HOW MUCH OF NORTH AMERICA IS STILL WILD?

2002 Applied Geography Conference
Binghamton, NY

Duane A. Griffin
Bucknell University
Geography Department

1. INTRODUCTION

The spectacular rise in human population over the past few centuries has been accomplished through the increasing domination of Earth's ecosystems, one of the most dramatic manifestations of which is the ongoing loss of biodiversity. (6, 19, 21) Thus far, mainland North America has been spared dramatic losses, which have been concentrated on islands. In part, this is due to biological differences in continental and island organisms, but also because the continent's land area is large, and our transformation of its habitats has been less than complete. Large tracts of wilderness remain, but most of these areas are in the biologically depauperate high latitudes of the continent. (11) South of the fiftieth parallel, species have avoided extinction because they have been able to persist in the wildland margins and interstices of otherwise humanized landscapes.

This study is an effort to assess the status of North America's wildlands in relation to its biodiversity. I use GIS analysis to address three primary questions: 1) what is the pattern of human land use intensity and population pressure, and how much of North America is still wild; 2) how does this pattern relate to the distribution of biological diversity on the continent; and 3) what areas have both high biodiversity value and extensive tracts of remaining wildland? Because the relationship between human activities and biodiversity depends on the combination of land use and population, addressing these questions requires us to consider the distribution of both land cover and human population, as well as biodiversity. (16, 19, 23)

2. METHODS

The analysis consists of two parts, wildland classification and biodiversity analysis. The wildland classification is based on two global data sets. Land cover types are from the U.S. Geological Survey's Global Land Cover Characteristics (GLCC) Version 2 database. (10) The GLCC data set is derived from satellite data collected from April 1992 through March 1993 and refined using supplementary Earth surface data. For population distributions, I used the LandScan 2000 database from Oak Ridge National Laboratory, which represents the modeled ambient population (i.e., the likely daytime population, in contrast to the number of nighttime residents) of each grid cell. (8) Both data sets have thirty arc second spatial resolution.

I extracted grid data sets for North America from the global LandScan 2000 and GLCC data files (all GIS analysis was done with ESRI ArcView software), classified them into four categories of increasing intensity of human use and occupancy, and assigned each class a weight from one to four (Table 1). The land cover weighting scheme for the

GLCC data set is based on subjective interpretation (e.g. grasslands eastern U.S. forests are assumed to have had greater human impacts that high-latitude forests). The LandScan 2000 weights are calibrated to rural areas with which I am familiar in the eastern, central, and southwestern United States, Mexico, and Central America.

To derive the landscape classification, I added the two weighted data sets and grouped the resulting data into five classes representing the wildland classifications (Table 2). I determined the groupings based on consideration of the possible combinations of land cover and population density and checked them by closely examining the resulting values for landscapes in the reference areas listed above. For area calculations, I projected the gridded wildland classification to Lambert's Equal Area Azimuthal projection centered at 100˚ W, 45˚ N and resampled the data set to a 25 km^2 grid.

The biodiversity analysis relies on three additional data sets. The first is Barthlott et al.'s map of global vascular plant species diversity, which maps species density (number of species per 10,000 km^2) as ten diversity classes. (2) The diversity pattern is broadly consistent with the higher-resolution results of Withers et al. but has the advantage of including Mexico and Central America. (24) Because the diversity of different taxonomic groups tends to be highly correlated at continental scales, this data set provides a reasonable proxy for overall biodiversity. (1, 7)

The second biodiversity data set is Conservation International's (CI) biodiversity hotspots map (13, 14), digitized from Myers et al. (14) The CI hotspots are areas with high concentrations of endemic species that are threatened by habitat loss. As such, they represent high priority areas for conservation and preservation efforts.

McClosky and Spaulding's Reconnaissance Level Inventory of Remaining Wilderness Areas (MSRLI) is the third data set included in the analysis. (11) McClosky and Spaulding used Jet and Operational Navigation Charts to map the global distribution of large (>400,000 ha) areas free of roads, settlements, and other evidence of human occupation or use. The MSRLI is dated but is useful because it identifies large tracts of land that are currently or recently free from modern human intrusions.

The biodiversity analysis consisted of tabulating the area of each wildland class for each country, hotspot, and plant diversity zone. To identify areas of high conservation potential, I selected MSRLI wilderness areas in regions with > 1000 species (Biodiversity Priority Type I) and areas within conservation hotspots classed as predominantly wild (Biodiversity Priority Type II). The designation is nominal and is intended to distinguish between large areas of undisturbed habitat in areas that are at least moderately diverse and those that are likely to harbor high levels of diversity, regardless of size.

Several caveats are in order regarding the wildland classification and biodiversity analysis. First, the accuracy of the analysis is limited to the accuracy of the original GLCC and LandScan data sets (both of which are continually subject to validation, verification and subsequent revision) and classification process. Second, the wildland classes conceal much important detail, and may be misleading. For example, logging, livestock grazing, and invasive exotic species may seriously reduce biodiversity value for areas in the western United States classed as wild or extensive-use rural. Inclusion of supplementary information on parks and other protected areas could help improve accuracy, though it would compromise international comparisons. Finally, the classification and biodiversity analysis are designed with stringent standards for inclusion in the conservation potential designations. This exercise identifies those areas where conservation efforts are likely to meet with high levels of success with a minimum burden on current land uses and economies. It does not imply that landscapes outside of these identified areas are not appropriate for biodiversity conservation efforts.

3. RESULTS

At a continental scale, the view that emerges from the wildland analysis shows North America to be predominantly empty and wild (Table 3). Over half of the continent's surface area falls within the predominantly wild category, with a further twenty percent or so given over to extensive land use. In contrast, the highest level of human impact (urban areas) is concentrated in only three percent of the total land area, with most food and fiber production located within the approximately 30% of the landscape devoted to mixed and intensive rural uses.

This view is deceptive, however, because it ignores the significant spatial patterning shown in Figure 1. One of the most striking patterns is the decreasing size and increasing intermixing of wildland classes from north to south. Most of the predominantly wild areas are in the boreal forests, tundra, and arctic deserts of Canada and Alaska. Most of the rest, and most extensive-use rural landscapes, are located in the western United States and northern Mexico.

Another conspicuous feature of the map is the broad concentration of intensive-use rural landscapes south of the Great Lakes, which forms a ragged bulls-eye surrounded by mixed rural landscapes. Also notable is the increasing intermixing of wildland classes from central Mexico south to Panama, reflecting a high degree of habitat fragmentation. The moist lowland forests along the Caribbean are a notable and biologically important exception to this pattern.

Given the strong latitudinal gradient in species density (Figure 2A) and the patterns described above, the biodiversity analysis is not surprising. Table 4 shows the distribution of wildland classes by species diversity zones. Areas with the highest species densities also have the highest proportion of their land areas in the mixed- and intensive-use rural classes. Conversely, most of the highest quality wildlands are located in landscapes with fewer than 1,000 species per 10,000 km^2.

Landscape conditions vary considerably between the biodiversity hotspots (Table 5). The California Floristic Province has the greatest area in the two highest quality wildland classes (62 percent of the total). Most landscapes in the Mesoamerica hotspot are mixed or intensive rural landscapes, though a considerable amount of the area (over 150,000 km^2) remains predominantly wild. Over half of the landscapes of southern Florida (in the Caribbean hotspot) are classed as intensive rural and urban, and less than twenty percent (mostly in the Everglades) as predominantly wild or extensive-use rural.

The MSRLI remaining wilderness areas are shown in Figure 2B, and the conservation hotspots and biodiversity conservation priority areas identified in the analysis in Figure 2C. The Priority Type I areas in the United States include Florida's Everglades and areas centered on the Bitteroot and Lewis Ranges in the Northern Rockies and in the Sierra Nevada. Substantial parts of all of the areas are encompassed within national parks and/or wilderness areas.

Further south, Priority Type I areas include wilderness areas in Nicaragua's Río Indio region, the eastern highlands of Nicaragua and Honduras, and Mexico's Vizcaíno and Altar Deserts and the Isthmus of Tehuantapec. Most of these areas are contiguous with relatively extensive Priority Type II areas, which enhances their conservation potential further.

All of the Priority Type I areas in the humid tropics face population and economic pressure. (20) Human encroachment is most evident in the Isthmus of Tehuantapec area, the entire northwestern half of which is now populated, according to the LandScan data.

In addition to those mentioned above, the most extensive Priority Type II areas are located in the California Floristic Province hotspot and in eastern part of the Yucatan Peninsula. The areas in the central cordillera of Costa Rica and Panama fall within Barthlott et al.'s highest diversity class (i.e. > 5,000 vascular plant species) and are thus especially significant. (2) Large areas also remain in Mexico's Sierra Madre Occidental, with smaller areas scattered throughout the Sierra Madre Oriental and elsewhere.

4. DISCUSSION AND CONCLUSION

North America's biologically richest areas have been transformed by human activity, but incompletely. (25) Thus far, the native fauna has suffered a number of close brushes with extinction—with resultant loss of genetic diversity for the species involved—but only one mammal and five bird species have been altogether lost. (12, 16, 18) It would be a mistake, however, to view the current situation as evidence of the biosphere's stable accommodation of human activities. Extinction is almost always a protracted process, and the rate at which it proceeds depends on the biology and biogeography of the organisms involved, combined with the environmental pressures leveraged against them. Nearly a thousand taxa of plants and animals are currently on the U.S. threatened and endangered species lists (not including Hawaii, which harbors another three hundred), suggesting that the current state of affairs is temporary.

Qualitative comparisons between Figure 1 and the geographic distribution of endangered species mapped by Dobson et al. suggest that North America's remaining wild landscapes have played an important role in allowing species to avoid extinction. (7) But they also indicate that the extensive-use rural areas—those landscapes still relatively unpopulated and not radically transformed—may be just as important, if only because they are more common than high-quality wilderness. The habitats they provide may be especially important in the highly fragmented landscapes of Mexico and Central America.

Historically, conservationists and ecologists alike have focused primarily on the wildest of landscapes, seeking to understand and preserve ecosystems and communities as free from human influence as possible. (3, 23) Despite recent critiques of the wilderness ideal, the scientific and conservation value of truly wild landscapes is immense and will only increase as human populations and economies expand in the twenty first century. (20, 22) The biodiversity analysis identifies several areas where protection can and should be undertaken or strengthened with a minimum of conflict with current populations.

Ecological restoration can improve the biodiversity value of already-impacted landscapes and can help expand and connect isolated patches of wilderness. It is, however, expensive. Focusing on the landscapes between the wild and the humanized ones and seeking to maintain or enhance the qualities that support species populations and diverse ecological communities within them may offer our best conservation investment in coming decades.

The challenge at this point is knowing what that focus should look like on the ground. The effort to develop a rigorous, predictive understanding of the ecological and biogeographical dynamics of wild ecosystems and landscapes is less than half a century old, is still incomplete, and contains many significant gaps. Systematic efforts to understand the dynamics of fragmented and reduced plant and animal populations in humanized landscapes—what Daily has recently called "countryside biogeography"—are more nascent still, so we cannot yet know how long and under what conditions species are likely to persist within them. (5)

The analysis reported here is an effort to contribute to developing such an understanding and to identify particularly promising areas for biodiversity conservation. It does so by providing a snapshot of the distribution of America's wildlands two centuries into what Crutzen and Stoermer have dubbed the "Anthropocene" epoch. (4) Despite its limitations, it improves on earlier, similar efforts (e.g. 9, 11) in the spatial and categorical resolution it offers, and should provide useful insights into the status of North American habitats and potentials for biodiversity conservation, especially in conjunction with ecoregional assessments. (13, 15, 17) But it is still a preliminary effort. More detailed regional and local analyses, particularly those based on improved data and incorporating more rigorous and extensive calibration and verification, will foster further progress in this direction.

5. REFERENCES

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TABLE 1
WILDLAND CLASSIFICATION CRITERIA AND WEIGHTINGS

Global Land Cover Characterization

USGS Global Ecosystem Code	Cover types	Weight
12, 14, 15	Water, ice, and rock	0
3, 5, 8-9, 13, 17, 20-23 28, 29, 33, 44, 53-54, 60-63, 78	Forest, bare desert, swamp and mire, tundra, and high latitude shrublands	1
2, 24-27, 32, 40-43, 46, 47, 51-52, 91, 100	Grasslands, second growth forests (eastern U.S.), dry tropical woods, and savannas	2
7, 19, 30-31, 34-38, 55-58, 92-94	Tall prairie and all agricultural lands	3
1 (expanded to include all cells with LandScan 2000 populations > 100)	Urban	4

LandScan 2000

Population	Interpretation	Weight
0 - 1	Unoccupied or very sparsely occupied	1
2 - 10	Sparse rural	2
11 - 30	Dense rural	3
> 30	Urban and suburban	4

TABLE 2
WILDLAND CLASSIFICATION SYSTEM

Wildland Class	Sum of Weights	Examples
Predominantly Wild	2	Unoccupied forest lands; wetlands; tundra; deserts; mountains and other rugged topography; parks and reserves.
Extensive Rural	3-4	Rangelands; second-growth forests; moderately exploited woodlands; recreational areas.
Intensive Rural	5-6	Cultivation, intensive animal pasturage, and sparse suburban development.
Urban and Suburban	7-8	Densely populated (> 30 people per grid cell) landscapes with human-modified land cover classes.

TABLE 3
AREAL EXTENT OF WILDLAND CLASSES BY COUNTRY

	Area (1000 km2)				
Country	**Predominantly Wild**	**Extensive Rural**	**Mixed Rural**	**Intensive Rural**	**Urban**
Belize	9.0	3.4	4.1	5.0	0.5
Canada	8,737.8	300.5	509.2	247.8	29.8
Costa Rica	7.5	17.2	8.8	13.1	4.7
El Salvador	0.4	0.8	1.8	7.1	10.6
Guatemala	5.8	29.0	16.3	33.0	25.5
Honduras	23.8	20.6	19.7	33.5	15.0
Mexico	124.1	678.7	607.0	441.3	109.5
Nicaragua	21.7	38.8	17.4	37.4	13.4
Panama	9.6	10.3	9.5	16.3	4.8
United States	2,341.9	2,696.9	2,056.6	1,823.1	380.8
Total	11,281.6	3,796.2	3,250.4	2,657.6	594.6
Percent	52	18	15	12	3

TABLE 4
AREAL EXTENT OF WILDLAND CLASSES BY DIVERSITY ZONE

	Area (1000 km2)				
Species/ 10,000 km^2	**Predominantly Wild**	**Extensive Rural**	**Mixed Rural**	**Intensive Rural**	**Urban**
<1000	8,729.5	126.7	518.9	177.7	10.6
1000-2000	2,211.9	2,812.1	1,657.9	1,518.5	285.9
2000-3000	191.2	568.0	734.2	529.4	129.4
3000-4000	69.9	195.1	249.6	272.2	103.2
>4000	17.9	53.6	69.7	137.2	55.7

TABLE 5
AREAL EXTENT OF WILDLAND CLASSES BY BIODIVERISTY HOTSPOT

	Area (1000 km2)				
Hotspot	**Predominantly Wild**	**Extensive Rural**	**Mixed Rural**	**Intensive Rural**	**Urban**
Mesoamerica	154.7	243.6	309.3	449.7	165.9
Calif. Floristic Province	95.1	138.5	78.0	43.3	21.3
Caribbean	5.9	6.8	19.4	20.7	14.5

FIGURE 1
NORTH AMERICA WILDLAND CLASSIFICATION

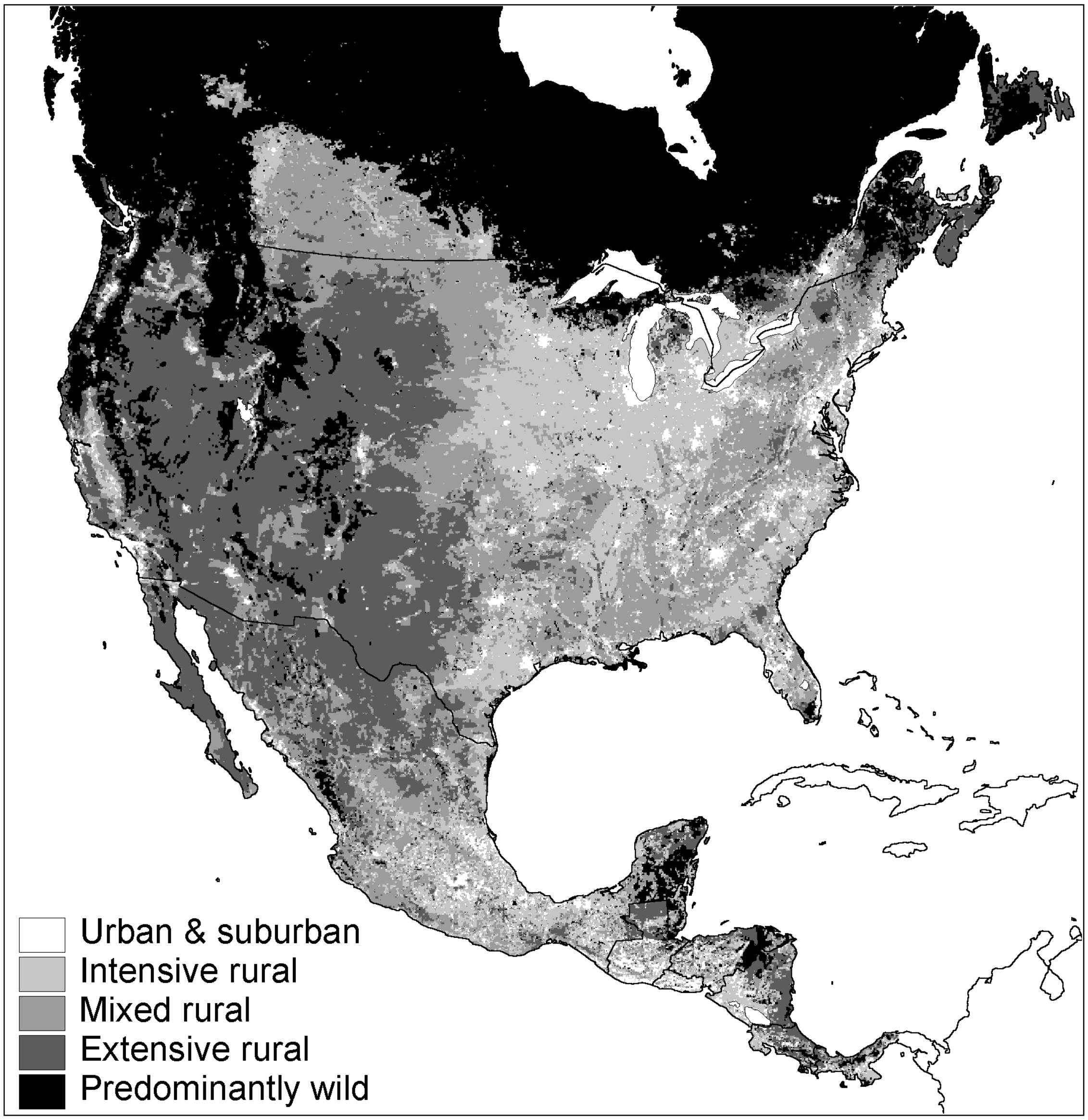

FIGURE 2
SPECIES DENSITY GRADIENT AND CONSERVATION HOTSPOTS