A World Ecoregions Map for Resource Reporting

by

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INTRODUCTION

The world encompasses wide variations in terrestrial environments ranging from forest to tundra and desert. Management and conservation of such a biologically diverse area must be based on an understanding of the overall structure and functioning of the component ecosystems. These ecosystems need ultimately to be understood at various levels of detail, ranging from comprehension of the entire ecosphere or at least The Biosphere down to individual plant communities on specific sites. One of the essential frameworks for environmental management, therefore, is an inventory of ecosystems at a level, and at a scale of resolution, that is appropriate to management–conservation objectives.

Regional variations in climate, vegetation, and soil, are important in the development of ecosystems; moreover, very often, different regions have very different management–conservation problems. For this reason, it is important to recognize regional differences at the highest level in the inventory. This regionalization facilitates (1) synoptic planning of large areas where it is necessary to study management–conservation problems and potential solutions on a regional basis; (2) organization and retrieval of data gathered in a resource inventory; and (3) interpretation of inventory data, including differences in indicator plants and animals among various regions.

The purpose of this paper is to present a proposal for an international mapping project to delineate such *regions*.

The need for a world map showing ecological regions has been recognized for some considerable time, perhaps beginning with A.J. Herbertson in 1905. Recently this need has been formally recognized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). UNESCO's Man and the Biosphere (MAB) programme aims at an inventory of natural resources of the Earth based on broad ecogeographic units. This initiative was taken up by the International Union for Conservation of Nature and Natural Resources (IUCN) (Dasmann, 1972) and adopted for UNESCO's MAB projects (Udvardy, 1975*a*). The 'Biogeographical Provinces of the World' have been mapped by Udvardy (1975*b*) at a scale of *ca* 1:40,000,000. Like similar 'ecosystem' maps (such as that of Olson & Watts, 1982), it relies heavily on vegetation criteria. This world-wide classification of biogeographical provinces is based on a simplified scheme of UNESCO's (1973) international classification of vegetation, but also takes into consideration, where available, already-existing schemes of biotic provinces, and of floristic and faunistic mapping. The units of this system are worked out at two levels of the hierarchy—realms and provinces—while the establishment of lower entities is left to local experts and authorities. Each biogeographical province is classified according to the major dominant vegetation unit of that particular geographical area.

The system of biogeographical provinces has now been widely accepted and has been the basis of many international management–conservation programmes, though there remains, of course, the need to refine the system and further subdivide the biogeographical provinces.

While this system is being further divided and refined for the continental United States (Franklin, 1977), Voronov & Kucheruk (1979) found that it did not adequately express the ecological conditions in the Soviet Union, and so introduced a number of modifications. In particular, they noted that the system does not take into consideration the differences in mountain provinces, but lumps mountains which differ radically in vertical zonality into one type of 'biome', the 'mixed mountain systems with complex zonality.' Workers in other areas have appreciated the fact that it does not give a satisfactory view of the differentiation of transitional zones (ecotones) such as those of tundra–taiga or forest–steppe.

A biogeographical province, as defined by Dasmann (1972) and Udvardy (1975*a*, 1975*b*), is distinguished by its vegetation, flora, and fauna. The physiognomy of the potential climatic climax vegetation is the first basis for recognition of a biogeographic province. Within the area of a physiognomically-defined plant formation, however, the presence of a distinctive flora or fauna serves to delineate provincial boundaries.

While the use of plant formations is useful in delineating ecological regions, there can be shortcomings with such an

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approach. First, the same formation may occur in different climatic regions; for example, the taiga's spruce–fir forest is characteristic of regions having a climate that is both colder and drier than that of the spruce–fir formation in the Appalachians. It is unlikely that the consequences of a specific conservation–management practice would be similar at diverse locations within the bounds of its natural range. Similarly, the effects of climate may be modified by soil factors. Soil texture and structure may be important, as they influence infiltration and percolation of moisture. It is well known that moisture-demanding species often extend into less humid regions on areas of sandy soils because these tend to contain a greater volume of available moisture than do heavier soils. In humid climates, the same soil-types support vegetation that is less demanding of moisture than it would be in dry climates.

As Rowe (1980) points out, vegetation maps are not necessarily ecological. To be meaningful as delineators of ecological regions, vegetation units need to be modified so as to correlate with other features of the landscape. To fulfill this need—and thereby supplement Udvardy's useful biogeographical provinces map (1975*b*)—we propose to map what we call 'ecoregions'. This follows a suggestion made a decade ago by Burger (1976).

Geographic Reasoning in Mapping Ecoregions

Ecosystem regionalization is the process of delineating usually large units of land according to the ecological relationships among neighbouring ecosystems. A boundary is placed around groups of ecosystems that are related, and that show similarities in both appearance and structure, for they are influenced by much the same climate, soil conditions, etc. Groups of spatially-related ecosystems can be considered as ecosystems of a higher order and commonly greater size, which we propose to call 'macroecosystems'. This terminology extends from the classical use of the term 'ecosystem' as proposed by Tansley (1935), in which the latter term is applied only to the smallest units. The units with related macroecosystems, herein referred to as 'ecoregions', seem to us similar in concept to 'ecobiomes' as proposed by Polunin (1984).*

Ecoregions naturally exist in often very different sizes, and can be identified at various scales and levels of detail in a hierarchical manner in any region. A hierarchy of boundaries will allow the incremental viewing of the world's environment from a very broad perspective or with greater and greater resolution at the more and more detailed sub-unit level. While the concept of ecosystem implies equality of level among all the component ecosystems of an ecoregion, all those components are not equally significant in defining levels in the hierarchy (Bailey, 1985).

* Our proposal of 'ecobiome' was strictly in deference to the need for scientific accuracy. The term biome having been proposed, and being widely and commonly used, for a *biotic* community of plants and animals, another term was needed 'comprising the biome *plus* all the involved inert components of soil, atmosphere, etc.' Though first used only in 1984, 'ecobiome' has already come into rather wide use—*inter alia* in our *Ecosystem Theory and Application* (John Wiley & Sons, Chichester–New York–Brisbane–Toronto–Singapore: xv + 445 pp., illustr., 1986)—for a collection of ecosystems that are characterized by dominance of a particular life-form. The present Authors' 'ecoregion' seems to us far wider and more suitable for their admirable purpose of categorizing regions on a world scale.—Ed.

The boundaries of ecoregions are determined to a considerable extent by climatic factors. The most important of those factors is the climatic regime, defined as the diurnal and seasonal fluxes of energy and moisture. As these change, the kinds and patterns of dominant life-forms of plants and animals change, as do the kinds of soils. From this it follows that the most important factor to consider in recognizing ecoregions is the climate. Such 'ecosystem regions' should reflect significant differences in climate. For this, the ecoregions should have the following six major attributes or groups of attributes:

First, the series of 'ecosystem regions' should express the changing nature of the climate over large areas. Unfortunately, climate changes within short distances owing *inter alia* to variations in local landform features and the vegetation that develops on them. It is necessary, therefore, to postulate a climate that hierarchically lies just above the local modifying irregularities of landform and vegetation. To this climate, the term 'macroclimate' is applied. As meteorological stations are too sparse in many areas, data are simply not available to map precisely the distribution of these ecological climates. Thus we substitute other distribution-bases which are the visible and tangible expressions of climate—such as, particularly, vegetation.

Second, the composition of the vegetation of the 'ecosystem region' changes with time in a sequence from pioneer vegetation through a successional series of intermediate steps to a relatively stable state called the climax (in the sense of Weaver & Clements, 1938; Polunin, 1960; Odum, 1983). The climax types are used to characterize regions because they tend to be far more site-specific than pioneer types, which may occur over a wider range of conditions.

Third, landform (with its geologic substrate, its surface slope, and relief) modifies macroclimate to local climate. Sites to be considered in regional delineation should be reasonably uniform sets of uplands, with well-drained surface, moderate surface-slope, and well-developed soils. In this manner the effects of landform differences are screened out, leaving the biologically effective climate as the main variable between regions. These sites correlate with zoned sets of ecosystems; the others are azonal.

Fourth, where stands of ecosystems cover large areas, in a quasi-uniform way, their mapping presents little difficulty. But simplifying and generalizing mountainous ecosystems into regions presents a more difficult problem. A suitable solution is to consider the sequence of altitudinal zones. Each part of a mountain range with the same sequence is a distinct ecological unit. These units correlate with the distribution of the lowland climatic zone within which the range is located.

Fifth, the mosaic of ecosystems found in major transitional zones (ecotones) should also be delineated as separate regions.

Finally, the boundaries of ecoregions emerge from the study of the spatial coincidences, patterning, and relationships, of climate, vegetation, soil, and landform. This is preferred to the superimposing of thematic maps by automated geographic information systems which create complications, because unit boundaries rarely conform to one another. This is also quite different from taxonomic methods which use cluster analysis of grid units to provide the map units. Often the best use of mathematical methods is after the fact, comparing and sharpening land units when once they have been mapped out by the application of ecological theory and good sense (Rowe & Sheard, 1981).

Useful scales for mapping 'ecosystem regions' may be from 1:30,000,000 to about 1:3,000,000.

Technique of Mapping Ecoregions

A technique for delineating these regions has been outlined elsewhere (Bailey, 1983), and a specific application of this technique has been developed and applied to the United States (Bailey, 1976, 1980), with later expansion to include also the rest of North America (Bailey & Cushwa, 1981). This technique grew out of earlier work by Crowley (1967). The system consists of a method for defining successively smaller ecoclimatic regions within larger regions. At each successive level, a different aspect of the climate and vegetation is assigned prime importance in the placing of map boundaries.

Four ecological levels are shown, with climate and vegetation as indicators of the extent of each unit. The broadest, *domains*, are based on observable differences that have developed largely because of prevailing climatic conditions. Then, on the basis of further climatic criteria, domains are broken down into categories called *divisions* which, on the basis of the climax plant formation that geographically dominates the area, are subdivided into *provinces*. Provinces are subdivided into *sections* which are the fundamental ecoregions and differ in the lifeform composition of the climax plant formation. Highland provinces and sections are distinguished where, as a result of the influence of altitude, the climatic regime differs sufficiently from that of adjacent lowlands to cause complex vertical climate–vegetation–soil zonation.

A total of 61 ecoregions were mapped at a scale of 1:7,500,000 at the section level for the United States. Fifty-six ecoregions were mapped at 1:12,000,000 which was the province level for North America. The explanation and part of that map are reproduced here as Table I and Fig. 1, respectively.

For the United States, Küchler's (1964) map of the 'Potential Natural Vegetation' was used in conjunction with maps of climatic regions as the base for delineating ecoregions. As a first step in regionalizing Küchler's map, all land areas were divided into lowlands and highlands, the pattern of montane vegetation, as exhibited on the map, being accepted as sufficient to identify those areas as a first approximation. Those areas were further refined by reference to Hammond's (1964) land-surface form map. Hammond's high mountains correlate well with the pattern of montane vegetation shown on Küchler's map (1964).

Within the lowland areas, sections and province boundaries were established by generalizing Küchler's map. The generalization was of two types. First, boundaries were simplified by eliminating enclaves and peninsulas that were deemed too small to show on the finished small-scale map. Second, there was a reduction in the number of Küchler types. Some of Küchler's mapping units show the presence of large areas of azonal soils, such as sand-plains and peat deposits. Those units were combined with surrounding zonal types in delineating provinces and sections; this relegated edaphically-controlled ecosystems to a lower level of classification and to more detailed maps than those showing sections.

Lowlands and highlands were then grouped into larger, ecoclimatic regions following the Köppen (1931) system. Köppen's system is simple, is based on quantitative criteria, and correlates well with the distribution of many natural phenomena, such as vegetation and soils.

Other bioclimatic methods for mapping zones at global or regional levels are those of Thornthwaite (1931, 1933), Holdridge (1947), and Walter & Box (1976). All use selected climatic characteristics that outline zones within particular general levels of vegetation homogeneity should be represented, for they also suggest a strong similarity of vegetation in equivalent bioclimatic zones in different parts of the globe. All of the methods appear to work better in some areas than in others, and to have gained their own following. Köppen's system has become the most widely-used climatic classification for geographical purposes, and was, therefore, taken as the basis for ecoregion delineation.

Particularly useful in delineating those ecoclimatic regions were the climatic map of the world, modified from the Köppen system (Trewartha, 1968) and the climatic map of North America (Thornthwaite, 1931). Boundaries of the climatic regions were altered in some cases to make them conform to potential vegetation boundaries.

This approach of using climate as the basis for delineating ecological regions has been partially tested and validated (Bailey, 1984). It is similar to the approach used in the FAO/UNESCO Agro-ecological Zones study for Africa (FAO, 1978).

In Europe, maps of forest regions such as those published by Rubner & Reinhold (1960), and of zones and sections published by Ahti *et al.* (1968), provide a good start for the recognition of 'ecosystem regions.' The UNESCO map of Mediterranean vegetation (UNESCO, 1970) could also be used to define such regions. Similarly, the forest vegetation zones of Japan (Shidei, 1974) provide a suitable starting-point for the further delineation of 'ecosystem regions.'

In more remote and less-studied regions, an alternative approach is to use remote-sensing imagery with its synoptic overview to look for zones where vegetation cover is relatively uniform. These zones are apparent in low-resolution imagery. The work of Tucker *et al.* (1985) in Africa provides a good demonstration of the utility of this technology in ecoregion mapping.

In some areas, problems resulting from disturbance and the occurrence of an intricate pattern of secondary successional stages make regional boundary placement particularly difficult. In such areas, those problems can be overcome by considering the pattern displayed on soil maps of broad regions such as the FAO/UNESCO World Soil Map (FAO/UNESCO, 1971–1978). Soils in general change far more slowly than vegetation, consequently providing a supplemental basis for recognizing ecosystems regardless of present land-use or existing vegetation.

A Project for Global Ecosystems Regionalization

Several international organizations and agencies—most notably the United Nations Environment Programme

TABLE I

Explanation of Portion of Ecoregions Map of North America Shown in Fig. 1.
(From Bailey & Cushwa, 1981, after J.M. Crowley, unpublished.)

	Lowland Ecoregions		Highland Ecoregions*
	100 POLAR DOMAIN		
120	TUNDRA DIVISION	H120	TUNDRA REGIME HIGHLANDS
	121 Low-arctic Tundra Province		M121 Brooks Range Province
	122 High-arctic Tundra Province		M122 Northeast Seaboard Mts Province
130	SUBARCTIC DIVISION	H130	SUBARCTIC REGIME HIGHLANDS
	131 Subarctic Parkland Province		M131 Alaska Range Province
	133 Boreal Forest Province		M132 Subarctic Rockies Province
			P133 Yukon–Sitkine Plateau Province
	200 HUMID TEMPERATE DOMAIN		
210	HUMID WARM-SUMMER CONTINENTAL DIVISION	H210	HUMID WARM-SUMMER CONTINENTAL REGIME HIGHLANDS
	211 Laurentian Mixed Forest Province		M211 Columbia Forest Province
			P212 Fraser-Nechako Plateau Province
220	HUMID HOT-SUMMER CONTINENTAL DIVISION		
	221 Eastern Deciduous Forest Province		
230	HUMID SUBTROPICAL DIVISION		
	231 Outer Coastal-plain Forest Province		
	232 Southeastern Mixed Forest Province		
240	HUMID MARITIME DIVISION	H240	HUMID MARITIME REGIME HIGHLANDS
	241 Willamette–Puget Forest Province		M240 Pacific Forest Province
250	SUBHUMID PRAIRIE DIVISION		
	251 Prairie Parkland Province		
	252 Prairie Brushland Province		
	253 Tall-grass Prairie Province		
	254 Aspen Parkland Province		
260	MEDITERRANEAN DIVISION	H260	MEDITERRANEAN REGIME HIGHLANDS
	261 California Grassland Province (Central Valley)		M261 Sierran Forest Province
			M262 California Chaparral Province
	300 DRY DOMAIN		
310	SEMI-ARID STEPPE DIVISION	H310	SEMI-ARID STEPPE REGIME HIGHLANDS
	311 Great Plains Shortgrass Prairie Province		M311 Rocky Mountain Forest Province
	312 Palouse Grassland Province		M312 Upper Gila Mts Forest Province
	313 Intermountain Sagebrush Province		M315 Sierra Madre Occidental Province
	314 Mexican Highlands Shrub Steppe Province		M316 Sierra Madre Oriental Province
	315 Sinaloa Coast Province		P313 Colorado Plateau Province
	316 Rio Grande Shrub Steppe Province		A314 Wyoming Basin Province
320	ARID DESERT DIVISION	H320	ARID DESERT REGIME HIGHLANDS
	321 Chihuahuan Desert		M321 Baja California Province
	322 American Desert Province (Mojave–Colorado–Sonoran)		
	400 HUMID TROPICAL DOMAIN		
410	TROPICAL SAVANNA DIVISION	H410	TROPICAL SAVANNA REGIME HIGHLANDS
	411 Everglades Province		M412 Sierra Madre del Sur Province
	414 Campeche–Yucatan Savanna Province		A413 Central Mexico Province
	415 Pacific Savanna Woodland Province		
420	TROPICAL RAIN-FOREST DIVISION	H420	TROPICAL RAIN-FOREST REGIME HIGHLANDS
	421 Caribbean Coast Rain-forest Province		M421 Central American Ranges Province

* Key to letter symbols: H = Highlands; M = Mountains; P = Plateau; A = Altiplano

(UNEP) and IUCN—have expressed an interest in expanding ecoregion mapping technology world-wide. In addition, the International Union of Forestry Research Organizations (IUFRO) has called for a global ecosystem regionalization effort. Accordingly, we propose to develop a small-scale map of world ecoregions showing three hierarchical levels—domain, division, and province—using the above technique. This is the same level of detail as is shown on the North American map (Bailey & Cushwa, 1981; cf our Fig. 1 and Table I), and can be built on to indicate sections representing fundamental ecoregions (*see* above).

The map will be based on published information and personal experience. Maps based on classifications of climatic types, vegetation formations, and soil groups, will be synthesized and generalized to delineate the areas to be shown on the world map. The ability to make this synthesis on a global basis depends on the availability of accurate maps of similar scale and level of generality. Because of the variability of existing maps, it will be necessary to make subjective judgments of the relative accuracy and level of generality of each map. In order to overcome the shortcomings resulting from inaccuracies in any one source, boundaries will be positioned by reference to correlative changes in several ecological components. This will be done visually.

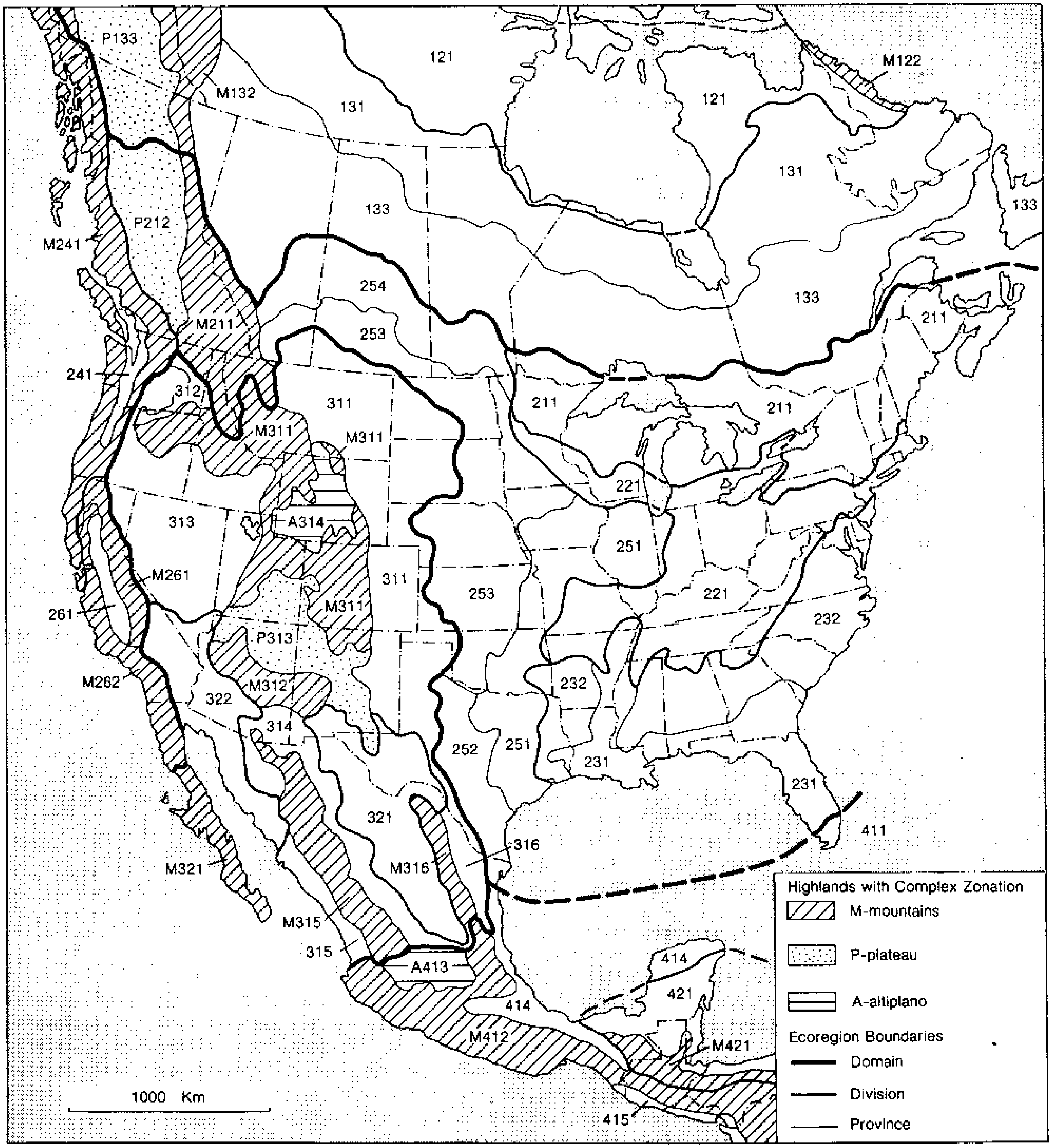

FIG. 1. *A scaled-down version in black-and-white of a portion of an ecoregions map of North America.* See *Table I for explanation. (From Bailey & Cushwa, 1981, after J.M. Crowley, unpublished.)*

Map delineations will be refined through consultation with local experts, and through interpretation of low-resolution remote-sensing imagery. Statistical analyses (such as those applied to the United States map by Bailey, 1984) will also be attempted to sharpen the delineations. Data gathered from 4,000 stations by Walter & Lieth (1960–1967) in their *Climadiagram Atlas* will most likely be used in this analysis.

Phase I

Ecoregions will be displayed at a scale of 1:25,000,000, which is small enough to allow the world to be shown in a convenient format on a single sheet. At the same time, this scale is large enough to display adequately three levels of ecoregion units.

The base-map will be similar to ones used on the FAO/UNESCO (UNESCO, 1979) maps of arid regions and desertification. The map will be accompanied by a description of the principal climatic, hydrologic, edaphic, and botanical, characteristics of the regions. Land-use practices in these areas will also be covered.

Phase II

While it has been documented that ecoregions are useful in estimating resource productivity and likely response to management–conservation practices, there are other issues that cannot be addressed at this level of resolution. As many policy considerations centre on soil characteristics, additional levels may need to be defined in which soils are explicitly included.

A specific region will be identified in Africa to explore the possibility of forming linkages between the Phase I map and a soils map of the region. This may involve extending the Phase I map to section or lower levels in the hierarchy where soil differences control the location of ecosystem boundaries. The attributes that make up soil groups can, in part, be inferred from other map sources, and can be used to refine and further subdivide ecoregion boundaries. Methods to infer these attributes will be explored. The likely scale of the Phase II map will be 1:3,000,000.

Potential Benefits

Development of a global ecoregions map will identify ecological units that can supplement the Dasmann–Udvardy system in two ways:

1. Because they are based on a correlation of several features of the landscape, subdivisions on the map show units that (theoretically) should be of greater ecological relevance than the original divisions. These units can be used to refine and revise biogeographical province boundaries.

2. It provides a more detailed breakdown of the world's macroecosystems (e.g. there are 31 ecoregion provinces identified for the United States as compared with 16 biogeographical provinces). This provides a basis for subdividing biogeographical provinces in an ecologically meaningful way.

In addition to biogeographical province mapping, there are a number of applications for the ecoregion concept—including those that improve our ability to bring data together in a more meaningful way than hitherto for planning, management, and conservation of natural resources. Several examples are described next below.

National-level Policy Analysis

The demand for resources is derived from the demand for the products which can result from their use. This derived demand is met by a resource supply that has both quality and quantity dimensions. Conservation policies may be formulated to control, restrict, or encourage, the more efficient use of resources, to minimize the degradation of the resource-base, and to meet other national goals. The analysis of these policies and implementation programmes requires a comprehensive knowledge of the interaction between resource demand, the quantity of the resource currently and potentially available, and the risks associated with their use. Some specific examples of policies that impact on the resource-base are:

- Foreign exchange earning or importation supplanting agricultural production programmes;
- Improving regional nutritional levels, particularly in areas without shipment/storage infrastructure;
- Directed growth to either protect or control use of key resource stocks;
- Balanced regional growth to avoid extreme regional income disparities; and
- Food security programmes.

In each of the above cases, a resources inventory, baseline estimates of resource use, and monitoring of change in use or condition by ecoregion, is useful if not essential for policy evaluation. This is because, in each case, issues such as resource suitability for alternative uses—including crop mix and the management required to assure sustainable productivity—are involved.

Environmental Monitoring

Monitoring stations that are representative of broad areas will provide more useful data than those selected otherwise. A regional approach as described here will provide a geographical framework for selecting sites in such a way that data will be regionally applicable.

As the results of monitoring programmes and of more intensive surveys are reported—such as of 'acid rain', atmospheric CO_2, desertification, etc.—they will have more applicability and will be more easily understood than hitherto. An ecoregional perspective will aid in the organization and interpretation of results of these studies by providing a context for generalizing and extrapolating from the available data, thereby broadening the utility of such information.

UNEP has recently initiated a global environment monitoring system (Gwynne, 1982). This system can be most effective if used within a framework of ecological regions.

Transfer of Agricultural Technology

It is known that individual soils, found in different areas of the world, commonly respond similarly to particular fertilizer etc. inputs. It is not known, however, where and to what extent these soils exist around the world. Consequently, the massive amount of crop response and crop management data that is available cannot be effectively utilized. Because the conduct of a full soil survey for a country or region is a lengthy and costly undertaking, there has been significant recent activity in defining a minimum data-base for technology transfer (ICRISAT, 1984). This work can be facilitated with an ecoregion map, particularly if a formal ecoregion-to-soil linkage can be made.

Improving Remote Sensing-based Systems for Monitoring Environmental Conditions and Agricultural Activities

Generally there are two choices for monitoring very large geographic areas with remote sensing. A low-resolution sensor (to minimize data volume), such as the Advanced Very High Resolution Radiometer (AVHRR) on meteorological satellites, can be used for full coverage. (Note: AVHRR is high-resolution in terms of meteorological satellites, but it is low-resolution in comparison with Landsat.) Alternatively, a sampling strategy can be devised for use with a high-resolution instrument that would permit more detailed analysis than hitherto without the very large data-volumes that are normally associated with the large-scale application of those systems. One approach in the latter case might be to develop ecoregion strata within which a sample of high-resolution data could be taken. An alternative is to utilize zones developed with the AVHRR for sample strata, and use high-resolution sensors in a multi-stage sampling strategy. In many ways these are equivalent procedures because the AVHRR is a proxy for the ecological region—but it does not provide by itself the required physical description of the different regions.

Estimation of Vegetative Biomass from Satellite Imagery

The use of satellite imagery for global biomass estimation has been proposed (Logan, 1985). Such estimates involve the development of relationships between biomass and spectral values, which relationships take the form of multivariate regression models. Numerous research workers have established linear and near-linear regression relationships for agricultural and grassland environments. However, as the vegetative environment becomes heterogeneous (e.g. with added species, increasing trees, so classically progressing towards forestation), the biomass–spectral relationships become progressively more non-linear, reducing the reliability of regression techniques. This has led to the observation that different biomass–spectral relationships exist for each vegetative environment (or ecoregion). Therefore, relationships developed by ecoregion should be more reliable than those developed otherwise.

Selection of Areas for Biological Conservation

One of the prime uses of biogeographical provinces is in the selection of areas for biological conservation, and, in particular, for UNESCO's international network of Biosphere Reserves. The selection process relies on the Dasmann–Udvardy system to define broad regions for consideration. However, considerable subdivision is usually needed to identify subregions of distinct climate, soils, and vegetation, in order to assure adequate representation of the characteristic ranges of ecological conditions, processes, and biota, in Biosphere Reserves and other types of macroreserves. The ecoregion approach can accomplish this at the level of resolution needed for macroreserve selection.

Land Management

Ecoregions delimit large areas within which local ecosystems recur more or less throughout the region in a predictable fashion. By observing the behaviour of the different kinds of systems within a region, it is possible to predict the behaviour of an unvisited one.

Ecoregions have two important functions for management. First, a map of such regions suggests over what area the knowledge about ecosystem behaviour derived from experiments and experience can be applied without too much adjustment. Second, they provide a geographical framework in which similar responses may be expected within similarly-defined systems. It is thus possible to formulate management policy and apply it on a regionwide basis rather than a site-by-site basis. This increases the utility of site-specific information and cuts down on the cost of environmental inventories and analysis.

Concluding Notes

We have underscored the utility of the Dasmann–Udvardy system on several occasions. In the United States, the adjustments in the biogeographical province boundaries to correspond with ecoregion boundaries were relatively minor. The biogeographical provinces tend to be broader than ecoregion provinces, the latter being subdivisions of higher resolution. Assuming that this is the case elsewhere, we would predict that major changes in the number and boundaries of biogeographical provinces would not result. Therefore, the administration of programmes which are keyed to such units would not be greatly affected.

Although this proposal is world-wide in scope, application at sub-world levels can be effected. As was done in the United States and for North America, other countries and continents could be mapped—to continue towards the production of a world map.

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Summary

An international project is proposed to create a map showing the world subdivided into macroecosystem regions within each of which ecological conditions are relatively uniform but which show certain natural potentials and limitations. The map should tend to supplement the Dasmann–Udvardy system of biogeographical provinces, being of higher resolution and greater ecological relevance. The primary purpose of the map will be to serve as a reporting structure for information about global resources and environment, though it will be based largely on published information.

Maps based on classification of climatic types, vegetation formations, and soil groups, will be synthesized and generalized to delineate the areas to be shown on the ecoregion map. Its delineations will be refined through consultations with local experts, and through the interpretation of low-resolution remote-sensing imagery. The usefulness of the map is considered favourably in relation to

national-level policy analysis, environmental monitoring, transfer of agricultural technology, compatibility with remote-sensing systems for monitoring environmental conditions, and agricultural activities, biomass estimation, macroreserve selection, and land management.

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