distance running is 22 km h^{-1} , while animals of the same size can reach about 60 km h^{-1} (Fig. 10.1). It is noteworthy that our species is the most inefficient sprinter (world record 36 km h^{-1} versus over 100 km h^{-1} in similarly sized animals). However, humans are among the best walkers in the animal world. Man can sustain a walking speed of about 4 km h^{-1} for a long period of time. The world record speed in race-walking for 20 km is 14 km h^{-1} . Military troops can undertake daily marches of over 40 km.

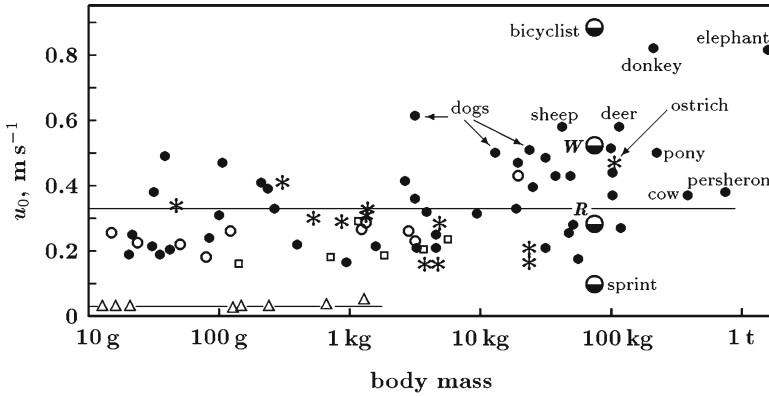


Fig. 10.1 Daily available speed u_0 for vertebrates of various body sizes. The daily available speed is the average speed that can be supported by the animal’s field metabolic rate. Horizontal lines in the figure denote averages for homeothermic (upper line) and poikilothermic (lower line) vertebrates. Triangles, asterisks, open dots, squares, and black dots stand for reptiles, birds, marsupials, echidnas and hedgehogs, and placental mammals, respectively. For *Homo sapiens*, four regimes (sprint, R running, W walking, and cycling) are shown. Note that u_0 does not coincide with the actual speed of movement. For example, by making very fast leaps (sprint), humans are able to cover a much smaller daily distance at the same energetic cost than, for example, while walking. After Gorshkov et al. (2000)

On average, humans in natural environments cover about 10 km per day (Rappaport 1971; Winterhalder et al. 1988). Taking the width of the band scanned for food to be about 1 m, and a time-scale of vegetation regeneration of 1 year (=365 days), for the area of individual territory needed for humans, we obtain $H = 10 \times 10^3 \text{ m day}^{-1} \times 365 \text{ days} \times 1 \text{ m}$, which is approximately 4 km². The linear size of an individual territory is therefore of the order of 2 km.

The ecological meaningfulness of this estimate is sustained by the fact that it can be obtained in a different way by considering the well-established dependence of home range on body size in mammals (Kelt and Van Vuren 2001) (Fig. 10.2). For herbivorous mammals, the area H (ha) of individual territory grows as $\log_{10} H = -2.64 + 1.08 \log_{10} M$, where M is body mass (g). For a human body mass of $M = 80 \text{ kg}$, we obtain $H = 450 \text{ ha} = 4.5 \text{ km}^2$. This is a minimum estimate, because omnivorous animals like *H. sapiens* have larger home ranges than herbivores of equal size (Kelt and Van Vuren 2001).

Assuming that the population density of humans, which is compatible with ecological stability and is encoded into the genome of our species, is of the order of 0.2 individuals km⁻², it is clear that in modern civilizations this spatial requirement, or the ecological right for space, is dramatically violated. The global mean population density (calculated for the total surface area of the planet, including the oceans) is 13 individuals km⁻², or 45 individuals km⁻² if the oceans are excluded (Table 10.1). This corresponds to a per capita area of 0.022 km², which is hundreds of times less than the ecologically sustainable area. In the urban landscapes of the world’s largest cities, the per capita available area A can be many thousands of

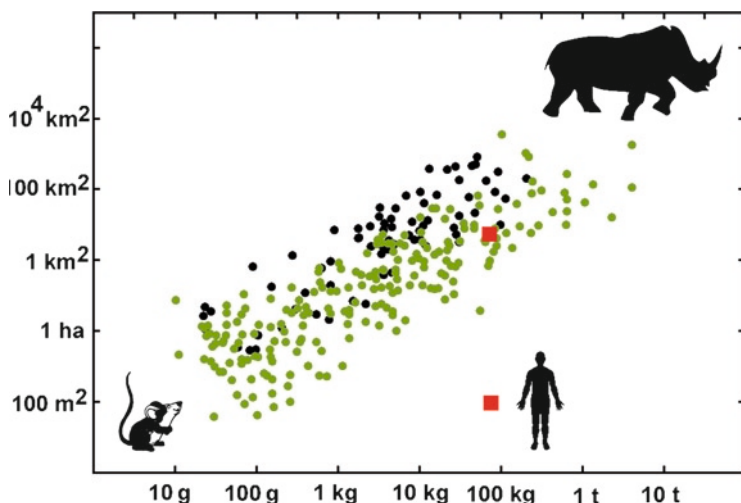


Fig. 10.2 The dependence of individual territory on body mass in mammals. *Green circles* denote herbivores, and *black circles* denote carnivores and omnivores according to the data of Kelt and Van Vuren (2001). The *upper square* corresponds to a natural home range $H=4$ km² per individual for a herbivorous mammal of equal size to *Homo sapiens*. The *lower square* corresponds to the per capita area available in modern urban landscapes (see Table 10.1)

Table 10.1 Population density and per capita available area A at different spatial scales in modern civilizations

Region	Population density, individuals km ⁻²	Per capita area A , km ² per individual	H/A , $H=4$ km ² per individual
Earth (incl. water surface)	13	0.078	51
Earth (excl. water surface)	45	0.022	182
Eastern Asia	129	0.0078	513
South–Central Asia	153	0.0065	615
South–Eastern Asia	124	0.0081	494
Western Asia	44	0.023	174
Russia	8	0.13	31
Western Europe	168	0.0060	667
Central America	58	0.017	235
South America	21	0.048	83
USA	31	0.032	125
Canada	3	0.33	12
Australia	3	0.33	12
Urban landscapes (cities)			
Moscow	15 000	0.000066	60 606
New York	10 500	0.000095	42 105
São Paulo	7 300	0.00013	30 769
Hong Kong	6 400	0.00016	25 000
Sydney	2 000	0.00050	8 000

The last column shows the ratio between the area, H , of the natural individual territory of *Homo sapiens* and the per capita available area, A , in the regions considered. (Data are for 2005; taken from the UN World Population Prospects, <http://esa.un.org/unpp>, retrieved November 14, 2008).

times smaller than the natural individual area H , which is of the order of a hundred square meters (Table 10.1). This is equivalent in size to the individual territory of a medium-sized rodent in natural ecosystems (Fig. 10.2).

10.3 Possible Consequences of the Violated Ecological Right for Space in Humans

Since the evolutionary survival of species is tightly dependent on the stability of the ecosystem to which the species belongs, it would not be surprising to find that the mechanisms ensuring ecosystem stability are encoded into the biological properties of the species. In other words, since the overpopulation of large animals poses a threat to the stability of the biomass store due to the high individual energy consumption rate of large animals, one can expect that the behavioral mechanisms preventing overpopulation should be clearly manifested in, and have profound implications for, the biology of species.

Extensive ecological literature exists on the subject of how animals defend their individual territories from intrusion (e.g., Mitani and Rodman 1979; Baker 1983; Adams 2001), thus sustaining optimal population density. There are many fewer studies that have addressed the biological effects of territory deprivation in natural animal species. However, the available evidence testifies that overcrowding in many species results in a considerable decrease in fertility (e.g., Sibly and Hone 2003). The pervasive importance of territory for normal biological performance can explain why it is often impossible to obtain viable progeny of large animals in captivity (e.g., in zoos), where animals are forced to occupy tiny areas compared with their natural territory requirements. For example, analyses of zoo environments, undertaken to investigate the causes of high mortality and suboptimal, unsustainable reproduction in captive populations of black rhinoceros (*Diceros bicornis*), revealed that the breeding success of captive animals was positively correlated with the size of their enclosure (Carlstead et al. 1999). Perhaps even more vivid is the fact that rhinoceros kept in open areas (where they could see, albeit not move across, a large territory) reproduced better than those enclosed by high walls. This means that the territorial requirements of the species are encoded on the physiological level; even a visual signal that a large territory is potentially available is essential for facilitating the reproduction process. Remarkably, an identical pattern was found in tiny jerboas (rodent family Dipodoidae), where, unless provided with a very large enclosure imitating their natural conditions, the animals could not reproduce, females did not care for their progeny (if they were captured when pregnant), the offspring refused to eat and did not gain weight, and pregnancy occurred very rarely and often led to female mortality (Fokin 1978). Data for captive animals show unequivocally that it is not food shortage (possibly related to overcrowding under natural conditions) that leads to a reduction in fertility, but rather that a signal of territory deprivation per se is received by the animal at the physiological level and translated to the observed inhibition of reproduction.

Until very recently, the effects of population density on fertility in humans remained practically unstudied. Recent work by Lutz and colleagues (Lutz and Qiang 2002; Lutz et al. 2006) revealed a significant correlation between population density and fertility in different countries, with fertility invariably reducing with growing population density. The researchers were able to uncouple population density effects from other potentially influential parameters, and concluded that population density is a key factor in the determination of human fertility. It can be proposed that the finding of the critical importance of individual territory for biological performance could be fruitfully studied from several other aspects, including a possible correlation with aggression, suicide rates, and other destructive behavioral manifestations.

10.4 Discussion: How Was the Major Ecological Right of Humans Lost?

Two inherent human features directly contributed to the loss of the major ecological human right. First, *H. sapiens* is a species with a genetically encoded ability/need to accumulate cultural information and pass it on to the next generation. Cultural heritage includes humanitarian and scientific information consisting of the cumulative memory store of the population. No other biological species ever existed on Earth which possessed this ability to accumulate cultural information *across* generations. Progress in the accumulation of scientific and technical information made our species the most competitive one in the biosphere, and also put our species in opposition to the rest of the biosphere. {Notably, this very property has brought humanity to the verge of ecological and environmental collapse. Natural biological and ecological laws and negative feedback [including emotion-(instinct-) based behavioral reactions] that ensure the stable existence of all other biological species do not function efficiently in the human population. The only way out of the crisis is therefore to use the accumulated cultural information effectively, to solve the survival problem scientifically, and then to implement the solution on a global scale by appealing to the reason of the peoples of the Earth.}

Second, *H. sapiens* is a social species. Sociability arises as a consequence of highly organized behavior and the corresponding complexity of the genetic program of our species (Gorshkov and Makar'eva 2001). The higher the level of organization of a species, the greater the rate of its spontaneous degradation. To compensate for this degradation, it is necessary to intensify the processes of competitive interaction among individuals in the population, identify individuals with a degraded (eroded) genetic program, and effectively exclude them from the population. These processes become most intense when a social structure is formed, i.e., when the population consists of individuals who continuously interact with each other and form a hierarchical structure where the status of each individual is determined.

Each social group possesses its own territory, which is equal in size to the product of the number of group members and the size of each individual territory.

The necessity of continuous interactions between group members ensures that the natural group size will not exceed a hundred members (e.g. Hayden 1981). (The footprint of this species-specific property can be traced in the sizes of the world's professional elites, where all members know each other and each other's status. Political and financial elites in various states are all approximately the same size.) Group territory is defended in competition with neighboring groups. In a natural environment with low a population density, this interaction did not give rise to any conflicts. Until very recently, such a lifestyle could still be observed in the aboriginal tribes of Papua New Guinea, Amazonian Indians, and tribes in the far north of Eurasia.

Many species are social, but only *H. sapiens* accumulates cultural knowledge. Cultural information changes the character of competitive interaction between social groups. When some new cultural information was occasionally discovered that imparted a competitive advantage to the corresponding social group, that group was able to out-compete the neighboring groups, invade and appropriate their territories, and subdue the population. Unlike in the rest of the animal world, that was done in spite of the genetic equivalence (equal orderliness of the genetic program) of the dominant and subordinate populations, and solely at the expense of cultural advancements occasionally acquired by the invaders. The increased size of the social group further contributed to its military power and facilitated further invasions. As a result, the social group was transformed into a hierarchical state, where the majority was compulsorily subdued to the elite minority. As a logical consequence, female and male social equivalence was gradually lost; in practice, female individuals functioned as biological machines producing military manpower for the state. Another essential feature of such radically transformed social groups was the inheritance of political and financial privileges. Corresponding moral, ethical, religious, and juridical norms gradually evolved that secured the status quo.

Importantly, in a very large social formation (state), the majority of the population is deprived of the opportunity to have a competitive interaction with the elite and to find out the true biological status of individuals that form the ruling elite. This undermines the fundamental biological and ecological meaning of social group formation, which consists in the identification of the most competitive and excellently performing individuals on the basis of competitive interactions between *all* members of the social group. The majority of the population was deprived of their individual territories and lost the ability to control their own population density. Their reproduction was further encouraged by the elite. Since they did not participate in competitive interactions with the majority of the population, the elite did not actually consider the population to be individuals genetically equivalent to themselves. Accordingly, the population was deprived of all major political and social rights, and in many cases was socially brought down to the level of domestic animals. Because they were not considered to be equal (or belonging to the same "species"), the presence of a dense population in the territory controlled by the elite did not impose any social or physiological stress on the elite.

Generally, the violation of the inherent hierarchical structure in a developing civilization inevitably leads to the genetic degradation of *H. sapiens* as a biological

species, which is manifested as the growing percentage of individuals born with mental or physical disorders.

The situation could be globally changed if the genetically encoded ecological requirements of our species became the target of focused studies. We have outlined a few perspectives along which the research could proceed. Currently, the Universal Declaration of Human Rights does not contain any reference to the ecological rights of our species. This situation is likely to change in the coming decades, when the necessity of re-evaluating our understanding of *H. sapiens* and our environmental interactions with the rest of the biosphere will be widely recognized by the world (scientific) community.

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References

- Adams ES (2001) Approaches to the study of territory size and shape. *Annu Rev Ecol Syst* 32:277–303
- Baker PR (1983) Insect territoriality. *Annu Rev Entomol* 28:65–89
- Carlstead K, Fraser J, Bennett C et al (1999) Black rhinoceros (*Diceros bicornis*) in U.S. Zoos: II. Behavior, breeding success, and mortality in relation to housing facilities. *Zoo Biol* 18:35–52
- Fokin IM (1978) The Dipodoidae. Leningrad University Press, Leningrad
- Gorshkov VG (1995) Physical and biological bases of life stability: man, biota, environment. Springer, Berlin
- Gorshkov VG, Makar'eva AM (2001) On the possibility of physical self-organization of biological and ecological systems. *Dokl Biol Sci* 378:258–261
- Gorshkov VG, Gorshkov VV, Makarieva AM (2000) Biotic regulation of the environment: key issue of global change. Springer-Praxis, London
- Hayden B (1981) Subsistence and ecological adaptations of modern hunter/gatherers. In: Harding RSO, Teleki G (eds) Omnivorous primates: gathering and hunting in human evolution. Columbia University Press, New York, pp 344–421
- Kelt DA, Van Vuren DH (2001) The ecology and macroecology of mammalian home range area. *Am Nat* 157:637–645
- Lutz W, Qiang R (2002) Determinants of human population growth. *Philos Trans R Soc Lond B Biol Sci* 357:1197–1210
- Lutz W, Testa MR, Penn DJ (2006) Population density is a key factor in declining human fertility. *Popul Environ* 28:69–81
- Makariev AM, Gorshkov VG, Li B-L (2004) Body size, energy consumption and allometric scaling: a new dimension in the diversity-stability debate. *Ecol Complex* 1:139–175
- Makariev AM, Gorshkov VG, Li B-L (2005a) Energetics of the smallest: do bacteria breathe at the same rate as whales? *Proc R Soc Lond B Biol Sci* 272:2219–2224
- Makariev AM, Gorshkov VG, Li B-L (2005b) Why do population density and inverse home range scale differently with body size? Implications for ecosystem stability. *Ecol Complex* 2:259–271
- Makariev AM, Gorshkov VG, Li B-L et al (2008) Mean mass-specific metabolic rates are strikingly similar across life's major domains: evidence for life's metabolic optimum. *Proc Natl Acad Sci USA* 105:16994–16999
- Mitani JC, Rodman PS (1979) Territoriality: the relation of ranging pattern and home range size to defendability, with an analysis of territoriality among primate species. *Behav Ecol Sociobiol* 5:241–251

- Mitchell J (1989) The “greenhouse” effect and climate change. *Rev Geophys* 27:115–139
- Rappaport RA (1971) The flow of energy in an agricultural society. *Sci Am* 225:117–132
- Sibly RM, Hone J (2003) Population growth rate and its determinants: an overview. In: Sibly RM, Hone J, Clutton-Brock TH (eds) *Wildlife population growth rates*. Cambridge University Press, New York, pp 11–40
- Stanley SM (1979) *Macroevolution: pattern and process*. Freeman, San Francisco
- Whittaker RH, Likens GE (1975) The biosphere and man. In: Lieth H, Whittaker RH (eds) *Primary productivity of the biosphere*. Springer, Berlin, pp 305–328
- Winterhalder B, Baillargeon W, Cappelletto F et al (1988) The population ecology of hunter-gatherers and their prey. *J Anthropol Archaeol* 7:289–328