SCIENCE

LETTERS

Biological Diversity and Agriculture

In his article "Biological diversity, soils, and economics" (10 Dec. 1993, p. 1676), Michael Huston argues that market forces, if left to operate on their own, would ensure that areas of high plant species richness (his surrogate for biological diversity) would be excluded from agricultural production because they occur on infertile soils. He states (p. 1676) that the "preservation of areas of high plant biodiversity does not require the sacrifice of productive agricultural lands." The implication from an uncritical reading might be that biodiversity conservation and agricultural production are not in conflict. In fact, they are.

Species richness, the number of species per unit area, is a measure of biological diversity, but it does not necessarily follow that high species richness equals high value for biodiversity protection. The potential value of an area to overall plant biodiversity conservation depends on which plant species that area contains, not how many. If an area contains few species and they do not occur elsewhere, it has high value indeed. Emphasis on species-rich areas allows for the possibility of species-poor areas being ignored, even if they contain different species (*1*).

The pattern of plant species richness Huston describes—poor in areas of very low soil productivity, rich in areas of low and intermediate productivity, and poor again in areas of high productivity—is widely acknowledged to hold at fine scales. However, land use planning decisions, including whether to conserve an area or not, are made at broader scales, where the patterns are quite different. Strong positive correlations between measures of productivity and tree species richness have been demonstrated at broad scales (2.5 degrees latitude × 2.5 degrees longitude and 72,000 square kilometers) (*2*). Nations or states within nations represent the real scale of conservation planning. Even if the hump-shaped model Huston describes were to hold, it is likely that, across many of those nations or states, only part of the curve would apply, making it unlikely that the overall relationship would be taken into account in decision-making.

In the real world, market forces only partly determine patterns of agricultural activity. Governments intervene with subsidies, tax incentives, and the like, making the use of marginal lands profitable. For example, cattle ranching in Latin America caused an estimated loss of 20,000 square kilometers of forest per year (presumably mostly on soils of low productivity) in the late 1970s (*3*).

Huston's definition of agriculture appears to exclude grazing on indigenous pasture. The deserts of the Middle East and North Africa have been greatly extended by thousands of years of grazing. Both the species and structural composition of arid rangelands in Australia have been changed profoundly by less than 200 years of grazing by introduced herbivores (*4*).

Finally, Huston does not account for human population pressure, which acts to bring marginal agricultural land into production in two ways. (i) Market demand from first world countries can make production from marginal lands economic (as happens in the production of hamburger meat for North America). (ii) Marginal lands may be all that is available to impoverished people. Population pressure, for example, forced farmers of small plots to migrate into Ecuadorian Amazonia, increasing the population there from 45,000 in 1950 to more than 350,000 today (*5*).

It would be comforting to think that agriculture and the conservation of biological diversity were not in conflict. Scientists, planners, and policy-makers, though, have to face the reality that they are in conflict before real progress can be made.

C. R. Margules
K. J. Gaston
Wissenschaftskolleg zu Berlin, Wallostrasse 19, D-14193, Berlin, Germany

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One significant underappreciated threat to biodiversity is the human conviction that there are many "win-win" solutions promising cost-free resolution to the severe problems that threaten the continued existence of life on Earth. Huston's is one such argument and it rests on a fundamental observation: at a global scale, the tropical belt is underlain by infertile soils that support the highest diversity of vascular plants on Earth. In contrast, the more fertile soils of both the temperate and tropical zones are less species-rich.

Huston's tidy solution works only by oversimplification. First, he states that the "fundamental unit" of biodiversity is the species; he therefore limits biodiversity to alpha species richness, whereas most commonly held definitions include genetic and ecosystem components and incorporate processes as well as composition (*1*). The goal of representation requires conservation of all ecosystem types and unique assemblages of species in blocks of original habitat sufficiently large to sustain the system. Often biodiversity found on rich soils is endangered. Huston also assumes that plant species diversity is correlated with alpha diversity for other taxa, an assumption questioned by recent work (for example, *2*). Huston states that this correlation may not hold, but does not address the problem.

Second, Huston seeks patterns at too coarse a scale for effective conservation planning. Even within subtropical and tropical countries, largely underlain by unproductive soils, substantial heterogeneity in soil fertility exists. Volcanic soils, flood plains, and river deltas are often species-rich and productive sites for agriculture, and they can often be found adjacent to less fertile areas. Huston regards these numerous cases as exceptions to a general pattern, but they point to the inappropriate scale of his analysis. Unfortunately, studies such as Huston's are used by international decision-makers, while conservation action must take place at the level of the local landscape.

Third, soils that are too poor to support commercial agriculture can yield valuable forest products that are harvested to gain foreign currency in developing countries. Just because large-scale agriculture is unsustainable on poor soils does not mean that these areas will be set aside for conservation by governments or ignored by landless farmers. We must recognize that there are no cost-free solutions to maintaining biodiversity and agricultural productivity.

Kent H. Redford
The Nature Conservancy,
1815 North Lynn Street,
Arlington, VA 22209, USA
Eric Dinerstein
World Wildlife Fund,
1250 24th Street, NW,
Washington, DC 20037, USA

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2. J. R. Prendergast, R. M. Quinn, J. H. Lawton, B. C. Eversham, D. W. Gibbons, *Nature* **365**, 335 (1993); R. J. Ranjit Daniels, M. Hegde, N. V. Joshi, M. Gadgil, *Conserv. Biol.* **5**, 464 (1991).

Response: I agree that conservation of biological diversity will not be achieved by protecting areas of high species richness alone and have not argued otherwise. Biodiversity is generally considered to have components at scales ranging from genes to continents and to include all taxa, not simply plants, to which my report was limited. Nonetheless, plants are a critical component of biodiversity and provide most of the energy and structural heterogeneity on which terrestrial (and most aquatic and marine) heterotrophs depend (*1*). In my report, I did not pretend to address all components of biodiversity; I do pretend to address them in my forthcoming book (*1*). As I stated in my report, areas with high plant diversity do not necessarily have high diversity of all types of animals. Likewise, areas of high diversity do not necessarily contain rare or endemic species. Nonetheless, an understanding of how diversity is related to physical properties of the environment, and how different components of diversity are related to one another, should provide a better basis for conservation planning than would a misunderstanding of these issues.

Margules and Gaston cite papers in which large-scale patterns of the numbers of plant and animal species were found to correlate positively with "energy." The data on species richness for these taxa are based on published range maps. The data on "environmental energy" or "productivity" are based on patterns of solar radiation and estimated actual evapotranspiration (AET), which under some conditions have been shown to be correlated with plant productivity. However, the large scale at which these estimates were made [and the fact that there has been no verification of the regressions for the regions to which they were applied, or for the scales at which they were applied (that is, actual measures of productivity)], makes the hypothesized positive relation between cause (productivity) and effect (diversity) highly suspect. Many important environmental factors that are correlated with AET vary across the study areas (Europe and North America), and the degree of environmental heterogeneity (specifically, variation in AET or actual measures of productivity) within the large areas for which estimates were made is not addressed. Furthermore, in the New World these patterns break down south of the southern limit of the published studies, which is the United States/Mexican border; thus they do not apply in the region where biodiversity is highest.

Income from grazing is included in the agricultural land values I used in my report. Grazing can lead to an increase, decrease, or maintenance of plant species diversity. Appropriate grazing may be compatible with preserving diversity in some types of grasslands, although arid rangelands with no evolutionary history of grazing may be particularly susceptible to degradation by introduced grazers. While grazing does seem to lead to desertification under some circumstances, many fluctuations in desert area are the consequence of climatic variations.

Redford and Dinerstein criticize me for using "too coarse a scale for effective conservation planning." I believe this criticism is directed at my use of the world soil map to address global-scale patterns of agricultural productivity and biodiversity. I also presented data at the scale of square meters, 0.1 hectare, 1.0 hectare; proportional land use within states in the United States; and proportional land use within countries of the world. Available data indicate that diversity patterns closely correspond to the scales of soil heterogeneity that Redford and Dinerstein mention (and which I discuss in my report), particularly the local scale at which conservation and land-use decisions are actually made. The figures in my report demonstrated that both within the United States and among the countries of the world, the potential agricultural value of land is related to the amount of land set aside for conservation and other public uses.

The problem in many tropical forests is that forest conservation laws are ignored or poorly enforced, corruption often determines the sale and rate of destruction of timber resources (including those in national parks), and pressure from populations displaced from valuable lands by governments or international corporations results in destruction of forests on marginal lands. Many tropical forest areas are not suitable for sustainable productive agriculture or even plantation forestry. However, forest management schemes have been developed that, if properly implemented, can allow sustainable management of natural forests with maintenance of most biodiversity.

"Subsidies, tax incentives, and the like" (to quote Margules and Gaston) are precisely the sort of subversion of market economics that results in habitat destruction, loss of biodiversity, and unsustainable agriculture. This occurs in South Florida, as well as in Brazil and elsewhere. In an economically rational system where agriculture was only practiced where it was sustainable and profitable, there would be no inherent conflict between conservation of plant diversity and agricultural production.

Many components of biodiversity have been and will continue to be lost. Many will only be preserved at some cost or with some economic subsidy. However, most of the Earth's biodiversity will have to be preserved in coexistence with the growing demands of the human population. Identifying "win-win" solutions and capitalizing on them before both biodiversity and agricultural potential are destroyed should be one of the primary tools for the preservation of biodiversity.

Michael Huston
Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831–6038, USA

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1. M. Huston, *Biological Diversity: The Coexistence of Species on Changing Landscapes* (Cambridge Univ. Press, Cambridge, United Kingdom, 1994).

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Omission of References

In our report of 8 April "Molecular nanotube aggregates of β- and γ-cyclodextrins linked by diphenylhexatrienes" (p. 249), we presented our observations of cyclodextrin nanotubes. Earlier reports of a similar phenomenon by R. A. Agberia and D. Gill at Ben Gurion University [*J. Phys. Chem.* **92**, 1052 (1988), and *J. Photochem. Photobiol. A. Chem.* **78**, 161 (1994)] have since been brought to our attention. In their work, extended linear aggregates (linear beads) were formed by inclusion of oxadiazole derivatives in γ-cyclodextrin and characterized by fluorescence techniques and light scattering. We regret the omission of these references and appreciate the opportunity to correct it.

Linda B. McGown
Guang Li
Department of Chemistry, Paul M. Gross Chemical Laboratory, Duke University, Durham, NC 27708–0354, USA

Corrections and Clarifications

A caption for the illustration on page 1694 accompanying Eliot Marshall's article "Highs and lows on the research roller coaster" (Genes and Behavior News Report, 17 June, p. 1693), cited the wrong chromosome as the focus of a 1987 study of manic depression among the Amish; that study focused on chromosome 11 (not 18).

In the introduction to the Women in Science '94 special section (11 Mar., p. 1467), associate editor Pamela J. Hines should have been credited with planning, inviting, and editing the Policy Forums in that section.