Changes in Land Use and Land Cover:

A Global Perspective

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Toward a Typology and Regionalization of Land-Cover and Land-Use Change: Report of Working Group B

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Making sense of changes in global patterns of land use or land cover requires drastic simplification. The complexity of changes on the world scale easily defies the most acute and informed observer. But simplification is no simple process. To be useful it must bring out into sharp relief what is most important and relegate to obscurity what can most safely be ignored. Hard decisions and expert judgments are necessarily involved. In making these decisions and judgments we are acutely aware that others might well have been made in their stead, and perhaps with equal justification. We regard our work as a first step that we hope will help others to take long strides toward a more complete understanding of global patterns of land-use and land-cover change.

The Objective: A Comprehensive Schema

Our aim is to provide a comprehensive analytic framework that will lead to a systematic typology, and ideally a scheme of regionalization, of land-use/land-cover change. We call this framework a schema. Regrettably but inevitably, the framework cannot include every instance of change; we have instead tried to capture the major and most important varieties of land-use and land-cover change. The major changes are those of great magnitude, defined by the area involved or the numbers of people affected. The most important changes (a set that obviously intersects with the set of major changes) are distinguished by their criticality from the points of view of human and scientific concern. For instance, certain land-cover changes, even ones small in magnitude, have extreme social costs, while others have few or none. The costly ones we regard as more important from the human point of view. Other changes, not necessarily large in magnitude, have vast consequences from the point of view of biogeochemical flows or of biodiversity. In concentrating on the largest-scale and most important types of land-use and land-cover change we intend also to isolate and identify the most interesting types from the point of view of research

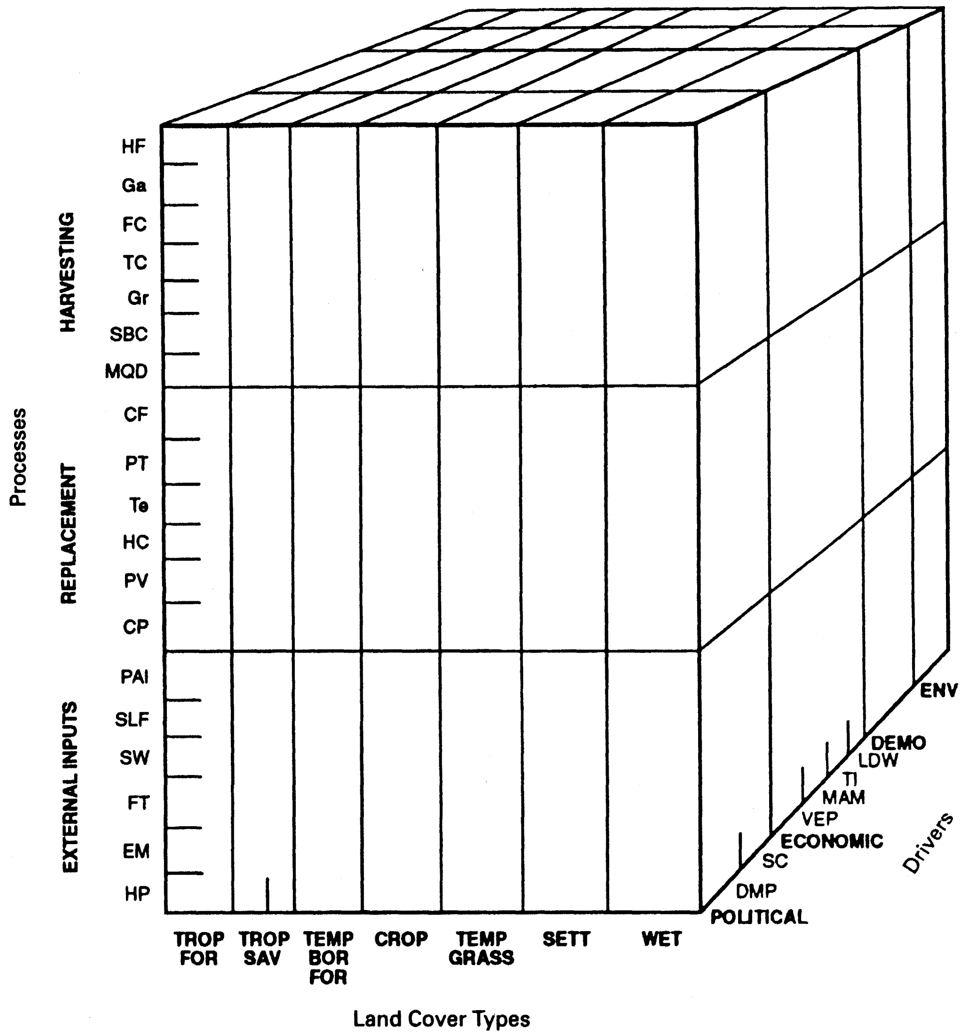

Figure 1. The cube

Land cover types

TROP FOR	Tropical forest
TROP SAV	Tropical savanna and grassland
TEMP BOR FOR	Temperate and boreal forest
CROP	Cropland
TEMP GRASS	Temperate grassland
SETT	Settled and built-up area
WET	Wetland

Drivers

Political	
DMP	Decision-making process
SC	State capacity
Economic	
VEP	Vulnerability to external pressure
MAM	Market allocation mechanism
TI	Technological intensity
LDW	Level and division of wealth
DEMO	Demographic
ENV	Environmental

needs. We hope our schema not only will lead to a deeper understanding of global change, but also will point to questions and cases that deserve high priority as research subjects. In the new and necessarily confused world of global change research, helping to sharpen the definition of research agendas is no small ambition.

Towards a Typology: The Axes and the Cube

Specific instances of change in land use or land cover may be defined by any set of characteristics. Possible examples include the duration, intensity, purpose(s), and consequence(s) of change. But confining ourselves to the most distinguishing characteristics, and keeping matters simple, we have selected only three, which taken together give a reasonably precise idea of any given land-use or land-cover change. These are:

- The *land-cover type* in which any given change takes place
- The *driving forces* producing change
- The specific *processes of conversion* of land cover.

Any single transition in land use or land cover can be analyzed from these three perspectives. Imagined in three-dimensional space, these three characteristics form axes, which taken together define a block or cube, in which every example of land-cover/land-use change occupies certain spaces (see Figure 1). After some elaboration of each of these axes, we will discuss how this schema works. In the appendix to this chapter, the schema is applied to actual cases of land-use or land-cover change.

Land-Cover Types

Scholars have created numerous classification systems of land cover. Each has its merits and its faults, and is appropriate for certain uses but not others. Ours has its

Caption for Fig. 1. *(cont.)*

Processes

Harvesting

HF	Hunting/fishing
Ga	Gathering
FC	Fuelwood cutting (industrial and domestic
TC	Timber cutting
Gr	Grazing
SBC	Slash-and-burn cultivation
MQD	Mining/quarrying/ drilling

Replacement

CF	Clearing/firing
PT	Plowing/tilling
Te	Terracing
HC	Hydrological control (irrigation, drainage)
PV	Planting or vegetation change
CP	Construction, paving, earth shaping

External Inputs

PAI	Plant or animal introductions
SLF	Supplementary livestock feed
SW	Supplementary water
FT	Fertilizer/trace elements
EM	Energy/machinery
HP	Herbicides/pesticides

faults (it is not all-inclusive, for example), but has the merit of reflecting the concerns of scientists interested in global land-use and land-cover change. We think it is the most appropriate system of classification for our purposes. It includes seven major types of land cover (see Table 1). Some of these are zones of natural vegetation; others represent land uses. But in every case, they describe what actually occupies the land.

The hard decisions and expert judgments behind this classification system of land-cover types rest upon criteria that ought to be made clear. First, we have included cover types that are important to global change research from the points of view of (1) the physical climate system on the global scale, (2) regional and continental energy and water balances, (3) global biogeochemistry, (4) atmospheric chemistry, and (5) biodiversity. Second, we have emphasized cover types important to the human dimensions of global change research as revealed in (1) land quality, soil fertility, and biodiversity (again); (2) sustainable development, sustainable agriculture, and resource development issues; and (3) land tenure, land access, and land-use issues. Beyond these two general guidelines governing our choices, we have also given weight to considerations of the current rate and magnitude of changes, to the simple areal extent of cover types, and, bowing to necessity, to gaps and uncertainties in available data. How these criteria for selection led to the seven cover types represented in our classification scheme is explained briefly in the second column of Table 1. The land-cover types in the table are arranged from most to least important according to the criteria listed above.

The underlying choices were hard, but the resulting classification scheme is simple. While this is a virtue not to be discarded rashly, the system may easily be expanded and/or subdivided to provide more complete coverage of the globe or to distinguish more finely among land-cover types. Indeed, one could easily create a classification system that recognized the gradients between desert and grassland and forest. For the moment, however, we prefer the simplest formulation that captures the most important varieties of land cover.

Driving Forces

The motors of land-cover/land-use change are countless. Some act slowly (and often obscurely) over centuries, while others trigger events quickly and visibly. In every case, several forces are at work, sometimes operating independently but simultaneously, sometimes operating synergistically. No aspect of global change is more complicated than the driving forces.

Our system of classification of driving forces, like our land-cover classification system, is one among many possible such schemes. It represents a theoretically informed set of choices and distinctions, designed specifically for the purposes of capturing the most consequential human and environmental causes of land-cover/land-use change. The major categories of driving forces are political, economic, demographic, and environmental (see Table 2). Within these broad categories, we identify specific attributes that strongly influence land-use and

Table 1. Important land-cover types

Cover Type	Rationale	Location
1. Tropical forest	• Large conversion extent • High rate of change • Wet regimes, high trace gas flux • Climate/water influence • Biodiversity • Difficult soil management • Sustainable development • Largest frontier • Developing countries • Typology for agricultural and commercial enterprise, geopolitical/	Amazon, West Africa, Southeast Asia, Central Africa, Central America
2. Tropical savanna and grassland	• Large extent of occupation • Large conversion extent • High rate of change • Frequent burning, non-CO_2 trace gases • Sustainable development • Dwindling frontier	Brazil, Sahel-Sudan, South Africa
3. Temperate and boreal forest	• Commercial timber harvest is dynamic • Agriculture unknown • Potential sink • Land intensive • Indirect effects	U.S., USSR, Europe, Canada, Scandinavia
4. Cropland	• Land intensive = trace gas • Land extensive = CO_2 • Rapidly increasing area • Tenure conflict • Sustainable development issues • Impact on frontier	Global
5. Temperate grasslands	• Unknowns in key regions: central Asia • High soil carbon • Potential degradation	
6. Settled and built up	• Extent unimportant • Sphere of influence could be important: core/periphery	
7. Wetlands	• High loss rate, large area uncertainty	

land-cover patterns. Each of these attributes can be expressed as a variable or set of variables. For example, almost every land-use or land-cover change takes place within a political context. At some level, international, state, or local, a decision-making process—or perhaps several of them—is involved. This process might be one with high public participation in an open system in which power is decentralized; or it might be just the opposite, a process in which few people are involved, exclusion rather than openness prevails, and power is centralized. Each polarity—

Table 2: Driving forces behind land-use change

Attribute	Variable	Kinds of Indicators
1. Political		
Decision-making process	Degree of public participation (open/closed, centralized/ decentralized	• Unitary or federal structure • Number of special-interest groups
State capacity	Public sector pressure/ influence	• Public sector expenditure/GDP • Public/total land area
2. Economic		
Vulnerability to external pressure (economic/ political)	Open vs. closed economy	• Exports/GDP • Partner concentration
	Primary sector dependence	• Primary sector exports/ total exports
	Type of exchange rate management	• PEA (Population economically active) agriculture/PEA total • Real exchange rate • Debt service ratio
Market allocation mechanism	State controlled, market driven	• Agricultural subsidies • Public sector expenditure/GDP
Technological intensity	High-low	• Energy intensity of GDP
Level and division of wealth (asset inequality)	Wealth/poverty-induce consumption	• Primary sector/GDP • Energy consumption/ capita • PEA agriculture/PEA total • Percent absolute poor in total population
3. Demographic		
Population pressure on the land	High-low	• Cultivated/arable land • Change in population density • PEA agriculture/PEA total
4. Environment		
Natural resource quality	Scarcity	• Stock, yield, flow

centralized vs. decentralized, e.g.—can be visualized as a continuum. Every polity falls somewhere along these continua. To know where, one must use indicators that provide an approximation of the degree of centralization or the degree of public participation in a given polity. The third column of Table 2 provides a list of appropriate indicators for each of the variables we find useful in characterizing driving forces. Most of these indicators are quantitative measures, although some are cruder instruments permitting only yes/no statements. Inevitably, some indicators are more amenable than others to precise measurement. This is part of the devilish complexity of dealing with the driving forces of global change.

Our system of classification differs from others in several respects. First, it gives great weight to the economic and political differences among societies. This is essential, because the same climatic or even demographic pressures can produce sharply different results in different political and economic circumstances. Recognizing the distinctions among political and economic systems, even on a fairly rudimentary basis, is a step away from crude demographic or climatic determinisms. Second, we have incorporated technology into the broader category of economic attributes rather than designating it as a major driving force in its own right. We do not consider technology to be a major determinant of land-cover or land-use change on the global scale. Technologies appear to us as social responses to needs and opportunities, devised, diffused, and used wherever they do well what people want done. It is the needs and opportunities that motivate people to adopt a given technology that seem to us fundamental.

This is a view that will leave many scholars uneasy, including some members of our working group. Certainly there are many historical examples that seem to run counter to it. To choose only one, the adoption of the heavy plow in the Russian steppes after the 16th century permitted the extensive conversion of grasslands to croplands in southern Russia and the Ukraine for several centuries. Without the right technology, that land-cover change could not have happened. But, equally, without the demographic expansion of Russian population, the new market opportunities that large-scale grain producers enjoyed, and the increasing military dominance of the Russian state over the pastoral peoples of the steppe, the change would not have happened either. In this example, all elements of the mix were necessary to produce the land-use change. In the modern world we find this to be true more rarely. More commonly it seems to be the case that social, political, economic, and demographic circumstances summon applicable technologies, and that the technologies themselves are not major variables. The chief exception is in transport technology. The presence or absence of transport infrastructure is so important that it commands special attention. The conspicuous difference in land-cover change between Zaire's tropical forests and Brazil's is in large part a direct result of the absence or presence of roads. However, even in this case, the construction of Brazil's Amazonian roads was in large part the result of political decisions.

A second noteworthy feature of our classification system for driving forces is the absence of any overt consideration of culture. All scholars working on land-use/land-cover change grant culture some importance, but most despair of forming any useful generalizations about it. Great discrepancies arise when one studies what people say, what they believe, and how they behave. The most accessible of these—what people say—is probably least relevant to land-use/land-cover change, and the most relevant is unhappily also the most difficult to ascertain and measure.[1] Furthermore, culture is so localized, so fragmented, and so mutable in most societies

[1] L. Arizpe, the Working Group B leader, prefers the view that what people say is especially important to understanding cognitive and political negotiations that have to take place to change people's land-use practices. (See also Rockwell, this volume.)

that it defies scholars' attempts to give it due weight. Only in local studies, where variations are minimized, is culture easily factored in to explanations of land-use or land-cover change. We have no simple solution to these problems. To some extent, cultural differences are present behind the political and economic variables that figure prominently in our classification scheme. Indeed, catching the manifestations of cultural traits indirectly, through political, economic, and even demographic variables, provides a more manageable approach to culture's impact on land use than the direct one, which so confounds measurement and generalization.

This axis, like the land-cover type axis, could easily be amended to be more inclusive or more refined in its distinctions. Our choices and judgments represent a compromise between simplicity and full accuracy.

Land Conversion Processes

This third axis of the cube in Figure 1 represents purposeful human activities aimed at increasing the productivity of land (whatever their real consequences). We have arrived at 19 discrete processes that have direct impacts on land cover and land use, and also have clear purposes, if often unclear side effects. These 19 processes are grouped for analytic convenience into three main categories: (1) harvesting, which is the appropriation of natural products resulting in modification but not conversion of land cover; (2) replacement, i.e., the conversion from one land cover to another; and (3) transfer, meaning processes that import from an external source additional resources or energy in an effort to improve or intensify production. The specific processes in each of these three broad categories are listed in Figure 1.

To our knowledge this system of classification is unique in trying to lend coherence to the welter of specific human actions affecting land use and land cover. Like the other axes, it is potentially subject to expansion or contraction. The present set of choices aims not to be all-inclusive, but merely to represent the principal mechanisms of land-use and land-cover change abroad in the world today.

From the Three Axes to a Typology

Every case of land-use or land-cover change takes place within a specific land-cover type or types, has certain specific driving forces that cause it, and consists of certain specific processes of conversion from one land use or cover to another. Hence every case, if analyzed from the perspectives represented by the three axes of Figure 1, can be plotted within three-dimensional space. Every case occupies a set of minicubes, each of which represents the intersection of a given land-cover type, a given driving force, and a given land conversion process. This set of minicubes we call a constellation, to emphasize that in practice the set is not likely to be contiguous. Obviously, several driving forces and often several conversion processes will be at work in any given case. As a hypothetical example, let us say that in a tropical forest zone, population pressure, security concerns of a military government, and foreign capital investment are driving conversion from forest to settled land and to cultivated land. This case would occupy 12 minicubes to account for all intersections of tropical forest land cover with the demographic, political (state capacity), and economic (vulnerability to external pressure) drivers and with the following processes: clearing/firing, plowing/tilling, slash-and-burn cultivation, and planting or vegetation change.

Translating the characteristics of a given case into the appropriate minicubes is not a mere mechanical business. Careful judgments are required, especially in identifiying the key driving forces. Is an internal colonization scheme sponsored by the military best captured as 'high state capacity' or as some other political attribute? In many instances modest amounts of research would be needed to generate the data and the judgments necessary to translate a case reliably into a constellation of minicubes. But if this can be accomplished, this method of analysis summarizes precisely what is going on, where, and why in any given case.

The next step is to amass and analyze cases. Imagine 20 or, better yet, 100 cases plotted in three-dimensional space and translated into 100 constellations. One is now in a position to ask, and answer systematically, a series of questions that will lead to the distillation of large numbers of cases into a few prototypical 'situations.' With 100 constellations to compare, one could easily examine how these relate to one another in space. Do the constellations cluster together? Which constellations overlap and where? Are there minicubes, or sets of minicubes, that show up again and again in the constellations? Do similar sets of driving forces and conversion processes operate in different cover types, or are the same cover types playing host to similar driving forces and/or conversion processes? There is probably no end to the variety of questions researchers might wish to ask of the data. This is perhaps the most appealing promise of our construct: the possibility of reducing the daunting irregularity of existing ecological, economic, political, social, and demographic data to a common template so that systematic and precise comparisons can be made and a clearer idea of what is afoot in global land use and land cover can be obtained. Naturally something is lost in reducing the irregular data that most closely correspond to the real world to a common template. But without this step, however brutal, comparison, typing, and aggregation among individual cases rest on impressions and intuitions: more an art than a science. We will return to this question of data and their handling below, when we take up the subject of further research.

With 100 cases plotted as constellations, and then compared and analyzed, it would be possible to map cases or groups of typical cases ('situations') on any scale desired, local, regional, or global. The visual display of the information yielded by our methods will be a simple and, we hope, extremely useful and revealing step.

The Time Dimension

Translating land-use or land-cover change data into easily comparable constellations of minicubes provides only a snapshot of what is happening. A more com-