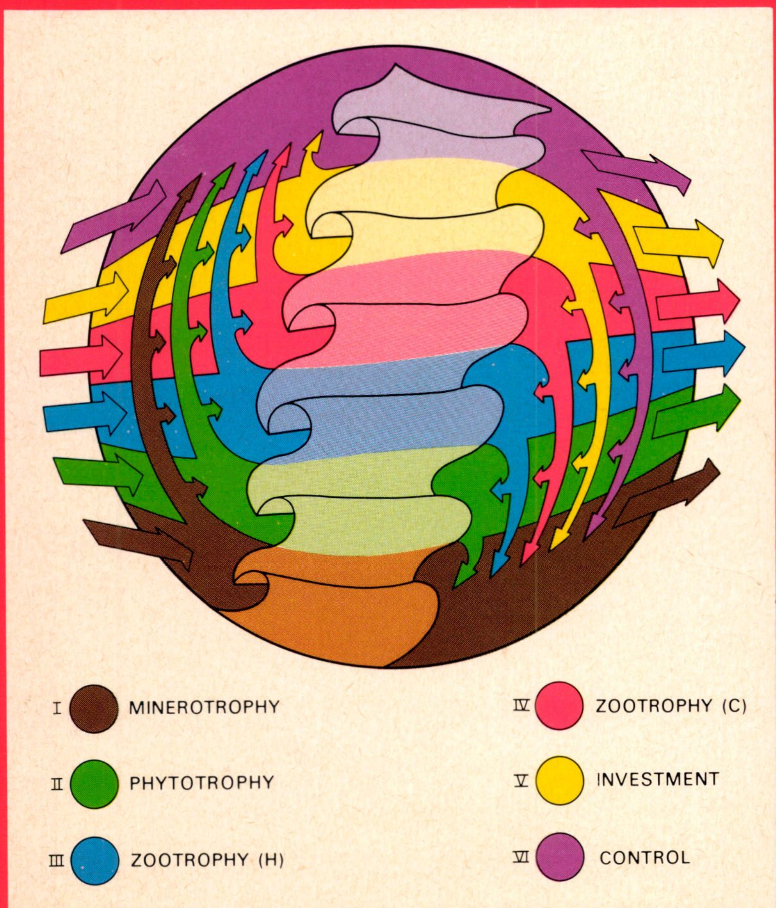
GEOGRAPHICAL PAPER No. 58

Ecological Grading and Classification of Land-Occupation and Land-Use Mosaics



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Lands Directorate
Direction générale des terres

Geographical Paper No. 58

Ecological Grading and Classification of Land-Occupation and Land-Use Mosaics

I. Presentation of a New System
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II. Mapping Methods and Problems
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Preface

The work of Dr. Pierre Dansereau in the application of the science of ecology to an understanding of human interactions with the environment and in the development of new rules of stewardship and responsible plans for environmental management is well known. The Lands Directorate, Environmental Management Service, Department of Fisheries and the Environment, is pleased to publish in the Geographical Paper series further work by Dr. Dansereau as a contribution to the general knowledge in this field.

R. J. McCormack
Director General
Lands Directorate

Préface

Les travaux de M. Pierre Dansereau relatifs à l'application de la science de l'écologie à la compréhension des interactions de l'homme avec l'environnement et à la mise au point de nouvelles règles de gestion et de plans pour la gestion responsable de l'environnement, sont bien connus. La Direction générale des terres du Service de la gestion de l'environnement du ministère des Pêches et de l'Environnement est heureuse de publier dans la série des Études Géographiques d'autres travaux de M. Dansereau qui contribuent aux connaissances générales dans ce domaine.

Le directeur général
R. J. McCormack
Direction générale des terres

Abstract

I. PRESENTATION OF A NEW SYSTEM

In a brief review of the principal and most influential systems for classifying land uses, the underlying criteria and the principal applications are considered. Whereas the value and usefulness of the World Land Use Survey and of the Canada Land Inventory are fully recognized, it is proposed to consider a new system more uniformly based on ecological criteria and less narrowly geared to the yields that are useful to man.

A shift, therefore, is made from *use* to *occupation*, and a model of the ecosystem is introduced as background to the definition and placement of ecological land-occupation types.

Four *panels* are recognized: A. Many parts of the planet are, to this day, very little affected by man's activity, and can be called *wild*. B. Others are much modified, and often cover very extensive areas, primarily for the production of a small number of foodstuffs (vegetable and animal), but sparsely occupied by man himself; these are called *rural*. C. The intensive, and always localized, application of technology by man permits manipulation of several kinds of raw materials, extracted, distributed, transformed by a number of *industrial* processes. D. The building of shelters, houses, stores, the development of communal services, and the congregation of dense populations create an *urban* environment.

These four panels reflect four steps in the escalation of human impact on the landscapes of the world. Each one is subdivided into 5 to 7 *blocks*, which are ordained according to the trophic level that predominates (e.g., industrial extraction of: I. mineral, II. vegetable, III. animal materials) and in an ascending scale of energy output (e.g., industrial extraction [block 1], transport lines [block 2], energy production [block 3], manufacturing [block 4], services [block 5]).

To these first and second digits, a third is added, characterizing the ultimate *type* (e.g., sand pit). The full formula thus reads, for instance: $\frac{\text{C 1 L,}}{\text{V,I}}$

where C is industrial panel,
1 is block 1 (extraction),
L is sand,

Résumé

I. PRÉSENTATION D'UN NOUVEAU SYSTÈME

Une brève recension des principaux et plus importants systèmes de classification de l'utilisation des terres invite à en considérer les critères sous-jacents et les applications. Quoique la valeur et l'utilité du World Land Use Survey et de l'Inventaire des Terres du Canada ne soient pas contestables, nous proposons un nouveau système basé plus uniformément sur des critères écologiques et moins étroitement dépendant des bénéfices afférents à l'homme.

L'attention se porte donc sur l'*occupation* plutôt que sur l'*utilisation*, et un modèle de l'écosystème est introduit comme l'arrière-plan à la définition et au placement des types écologiques d'occupation des terres.

Quatre *volets* sont reconnus. A. Plusieurs parties de la planète, encore aujourd'hui, sont à l'état *sauvage*, étant peu affectées par l'activité humaine. B. D'autres sont fort modifiées, et souvent sur des étendues considérables, surtout pour la production de matières nutritives (végétales et animales), mais peu densément occupées par l'homme lui-même: on les appelle *rurales*. C. L'application intensive, et toujours fortement localisée, de la technologie par l'homme permet la manipulation de diverses matières premières, extraites, distribuées, transformées grâce à nombre de processus *industriels*. D. La construction d'abris, maisons, magasins, la mise sur pied de services communautaires, et la congrégation de populations denses créent un environnement *urbain*.

Ces quatre volets correspondent à quatre stages dans l'escalade de l'impact humain sur les paysages du monde. Chacun est subdivisé en 5 à 7 *blocs* ordonnés selon le niveau trophique prédominant (e.g., extraction industrielle de matière I. minérale, II. végétale, III. animale) et sur une échelle de dépense énergétique ascendante (e.g., extraction industrielle [bloc 1], voies de transport [bloc 2], production d'énergie [bloc 3], manufacture [bloc 4], services [bloc 5]).

A ce premier et second membre un troisième est ajouté, désignant le *type* (e.g., la sablière). La formule complète se lit alors comme suit: $\frac{\text{C 1 L}}{\text{V,I}}$

V is investment,

I is mineral

Whereas existing systems for classifying and mapping land generally do not provide groupings of the ultimate units in related series, the Ecological Land-Occupation scheme does attempt an ecological weighting and a placement within parallel series. A number of cases are offered to show the relays of trophic charges, whether a shift in occupation of a particular site comes about through spontaneous change or through human intervention.

II. MAPPING METHODS AND PROBLEMS

The Ecological Land-Occupation scheme is essentially devised for mapping.

Where it is possible to use colour, the following gamut has been chosen: A, blue for the wild panel; B, green for the rural; C, yellow for the industrial; D, red for the urban. Within each panel, the intensity of colour increases from very light in the lowermost block (1) to very dark in the topmost (5, 6, or 7).

Where it is necessary to resort to black-and-white, A (wild) is shown in stipples; B (rural) in horizontal lines; C (industrial) in shaded tones; and D (rural) in grids. The blocks, in ascending order, show finer texture and darker ground.

As for the ultimate letter symbol that corresponds to the *type*, it must be superimposed upon the coloured or textured background of the cell. Whereas it seems useful also to indicate the block (1 to 7) by a symbol, it is not necessary to spell out the whole formula on the cell. Thus, a sand pit will carry only 1 L on a very light yellow background.

Of course, the degree of precision and the techniques of mapping are hardly the same in large- and small-scale maps. Some of the difficulties experienced at different scales are reviewed and a number of elements of solution are proposed.

The conventions, techniques, and procedures of data gathering and of map construction are described.

Three maps in colour and one in black-and-white are offered as demonstration of the method and as samples of the solution we have found to cartographic problems.

où C est le volet industriel,

I est le bloc 1 (extraction),

L est le sable,

V est l'investissement,

I est la minérotrophie.

Alors que les systèmes existants de classification et de cartographie des terres n'offrent pas des regroupements des unités ultimes en séries cohérentes, la classification écologique des terres (CET) propose une pondération écologique et un rangement à l'intérieur de séries parallèles. Un certain nombre de cas démontre les relais de charges trophiques, que le changement d'occupation sur un site donné soit dû à la succession spontanée ou à l'intervention humaine.

II. MÉTHODES ET PROBLÈMES CARTOGRAPHIQUES

La classification écologique des terres (CET) est essentiellement conçue en fonction de la cartographie.

Là où il est possible d'utiliser la couleur, la gamme suivante a été choisie: A. le bleu pour le volet sauvage; B. le vert pour le volet rural; C. le jaune pour le volet industriel; D. le rouge pour le volet urbain. A l'intérieur de chaque volet, l'intensité de la couleur augmente depuis une teinte très claire dans le bloc inférieur (1) jusqu'à une teinte très foncée dans le plus élevé (5, 6 ou 7).

Là où il faut se limiter au blanc-et-noir, A (sauvage) est représenté par un pointillé; B (rural) par un rayé horizontal; C (industriel) par un grisé; et D (urbain) par un quadrillé. Les blocs, dans la progression ascendante, ont une texture plus fine et un fond plus obscur.

Quant à la lettre symbole qui correspond au *type*, elle doit être surimposée à la couleur ou à la trame. Alors qu'il semble utile d'indiquer aussi le bloc par un symbole, il n'est pas nécessaire de reporter sur la cellule la formule entière. Ainsi, une sablière portera seulement 1 L sur un fond jaune très pâle.

Evidemment, le degré de précision et la technique cartographique doivent être ajustés à l'échelle. Quelques-uns des problèmes encourus à petite et à grande échelle sont passés en revue et des éléments de solution sont proposés.

Les conventions, techniques et procédures de prélèvement des données et de confection des cartes sont décrites.

Trois cartes en couleur et une en blanc-et-noir sont offertes comme démonstration de la méthode et comme témoins des solutions que nous avons données à des problèmes cartographiques.

Acknowledgements

I am much indebted to the University of Western Ontario for having originally sponsored this research in March 1973, and to Environment Canada under whose auspices it was continued from October 1974 to March 1976. Mr. R. McCormack, Mr. Donald Coombs, and other members of the Lands Directorate have been very helpful in many stages of this work, especially the mapping. I owe very much to my assistant, Gilles Paré, with whom the new scheme proposed herewith has been repeatedly discussed and who prepared and drew some of the maps that accompany this report. Nicole Nantel, Lucie Carrières, and Claude Duchemin were responsible for the drawing of figures and final versions of the maps. My students at the University of Waterloo (Andrew Hanna, Brian Bailey, Daniel Nixey) and at the Université du Québec à Montréal (Roger Lapointe, Solange Gagnon, Jacques Lalancette, Michel Chamberland, Richard Desbiens, Lorenne Girard, Lucie Carrières, Nicole Nantel, Pierre Dugas) have made useful tests which will be exploited in this project. I must add that I have adopted many of their suggested alterations and shifts of categories. Professors Warren Moran (University of Auckland), Arleigh Laycock (University of Alberta), Lawrence Anderson (University of Victoria), Peter Nash and Robert Dorney (University of Waterloo) have made very useful criticisms. Virginia A. Weadock has typed the several versions, always with a critical eye, and I am thankful for the many corrections she has suggested.

Pierre Dansereau.

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PART II

I. Presentation of a New System

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INTRODUCTION

As an ecologist with basic training in the biological sciences I have had a long-standing relationship with geographers, in my teaching, research, and other professional activities. I have often been encouraged to think of myself as an insider, as a geographer, and therefore dare to venture into the field of land classification.

The recognition of biogeography as one of the main disciplines of geography has not been so generally accepted as to go without saying. At this late hour, the full penetration of the biological thrust into the earth sciences has not been achieved. I believe that it is useful to reconsider the topic of land-use[1] in the light of ecological theory and methodology and to attempt a re-cast of land-use survey categories, with special reference to the Canadian effort.

I hope this proposal, which I will label ELO (for Ecological Land-Occupation), can be considered a contribution to that wedding of the natural sciences and of the sciences of man which is so indispensable to the solution of environmental problems. A new synthesis is necessary to the improved management of the landscape and it is being implemented in many large projects, such as the development of airports, cities, power-dams, etc.[2]

An ecological texture is essential as a matrix within which to evaluate and assess environmental fitness. It may well be that an ecological perspective will enable us to re-set the unity of knowledge in our time: could history be re-written by the next generation in the context of resource exploitation, exploding once more the earlier frames of military, political, economic, and social compass?

However contested some of the claims of contemporary geographers may be, the designing of maps is unquestionably their privileged operation. The ways and means of symbolizing and presenting phenomena in their spatial dimensions is the very stuff of geography. I shall therefore consider the requirements of land-use study, proceed to an ecological analysis thereof, review some of the land-use prospectives, and propose a new conspectus of land-occupation categories, or *ecological land-occupation* (ELO).

Land-occupation patterns can best be understood if they are graded according to the dynamics of their component ecosystems. Each cell is the result of transformations imposed upon it either by direct interference or by changes that have occurred in the region as a whole. Thus, a site now occupied by a bank may once have been a pasture, a park, and a parking lot (see Figure 6D). The relations of these successive occupancies to bedrock, soil, water, light, heat, plant and animal life are very different as are their connections with surrounding territory and indeed with distant sources of exchange.

Thus the ecologist is led to analyze the landscape in terms of its energy flow (past as well as present) and accordingly to shuffle the categories proposed by land-use analysts, foresters, agronomists, developers, economists, and administrators. This is what I propose to do, by examining the way in which land-use studies are now being conducted and the prospectives that such studies offer to the planners, in order to develop an ecological review that may lead to a new conspectus. I shall try to cast such a proposal upon the background of a few landscapes with which I am familiar.

It will be noted that I consistently hyphenate land-use. This is meant to emphasize the conventional, technical meaning of this term. In fact, I find it more appropriate to refer to *land-occupation* (also hyphenated) instead of land-use inasmuch as some of the areas are not "used" by man at all and were never actually occupied by him or have long reverted to the "natural" or indigenous agents (mineral, plant, animal) that originally tapped its resources. Thus *land-occupation* is a more fundamental term.

In undertaking the present series of studies, several levels of investigation are involved. In order to do justice to such a vast subject, the following objectives should be set.

A) Thoroughness of *description* for comparative purposes of the *kinds of occupation* of the land, leading to a *taxonomy of land-occupation types*. This requires a consistent set of criteria, a fairly wide awareness of the existing variations of single occupation-types, and

[1 & 2] I have discussed this question in many previous papers (1966, 1969, 1970a, 1971a, 1973, 1975). Although I have been at pains to present the work of my team on the site of the new Montreal International Airport as an experiment and not as a model to be followed, the preliminary reports (1971b, 1972b) and the final report (1976) do attempt a new synthesis on the working order of the pertinent disciplines.

both the capacity and willingness to separate the actual from the potential.

B) A sounding of the inner forces (*or the potential*) that makes a given area *capable* of one or more different categories of yield (*vocations*). This means an implicit or explicit knowledge of the resource base.

C) Previous knowledge of the *correlations* (actual and potential) *or types* among themselves. This supposes a preoccupation with the total dynamics of landscape and a knowledge of the forces that either induce change or maintain stability.

D) Reference to presumed and observed causal factors that can (more or less reliably) allow the *development of potential* exploitability in different sites and in different types at various times.

E) The *measurement* and *representation* of geographic, topographic, and ecological land-occupation units must have some conceptual coherence and some visual or mathematical appeal. These will largely depend on the hierarchy of criteria and on the graphic style as well as on scale.

It is therefore imperative, in the framework which I am setting for these studies, to meet separately the requirements of *four phases:* the first is *descriptive* (a conspectus of existing *types*); the second is *perspective* (inquiry into underlying or *background* features); the third is *prospective* (a search and evaluation of *potentials*); the fourth is *prescriptive* (a proposal for *planning* and implementation).

THE STUDY OF LAND-OCCUPATION

Having entered this field as an ecologist with a background in biology, I lack the scholarship that is needed for a historical retrospective of land classification. Although the geographers are kind enough to recognize me as one of them, I shall make no attempt to seek out the early tracings of land categories in the national planning scheme of Vauban or in the designs of the Dutch dyke-builders or the British land economists, nor shall I seek for traditional bases to the Chinese communes. I would like to think that I may eventually undertake something of the kind. But I really do not believe it to be necessary to my present endeavour.

On the other hand, a recourse to the origins of contemporary land design is essential if we are to respond to the needs of the day and to evaluate the cultural pressures that will always exert a powerful stress upon resource distribution or allocation, and I shall have occasion to identify some of the patterns. Indeed the whole topic of cultural landscape (see Salter 1971) is very close to my preoccupations and I have recently ventured to express myself on the subject of "inscape and landscape" (Dansereau 1973), in the belief that the inner image is the template upon which design is cast and implementation eventually carried out.

I shall concentrate for the moment on the classifications that are in use and offer a few reflections on the background information which they require and variously utilize. *It seems essential to me that descriptive analysis should be very carefully separated from perspective interpretation of background factors, the better to be synthesized in a prospective and eventually a prescriptive formula.*

Land-use surveys: descriptive schemes

Whereas I hope, eventually (as I have stated above), to attempt a historical retrospective on the ways in which land has been classified, I propose to concentrate, for my present purpose, on the systems that have been most widely and most successfully applied in recent years.

Table I shows the classification (first published by Van Valkenburg in 1950) adopted by the International Geographical Union at the recommendation of its "Commission to study the possibility of a World Land Use Survey" appointed in 1949. This commission was originally composed of S. Van Valkenburg (Chairman), L. Dudley Stamp, Hans Boesch, Pierre Gourou, and Leo Waibel (Van Valkenburg 1952). After the death of Waibel, Henri Gaussen and Preston James were added to the "Commission on World Land Use" (Van Valkenburg 1956).

This runs very close to the first Land Utilization Survey of Britain (Table II) where urban and industrial occupations are not labelled as such, but as "non-agricultural." Many wild lands (if not forested or swampy) are called "unproductive."

It is readily seen that Dudley Stamp's influence was preponderant.[3] He had initiated this first land utilization survey of Britain in the thirties and was still directing it. Stamp's (1950) commentary on this survey fully documents and justifies the scientific background, the geographical validity, and the practical usefulness of this series of maps. The coverage was eventually complete but a good number of the sheets were lost during the war. As Alice Coleman, Stamp's successor, points out (Coleman and Maggs 1964), they were of course out-of-date and a new survey had to be initiated (see Table III).

Comparisons between the maps of the first and second surveys are of the greatest value in that they record change, with which I shall concern myself presently. For the moment, however, it is the meaning of the British and the World surveys which I shall analyze and compare with many others, in different parts of the world, that have been variously influenced by this attempt at standardization. Table I contains such elements, to which I will return later.

Both the alignment of categories and the vocabulary reveal an agricultural slant, although in the second British survey (Table III) the post-war shift from agricultural to urban crises earns a more positive recognition for cities, industries, and even transport. The larger scale also allows for much more detail, for instance, in actually identifying crops.

[3] It is fitting to say, before I attempt a critical analysis, how strong was Dudley Stamp's influence on my own thinking (from 1947 onwards) and with what abiding respect I look upon his work, and what grateful memories I have of our conversations. His insights, varied knowledge, and warm humour were great sources of encouragement.

TABLE I

The World Land Use Survey (Van Valkenburg 1950, 1952, 1956) and its equivalents in the proposed new classification (Table VIII).

Number	Category	Colour	Predominant trophic level (Fig. 2)	Equivalents (Tab. VIII)
1	Settlements and associated non-agricultural lands	dark and light red	V-VI	D,C
2	Horticulture	deep purple	V, II	B 1 B-G B 2 B,G
3	Tree and other perennial crops	light purple	V, II	B 2
4	Cropland:			
	a. Continual and rotation cropping	dark brown	V, II	B 1 H,I, J,M
	b. Land rotation	light brown	V, II	
5	Improved permanent pasture (managed or enclosed)	light green	V, III	B 3 A
6	Unimproved grazing land:			
	a. Used	orange	V, III	B 3 B
	b. Not used	yellow	II	A 4, 5
7	Woodlands:			
	a. Dense	dark green	II	A 5 A
	b. Open	medium green	II	A 5 B, C
	c. Scrub	olive green	II	A 5 D
	d. Swamp forests	blue green	II	A 3 A
	e. Cut-over or burnt-over forest	green stipple	V, II	B 2 A
	f. Forest with subsidiary cultivation	green with brown dots	II, V	A 5 A—B 2
8	Swamps and marshes (fresh- and salt-water, non-forested)	blue	II, III	A 3
9	Unproductive land	gray	I, II	A 1, A 4 D, E B 5 D C 2 J D 1 E

TABLE II

The first Land Utilisation Survey of Britain for the one-inch to the mile scale, as recorded on maps.

Forest and woodland
- Deciduous
- Coniferous
- Mixed
- New plantations

Arable land (including fallow, short ley, rotation grass and market gardens)

Meadowland and permanent pasture
- Grassland in parks

Heath and Moorland
- Heath, Moorland, Commons and rough pasture
- Rough marsh pasture

Gardens, etc.
- Houses with gardens sufficiently large to be productive of fruit, vegetables, flowers, etc.
- Orchards
- New Housing areas, nurseries, and allotments

Land agriculturally unproductive
- Land so closely covered with houses and other buildings or industrial works as to be agriculturally unproductive
- Yards, cemeteries, pits, quarries, tip heads, new industrial works, etc.

Table IV records the Canadian adaptation of the World Land Use Survey, better known as the *Canada Land Inventory.* This is a well-tested system, astonishingly adaptable to a huge and varied territory, and carried out with much respect for regional originality by well-disciplined and dedicated teams. The coverage now extends over virtually all of inhabited Canada. Besides the British Isles, the Canadian survey is probably the most thorough and comprehensive experiment in land-occupation mapping anywhere in the world at this time. Table IV is drawn from the over-all scheme adopted by the Canada Land Inventory (1970). It is a definitive outline of the higher orders of land categories. In actual surveys ("a mari usque ad mare") field investigators have developed many further subdivisions. For instance, Clibbon (1975), using the scale of 1:20,000, has recognized a great number of smaller units based on particular crops or practices (compare with subdivisions of "arable land" in Table III).

The logic of these classifications (as shown within the first four tables) rests upon the dichotomy of used vs. unused land. It tends to reflect *what man has done* to the land. There is, however, no linear sequence from either the most intensively used or the most productive to the least used (or disturbed) or least productive in the scheme as a whole or in its subdivisions. The colours that are proposed do not reflect (as the Toulouse system does: see Gaussen 1958, Rey 1958) any particular relationship (except within a given subdivision). The main concern is obviously legibility and practical application.

These preoccupations are appropriately utilitarian. The first British land-use scheme (which is the prototype of all of them) is obviously slanted to agriculture, as it may well have been in war-time Britain. There is yet another reason for this in the fact that agricultural land (however used or neglected) not only occupies larger areas than corresponding industrial or urban affectations but also consists of larger cells. As for wild, "natural," or "semi-natural"

TABLE III

The Second Land Use Survey of Britain on the scale of 1:25,000 (Coleman and Maggs 1964), and the equivalents proposed in Table VIII.

Number	Category	Colour	Overlays	Equivalents (Table VIII)
1	Settlement Built up areas Caravans	 grey	 Pencil shading Car	D D 4, 5, 6, 7 B 5 B + D 4 A
2	Industry Manufacturing Extraction Tips Public utilities	red	 Outline of area. I plus type number. Notes on back or margin of map. Pencilled cross hatching. Name type of extraction if not already named. Outline area and name "Tip". Tick existing names and check area *or* name new utilities.	C C 4 C 1 D 1 B C 5
3	Transport	orange	T (This should be written on all metalled roads)	C 2
4	Derelict land	black stipple	heavy pencil dots	A 1, C 2 J, D 1 E, B 5 D
5	Open spaces	lime green	O.S.	D 2, 3
6	Grassland With Juncus rush With scrub	light green	G (if an undoubted ley, add L) G G -o- Horses, Donkeys, Sheep, Calves or Cattle not identified, Beef Cattle, Dairy Cattle, Pigs, Goats, Chickens, Ducks, Geese, Turkeys and Bees	Ley=B 1 J B 3, A 4 A, B, C A 3 B A 5 D
7	Arable land Cereals Ley legumes Roots Green Fodder Industrial crops Fallow	light brown	 Wheat, Barley, Oats, Rye, Dredge Clover, Lucerne, Trefoil, Vetch, Sainfoin Turnips, Swedes, Kohl Rabi, Marigolds, Sugar Beet, Fodder, Carrots Kale, Rape, Peas, Beans, Mashlum, Mustard, Maize, Lupins, Linseed, Fodder Cabbage Flax, Chicory, Black Mustard, Sugar Beet, Birdseed Fallow	B 1, 2 B 1 I B 1 J B 1 D B 1 C B 1 D, G, H B 1 M
8	Market Gardening	purple	Mixed crops, Potatoes, Brassica, others named in full Nurseries, Allotments Flowers; name type. Soft Fruit; name any dominant concentration. Hops	B 1 C, D B 2 B B 1 L B 1 B B 1 G
9	Orchards A notation in three parts separated by strokes: *Tree name* Apple, Pear, Plum, Cherry, Nut	purple stipple *Ground Use Name* Market Gardening or Soft Fruit, Fallow or Arable Grass	 *Animal name*, as given under grassland	B 2 D
10	Woodland (Deciduous, Coniferous, Mixed) Coppice Coppice with standards Scrub	dark green	 W -o-	A 5 A, B, C, D A 5 A A 5 D A 5 D
11	Heathland, Moorland and Rough Land	yellow		A 5 D, A 4 D
12	Water and Marsh Water Marsh	blue	 Note any special use. Distinguish fresh water and salt marshes.	A 2, A 3 A 2 A 3
13	Unvegetated	white	U	A 1, B 5 D, C 2 J, D 1 E

TABLE IV

The Canada Land Inventory (Canada Land Inventory, Report No. 1, 1970), and its equivalents in the new system (Table VIII).

Category	Type	Dominant trophic level	Processes	Canada Land Inventory		New System
				Symbol	Colour	Symbol
I	*URBAN:* Land used for urban and associated non-agricultural purposes	V-VI	urbanization			D/VI-I, C/VI-I
	1. *Built-up area*	V V V-VI V VI VI	construction commerce industrialization transport education administration	B	red	D 1/V, I, D 2 D/V, II, D 3/V, D 4,7/V, VI
	Parks			B	red	D 2 D/V, II
	Other open spaces within built-up areas			B	red	D 3/V, D 2 D/V, II
				B	red	D 1/V, I
	2. *Mines*	I I I II	mining ablation soil removal destruction of vegetation	E	wine-red	C 1 H/V, I
	Quarries			E	wine-red	C 1 J/V, I
	Sand and gravel pits			E	wine-red	C 1 L/V, I, C 1 K/V, I
	Land used for removal of earth materials			E	wine-red	C 2 J/V, I
	3. *Outdoor recreation* (Golf courses, parks, beaches, summer-cottage areas, game preserves, historical sites)	V	preservation construction recreation outfitting	O	pink	D 2,3/V
				O	pink	B 5 B/V
II	*AGRICULTURAL LANDS*	II-VI	agriculture			B/II-VI
	1. *Horticulture*	II,V	fertilization harvest	H	pale blue	B 1 B-G/V, II, B 2 B,G/V, II
	Poultry operations	III,V	breeding feeding shelter	H	pale blue	B 4 H/V, III
	Fur operations	IV,V		H	pale blue	B 4 B/V, IV
	Intensive cultivation of vegetables and small fruits, including market gardens, flower and bulb farms	II,V	seeding cultivation harvest	H	pale blue	B 1 B-G,L/V, II, B 2 G/V, II
	Nurseries	II,V	planting cultivation	H	pale blue	B 2 B/V, II
	Sod farms	II,V	seeding fertilizing removal	H	pale blue	B 1 A/V, II
	2. *Orchards*	II,V	planting cultivation harvest	C	violet	B 2 D/V, II
	Vineyards			G	violet	B 2 C/V, II
	Lands used for production of tree fruits, hops, and grapes			G	violet	B 2 C,D,E/V, II

	3. *Cropland:* Land used for annual field crops:	II,V	seeding planting cultivation harvest	A	orange	B 1 B-I,L / V, II, B 1 M / V, I, B 5 D / V, I
	Cereals			A	orange	B 1 I / V, II
	Sugar beets			A	orange	B 2 D / V, II
	Flax			A	orange	B 1 E / V, II
	Tobacco			A	orange	B 1 C / V, II
	Potatoes			A	orange	B 2 D / V, II
	Vegetables			A	orange	B 1 B-D / V, II
	Fallow land	I-II	ploughing	A	orange	B 1 M / V, I
	Land being cleared for field crops			A	orange	B 5 D / V, I
	4. *Improved pasture*	II III V	seeding fertilization plant growth grazing	P	brown	B 3 A / V, III
	Forage crops			P	brown	B 1 J / V, II
	Land being cleared for pasture	I,II,V	ploughing seeding	P	brown	B 5 D / V, I
	5. *Rough grazing land*	II III	regeneration grazing	K	yellow	B 3 B / V, III
	Rangeland: a) Areas of natural grasslands, sedges, herbs			K	yellow	A 3 B / II, A 4 A,B / II, B 3 B / V, III
	Abandoned farmland, whether used for grazing or not. Bushes and trees may cover up to 25% of area			K	yellow	A 4 A / II, B 3 B / V, III
	Intermittently-wet, hay lands (sloughs or meadows)			K	yellow	A 3 B / II
	b) Woodland grazing: if the area is actively grazed and no other use dominates, in some grassy, open woodlands, bushes and trees may somewhat exceed 25% cover			K	yellow	B 3 B / V, III
III	*WOODLAND:* Land covered with:	II	plant growth			A 5 A,B,C,D / II, B 2 A,F / V, II
	Trees	II	regeneration	T	dark green	A 5 A,B / II
	Scrub or shrubby growth			U	apple green	A 5 C,D / II
	1. *Productive woodland.* Wooded land with trees having over 25% canopy cover and over ca. 25 feet in height			T	dark green	A 5 A,B / II
	Plantations and artificially reforested areas included, regardless of age	II,V	tree growth	T2	dark green	B 2 F / V, II
	2. *Non-productive woodland.* Land with trees or bushes exceeding 25% crown cover, and shorter than ca. 25 feet in height	II	regeneration	U	apple green	A 5 C,D / II
	Much cut-over and burned-over land			U	apple green	B 2 A / V, II

IV *WETLAND*	II,III	plant growth animal life	M	dark blue	A 3 A,B,C,D / II
Swamp			M	dark blue	A 3 A / II
Marsh			M	dark blue	A 3 B / II
Bog			M	dark blue	A 3 D / II
V *UNPRODUCTIVE LAND:* Land which does not, and will not, support vegetation, e.g., eroded soil or rock and active depositional features	I				A 1 / I, A 1 A,D,E,F,G / I
					C 1 H / V, I
1. *Sand,* sand flats			S	gray	A 1 D / I
Sand bars		weathering erosion sedimentation	S	gray	A 1 D / I
Dunes	I	wind erosion	S	gray	A 1 D / I
Beaches		flooding	S	gray	A 1 D / I
2. *Rock and other unvegetated surfaces:* Rock barrens		weathering erosion sedimentation	L	yellow-ochre	A 1 B / I
Alkali flats	I	deposition	L	yellow-ochre	A 1 G / I
Badlands, gravel flats, eroded river banks		erosion	L	yellow-ochre	A 1 C,E,F / I
Mine dumps		accumulation	L	yellow-ochre	C 1 H / V, I
VI *WATER*	I-IV	flow evaporation	Z	white	A 2 / I

areas, the logic in recognition of categories does not lie so much in their contrasting inherent features as in their usefulness. However, it may well appear that this overriding criterion does not meet the requirements of a multipurpose environmental analysis.

But one cannot discuss symbols, textures, and colours without reference to scale. It is all very well to design a world-wide system as long as it takes in sizable portions of the earth's surface. When larger scales are being used, the maintenance of a world scheme is likely to result in almost illegible shadings of one colour or variants of one texture. Thus, Brockmann-Jerosch's (1954) map of the formation classes of the world (1:10,000,000) shows the Eastern North American deciduous forest in pale green, but if E. L. Braun's (1950) map of that formation (1:1,000,000) were to be coloured in shades of pale green it would hardly impress the eye in the way that a good map should.

To return to points A to E of the introduction, it is necessary to *separate description from potential* if we are not to indulge in too much of the circular reasoning that has all too often afflicted biogeographical research.

However, totally unbiased description is not conducive to useful taxonomies, and some knowledge of causal factors and of background forces is necessary to the very choice of proper taxonomic criteria.

Background information: the resource perspective

Before criticizing the established schemes and venturing to shuffle their components or force their dimensions, it will be useful to consider the kind of information which is necessary to the development of divisions that have real significance. It obviously matters a great deal whether a land-mosaic in a given area is mostly agricultural or wild and what its present regime of exploitation may be.

Reading of airphotos by a geographer who has personal experience of the area would seem to promise the achievement of a record of things-as-they-are. However objective such a plotting may be, it is in no way self-explanatory. The present (and possibly quite ephemeral) occupation of land can only be explained by overlaying it with equally precise data, some of which pertain to natural forces and others to man's impact.

Climate, physiography, and soil, inasmuch as they provide the mineral resource basis, must be known in considerable detail. The seasonality and rhythm of the provision of heat, light, and water determine their *availability* and very largely their *quality* and *quantity* at the macroclimatic level. Topography, on the other hand, modifies *receptivity, distribution,* and *storage,* therefore the predictability of erosion—sedimentation, drainage, run-off, evaporation, and accumulation. *Parent-materials* are the result of more or less remote geological sequences and further modify the buffering capacity of the present topography. *Soils* are the (more or less stable) result of weathering plus biological impacts.

It cannot be emphasized too strongly that *meteorological*-data are the only proper direct expression of climate; that *landforms* are the only true measure of physiography; and that the texture, composition, and structure of *particles* (gaseous, liquid, and solid) provide the only acceptable description of *soil*. It is difficult, at times, to disregard a slanted vocabulary that presupposes correlations such as "rainforest climate," "marshy lowland," "prairie soil."

I shall not pretend that circular reasoning is altogether avoidable and shall not insist that long-standing vocabulary be "cleaned up" in the interest of more objective statements.[4] I am bound to call, however, for a critical detection of widely accepted correlations of climate-soil-vegetation which can only be achieved when the variables have been directly and separately apprehended.

Vegetation and *animal life* in their geographical dimensions have not been recorded nearly so uniformly as climate, geology, and soil. "Floras" and "faunas" (lists of species) are of relatively little usefulness in this respect, although they are an indispensable prerequisite for comprehensive inventories.

Small-scale maps of vegetation cannot possibly be the result of direct observation, although remote sensing seems to offer some possibilities. They are necessarily extrapolated at once as retrospectives and prospectives (which see below), whereas large-scale maps are capable of recording actual occupation by vegetation. But, in what terms? Botanists are generally bound to require specific identification, at least of certain dominant or characteristic species; geographers may well be content with structural units; and planners show more interest in functional features. The true student of vegetation for its own sake will hardly accept any definition of mappable units of vegetation that does not refer to all three: *composition*, *structure*, and *dynamics* (see the fundamentals of vegetation mapping in Gaussen 1961 and Küchler 1967).

The manipulation, exploitation, and transformation by man (again in retrospective and in prospective) are the true object of land-occupation study. Mineral masses and biomasses have been shuffled in various ways: mountain razing, damming, ploughing on the one hand, and lumbering, stripping, planting and sowing, as well as hunting, mustering, and domestication on the other.

As one looks at contemporary landscapes, the processes that govern these various interventions of man on the matrix of the lithosphere—hydrosphere—atmosphere cast unmistakable stamps, each of their kind. In spite of the differences in products and in practices between tropical and temperate agriculture or forestry, the World Land Use System can well propose agriculture and forest exploitation as major universal land-use categories. And no doubt, this is even more so of industrial and urban developments. It is being assumed that the differences between the varieties of agriculture from one climatic zone to another are of a lesser order of magnitude (or relevance) than their similarities. It also stands to reason that no useful description, at the regional level, is achieved by assignments to these high levels. Of course, the forest must be qualified as deciduous or evergreen, as eucalypt or pine, etc., and agriculture as to principal crop (wheat, sugarcane, pineapple, . . .).

The question really is: how many major and minor categories are there? how can they be defined? how do they relate to each other? Although I am bound to recognize the ecological preoccupation of many of those who have contributed to the elaboration and application of land-use schemes, I shall argue that a certain lack of consistency in ecological ordination necessitates a new analysis and justifies a new scheme.

Most of the land-use studies that have been published demonstrate careful consideration of background determinants. They very frequently offer as a perspective to the area under consideration a series of maps (on a uniform scale) showing: climate, relief, exposure, drainage, soil, erosion, vegetation, and such major (and more or less irreversible) human *investments* as levees, roads, dams, etc. (See, for instance: Druce 1957.)

It is eventually the retrieval of information gathered from the correlation of background data and actual occupation (and relative yield) that will allow the design of prospective categories of classes of potential. The latter will be considered presently and current practice will be evaluated. In attempting such an assessment, I need first to fully define the ecological yardsticks that give some coherence to my criteria. This will allow a tighter framework to be offered for the purely descriptive phase.

AN ECOLOGICAL ANALYSIS

An ecological map of an area should not merely be a vegetation map, nor is it necessarily a land-use map. Vegetation maps are in high repute among ecologists since it can truly be said that vegetation *integrates* other features of the landscape. It is true enough that the properties of the substratum (limestone or sand, wet or dry, etc.) can often be safely inferred from the presence or abundance of certain kinds of plants or masses of vegetation. These units, in turn, can be presumed to harbour certain animal forms and not others.

But this is not good enough and the collection of what can only be called case-histories does not fully support a world system, even if it goes a long way towards supplying information for a regional scheme. But the latter is, precisely, subordinate to a higher order of magnitude.

I therefore find it profitable to review the *essentials of*

[4] Periodically this has to be done, as witness the Seventh Approximation of the World Soil Classification (USDA: Soil Survey Staff 1960). I have myself resorted to a new start in the matter of vegetation structure: after many years of using forest, savana, tundra, I have proposed a Latin nomenclature that better fits a new definition (Dansereau 1968a), and sweeps off, as it were, any mythical allusions.

ecological theory as they weigh upon land-use classification; and then to consider the historical *development of man's power* to modify the land; and finally to examine the application of the known *mechanisms of succession* to the shaping of landscapes.

The setting of an ecological model

Recognition of the *ecosystem* as the basic unit of ecological study has not led all ecologists to a necessarily unified concept and least of all to a universally acceptable definition of the term and to an agreed methodology. It would badly unbalance the present essay if I were to attempt a full examination of this predicament and to explore the justifications and applications of different "schools." I have possibly made some contribution to such a debate (Dansereau 1946, 1956, 1957, 1971a), but I have been more preoccupied with a frame of consistency that would afford a more usable matrix to the definition of environmental categories. I therefore propose to maintain an earlier ecological perspective (1957) which I have been led, in recent years (1966, 1971a, 1973, 1976), to enlarge by making an attempt to integrate socio-economic factors.

I am inclined to re-emphasize my preoccupation with orders of magnitude in the environment as *containers of phenomena and processes that variously constrain the exchanges that take place at lower levels.* For this reason I do not think that ecosystems can be of all and any dimensions, although such a premise is accepted by ecologists whom I greatly respect (Evans [1956], Odum [1971, 1975], Duvigneaud [1974], Margalef [1968, 1974]). My own definition is as follows: *an ecosystem is a limited space where the cycling of* resources *through one or more trophic levels is effected by more or less fixed and numerous* agents *utilizing mutually compatible* processes, *simultaneously and successively, which engender* products *that are usable on short or long term.*

I have built up and spelled out this definition elsewhere (1971a, 1973, 1976) and will not do so here except to relate its terms to land-occupation units. Table V shows an attempt to devise a general framework for environmental units. The main assumptions are the following:

1) the processes and responses at each level of integration are conditioned by all higher levels and transmitted to all lower levels;
2) the thresholds between units of the same level and between units of different levels are presumably of a different kind and call for different responses.

This can be briefly illustrated by a few examples. Figure 1 draws a parallel between a situation in the Montreal Plain and one in northernmost Quebec. The provision of light, heat, precipitation is such that the bioclimate is cold-temperate and arctic, respectively, and this induces a regional vegetation regime of deciduous forest and of tundra (formation-class); the zonal dominance of vegetation (climax-area) is beech-maple forest and bilberry-cladonia tundra. The repertory of climate and soil allows the prevalence of characteristic vegetation on moraines in one instance and on the deeper soils on the other. But the range of ecosystems in each landscape comprises many other types: this mosaic is conditioned primarily by landforms and drainage patterns.

In turn, within each ecosystem (that provides a homogeneous resource-complex), one or more communities will prevail, according to physical and chemical properties of site and soil and length of occupation. Ecological strategy is to be studied at that level, but the actual *place of exchange* lies lower still: contact of plant, animal, and man with air, water, soil, and other living beings takes place in the ecotope, and can only be measured there.

TABLE V
Subdivisions of the biosphere, or orders of magnitude of the environment.

<table>
<tr><th rowspan="2">Unit</th><th colspan="2">Control</th><th rowspan="2">Nature of Response</th><th rowspan="2">Area Occupied</th><th rowspan="2">Unit of Vegetation</th><th rowspan="2">Animal Unit</th><th rowspan="2">Human Unit</th></tr>
<tr><th>Element</th><th>Factor</th></tr>
<tr><td>BIOCHORE</td><td>AIRMASS REGIME</td><td>meteorological</td><td>structural</td><td>continent or province</td><td>super-formation</td><td>major groups indicator</td><td>n.a.</td></tr>
<tr><td>BIOCLIMATE</td><td>CLIMATE</td><td>meteorological</td><td>structural and functional</td><td>province</td><td>formation-class</td><td rowspan="2">climatic groups</td><td>economic, political</td></tr>
<tr><td>CLIMAX AREA</td><td>CLIMATE</td><td>meteorological and physiographic</td><td rowspan="2">structural and floristic, faunistic, or ethnic</td><td>zone</td><td>climax-complex</td><td>economic, regional</td></tr>
<tr><td>LANDSCAPE</td><td>GEOMORPHOLOGY</td><td>physiographic</td><td>region</td><td>seres</td><td>relatively independent communities</td><td>mosaic of land-use</td></tr>
<tr><td>ECOSYSTEM</td><td>LAND-FORM</td><td>physiographic-edaphic</td><td>physiological & physiographic</td><td>habitat</td><td>sere</td><td>interdependent communities</td><td>land-use type</td></tr>
<tr><td>SITE</td><td>SOIL</td><td>edaphic</td><td>sociological</td><td>belt</td><td>community</td><td>multispecific community</td><td>working and living space</td></tr>
<tr><td>LAYER</td><td>MICROCLIMATE</td><td>micrometeorological</td><td>epharmonic</td><td>layer</td><td>union</td><td rowspan="2">microsociety or population</td><td rowspan="2">family</td></tr>
<tr><td>ECOTOPE</td><td>MICROSITE</td><td>micrometeorological, biological</td><td>microedaphic</td><td>niche</td><td>microsociety or population</td></tr>
</table>

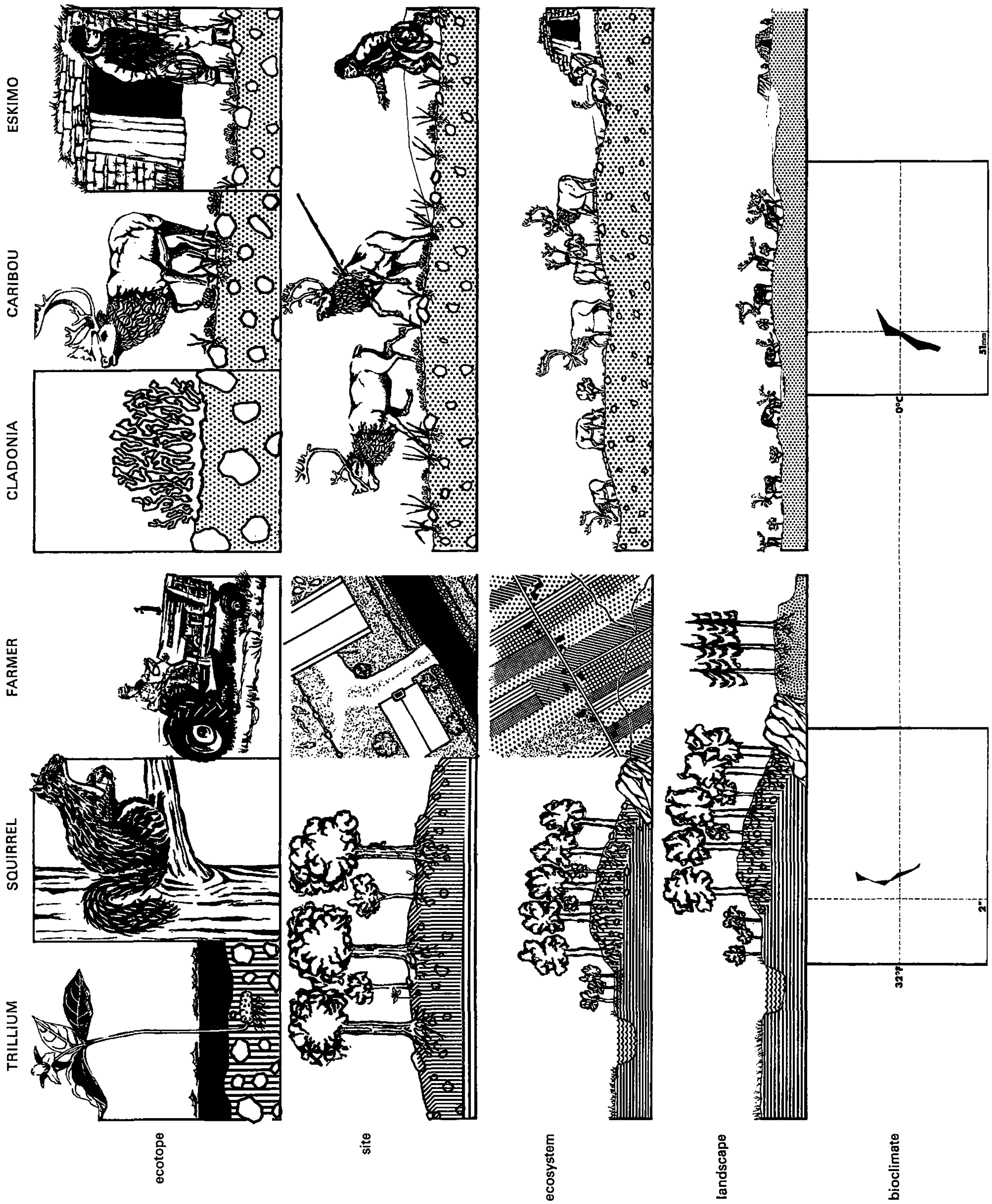


FIGURE 1. The orders of magnitude of the environment, from the ecotope to the bioclimate, illustrated by examples of plant, animal, and man from two different regions: Sainte-Scholastique and the Quebec Arctic.

Figure 1 has just been read from the bottom up. It must also be read from the top down. The white trillium, the gray squirrel, and the Quebec farmer, as well as the cladonia lichen, the caribou, and the Eskimo, in this game of Russian dolls, first undergo the immediate effects of their contacts within the ecotope. But air, food, and shelter are subject to the enveloping influences, the dispensation of resources, and the meting out of adversities that originate on the site and in the ecosystem as a whole. Finally, the surrounding landscape affords a number of inputs and remains within the control of the prevailing bioclimate.

The recognition of orders of magnitude, and of their constraining force, to which I must return later, is therefore a sort of prerequisite to both landscape analysis and ecosystem study. But, the latter is the most essential, inasmuch as the ecosystem is the fundamental unit of the landscape mosaic.

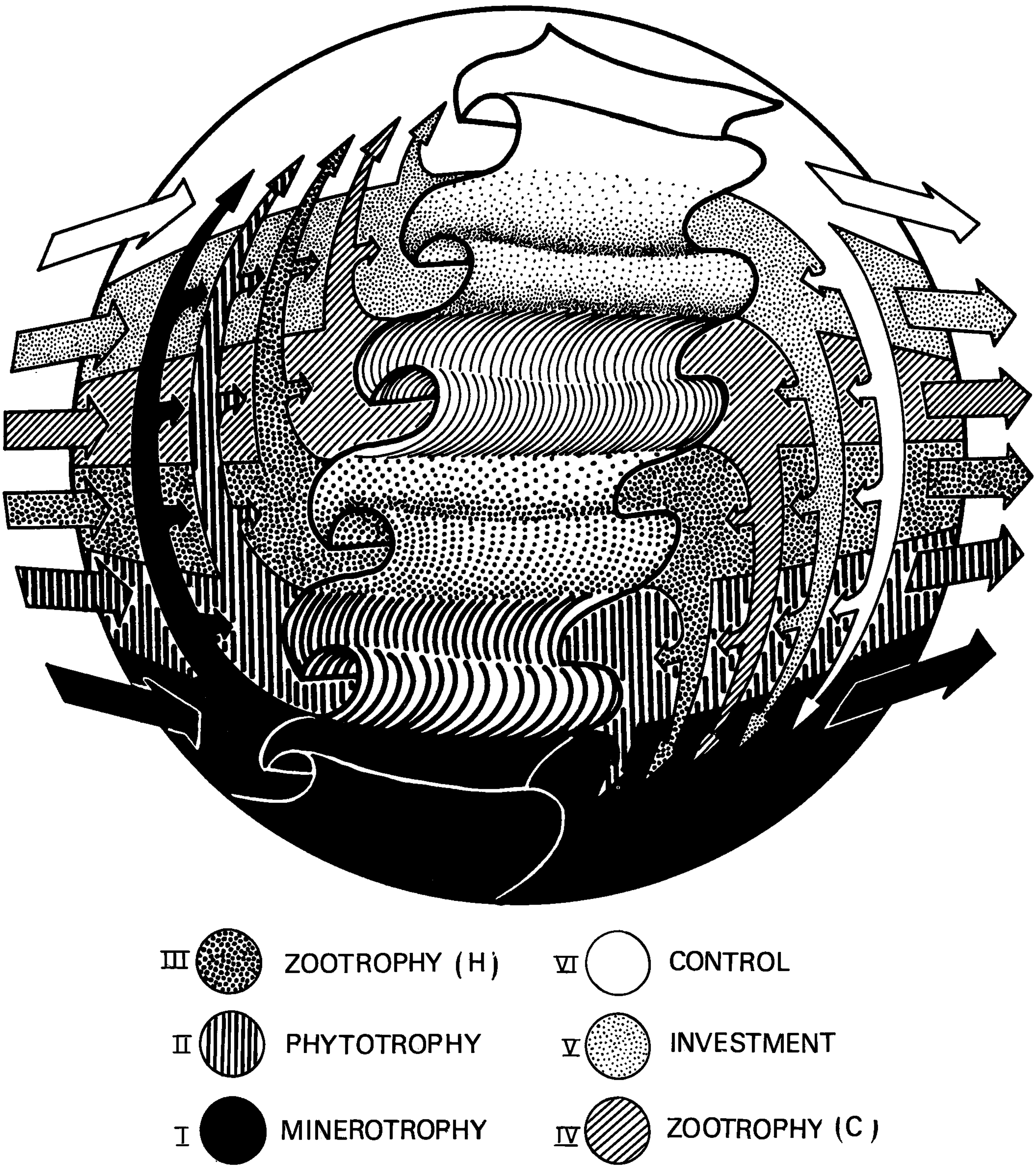


FIGURE 2. The ball of cycling arrows, a model of the ecosystem showing a projection on six trophic levels of the mainstream flow of energy (central part), the inner conveyance of resources (left part), and their reinvestment (right part), as well as the import (left margin) and export (right margin) from and to other ecosystems (Dansereau 1971a).

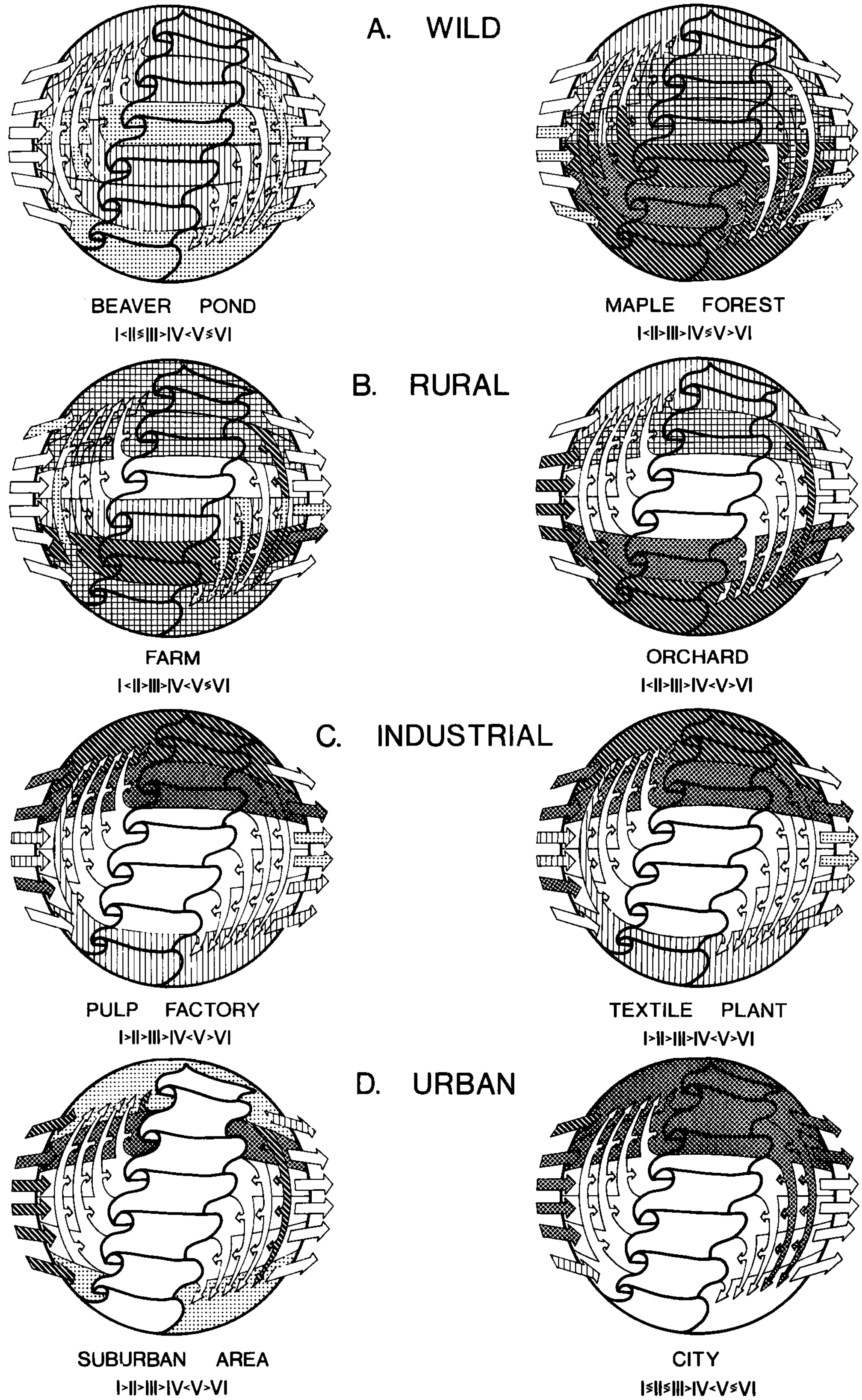


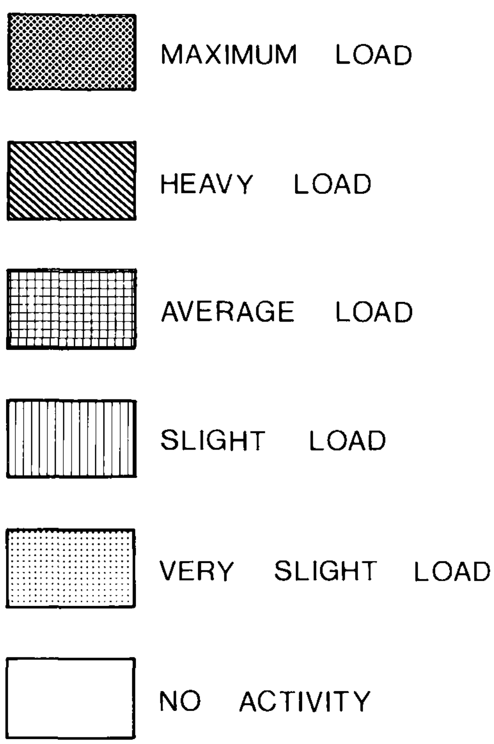
FIGURE 3. The relative trophic load of typical ecosystems in wild, rural, industrial, and urban conditions. See Figure 2 for the identification of trophic levels.

Figure 2 shows my basic concept of the ecosystem, to which I shall relate much of the discussion that follows and eventually the new scheme of ecological land-occupation (ELO) types which I shall offer. It encompasses the earlier classical recognition of biocycling processes from the uptake of minerals by plants, the elaboration of plant tissues, through photosynthesis and other processes (primary production); the consumption of plants by phytophagous animals that build up tissues and organs (secondary production) that will be consumed by carnivorous animals (food-chains); and the partial return by bioreduction to soil, water, and atmosphere. However, it prolongs the energy relays through two more levels, namely *investment* and *control*.

By investment is meant the storage of resources not in immediate use (starch, fat, etc., in the bodies of plants and animals); the elaboration of artifacts of continuous or periodic usefulness (fences, houses, levees, ditches, reservoirs, banks). Control, on the other hand, refers to a more or less abiding power of leverage on the cycling processes as a whole, such as that exerted by a beaver on a pond, cyclic fire in a savana, financial, political, and religious institutions upon the selective cycling of resources (taxation of property, regulation of sexual activity, access to water, etc.).

This makes a total of six trophic levels. Each one features a *regime* that is characterized by an array of *resources*, which are exploited by a variety of *agents* through peculiar *processes* that yield certain *products*. In any given ecosystem, resource, agent, process, and product lend themselves to very precise and strikingly different qualifications and quantifications.

What the model (Figure 2) intends to convey is the possibility of energy transfers from any level not only to the one immediately above it (mainstream), but to all the areas above (left: upward movement) and below (right: downward movement). Moreover, the ecosystem as a whole, being more or less closed, is also more or less open to incoming influences and inputs (arrows from the left) and to outgoing currents and outputs (arrows to the right), in other words to imports of resources and exports of products and wastes.



Legend to Fig. 3

I shall constantly refer to trophic levels as shown in Figure 2 by Roman numerals I to VI. I hope these symbols can be borne in mind without constant explicit reference to Figure 2. This model was originally published in 1971 and served as a focus for an interdisciplinary ecological investigation of the area surrounding Mirabel (the new Montreal International airport, inaugurated in 1975). (See also Dansereau 1972a, 1973, 1975, 1976, Dansereau, Clibbon, and Paré 1975.)

This duplicate system of circulating resources and products leads to two main considerations. First is the *relative weight of trophic activity* at any one level, and second is relative *autarky*. I have discussed these two points at length in other publications (1971a, 1976) and will confine myself to a cursory rundown of examples.

Here are some that bear on the first point:

I. *Minerotrophy* is predominant, almost exclusive, on a glacier, a recent lava flow, an active dune, a parking lot.
II. *Phytotrophy* prevails in a forest, a banana plantation, a saltmarsh.
III. *Zootrophy* (*herbivory*) prevails in an oyster bed, a deeryard, a sheep pasture.
IV. *Zootrophy* (*carnivory*) prevails in a lion's den, an eagle's nest, a walrus island, a coral reef.
V. *Investment* is predominant in a troglodyte settlement, a farm, a railroad, a bank, a museum, a factory, a town.
VI. *Control* (or noötrophy) is dominant in a termite mound, a beaver dam, a school, a church, a courthouse, a parliament.

A good number of ecosystems show great activity at many levels; virtually all of them function at all levels, although they may be productive at only one or two. When this is so, resources are bound to enter the ecosystem from other ecosystems and, conversely, products of the ecosystem in question are bound to be fed to other ecosystems.

Examples bearing on the relative *autarky* (or self-sufficiency) of ecosystems are given in Figure 3, which borrows the framework of Figure 2 and shows how relatively great is the activity (or productivity) at each one of the six trophic levels. In other words, it locates the relative energy charge of each ecosystem as well as its relative amount of import and export at each level.

1. The *beaver pond*, whose water level is deliberately controlled by the beavers, is rather heavy at level VI. Nevertheless, it is fully active and indeed productive at levels I to V as well. Some water, heat,

light come in from the outside; aspen logs are also dragged in; moving predators make occasional catches. But it is rather a closed ecosystem.

2. The *maple forest* (in its primeval state) appears even more self-contained. The resources that enter it pertain, in a sense, to a higher order of magnitude.
3. The *farm* ecosystem is entirely geared to high productivity at levels II and III where it accumulates large yearly surpluses that are exported to other ecosystems and compensated by imports at levels I (fertilizer), II (seed), III (livestock), V (furniture, exotic food), and VI (education, information); level IV is virtually neutralized.
4. The *orchard* ecosystem is a more simplified one. Whereas management of the farm tended to completely inhibit level IV activities and to severely limit level III consumption, in the orchard virtually all animal activity is stopped. As for level II, its product is almost entirely exported and other vegetal material must be imported. The specialized nature of the exploitation requires heavy investment (V) and sophisticated management, and constant attention to market (VI).
5. The *pulp factory* utilizes water power (I) but none of the soil resources; the lumber (II) comes from another ecosystem; its animal energy (III-IV) is confined to man; its investments (V) are building, chemicals, machinery, vehicles; its control (VI) may be inner (proprietor-manager) or outer, although marketing and transport are strong outside influences.
6. The *textile plant* shows more complexity, higher expenditure of energy, and great dependence upon other ecosystems. In fact, its investments (V) much outweigh all other trophic activity. Its raw material (II) comes from long distances, it imports all the vegetal (II) and animal (III-IV) food it consumes. Its control (VI) over levels I-IV is quite strong, but the control that is exerted upon it from outside is even greater.
7. The *suburb* is, in a sense, a simplified urban development (as the orchard is a simplified agricultural one). Being overwhelmingly residential, it contains heavy investments (V) derived from products of other ecosystems. Its soil produces virtually no consumable products; these (II-IV) are obtained from other ecosystems. In turn, it contributes little to other ecosystems save the periodic exodus of some of its producers at levels V and VI.
8. The *city* has the least autarky and the greatest power to control (VI). Whereas its minerotrophic activities (I) are literally sealed off, its biotrophic activities (II-III-IV) are limited to human metabolic and reproductive cycles at the expense of imported resources. Its investments (V) are tremendously large (and varied, unlike industry's and the suburb's) and its power to control (VI) any number of other ecosystems near and far is enormous.

In the course of a two-year study in a segment of the Montreal Plain expropriated for the development and buffering of a new international airport (at Mirabel), a detailed survey of land-use over some 96,000 acres was made by my collaborator, Peter B. Clibbon (1975). Inasmuch, however, as we had several teams involved in this research and that background information was being gathered on all six trophic levels, it was possible to develop a table of ecosystems which is presented here as Table VI (from Dansereau 1976), and to correlate the land-uses listed in the Canada Land Inventory (Table IV).

I shall have occasion to comment on all of the features listed in this table later on. My purpose for the moment, however, concerns the major divisions (A, B, C, D) as shown both in Figure 3 and in Table VI, which lists 55 such ecosystems and places them in a framework that identifies the forces that determine it and its principal characteristics.

Impacts of escalation as ecological relays

My main division of the ELO (Ecological Land-Occupation) scheme into four large units is essentially based on the historical escalation of man's power over environment, which has recently achieved new dimensions. In four previous papers (1969, 1971a, 1973, but especially 1970b) I have attempted to draw a general account of this. Table VII provides a foreshortened view of this progressive possession of the planet and eventual exorbitation. The access to a new stage is conditioned by the liberation of resources heretofore untapped (or at least uncontrolled) by man. Thus six major revolutions are seen as:

I. the development of *instruments* that give man capacity to extend his muscular and mental power;
II. the *domestication* of plants and animals in some way useful that provide him with a continuing and dependable resource;
III. the *cultivation* of land that assures a surplus and the fixation of abode (settlement) that makes for security and continuity;
IV. the serial *fabrication* of exchangeable objects by the concentration of mechanical means;
V. the sophistication of calculating and ponderating (*cybernetic*) devices that allow *storage and retrieval* as well as the *release of new energies* (especially nuclear) and initiate a new communication network;
VI. the access to *extra-terrestrial* space and bodies.

The repercussions downwards from the cosmic powers of man may seem to be all-pervasive, although we have hardly begun to realize this, scientifically or psychologically. In a place like Cape Canaveral, no doubt traces of all six revolutions (or all eight stages) can be witnessed, down from the moon-launch pad (8) through the cloud-seeding places (7), to coastal cities (6), to canning plants (5), to orange groves (4), to grazing herds of sheep (3), to tuna fishing (2), to berry-gathering grounds (1).

The visibility of these various ways in which man has successively and often cumulatively altered the landscapes

TABLE VI

Ecosystems of the Mirabel Zone and their principal characteristics (Dansereau 1976). CLI equivalents are those mentioned in Table IV. See Clibbon (1975, pp. 360-369) and Dansereau, Clibbon and Paré (1975) for a more detailed application to Mirabel, given here in parentheses.

Degree of management (and determining regime)	Control	Ecosystem	Occupation	Predominant trophic level Fig. 2	Canada Land Inventory Table IV	Ecological Occupation Table VIII	Relative autarky	Stability	Productivity	Diversity
A wild (physiography)	A. Rock outcrop	1 rock	cladonias	I	L(Rn)	A 1 B	5	4	1	1
			rosettes of sorrel			A 4 E				
	B. Moraine	2 moraine	maple bush	II	T(6)	A 5 A	5	5	4	4
		3 talus	cedar thicket			A 5 B	5	3	2	2
	C. Terrace		birch wood			A 5 A	5	2	2	3
		4 plateau	pine forest	I-II		A 5 A	5	3	2	3
			oak forest							
			maple forest							
		5 ridge	pine forest			A 5 A	5	4	2	2
		6 dune	dune-grass prairie		S(Sn)	A 4 A	2	1	1	1
	D. Closed basin	7 lake	waterlilies	II-III-IV	Z(EAU)	A 2 F	3	4	3	2
		8 bog	leatherleaf	II	M(M2)	A 3 D	5	5	2	1
	E. Plain	9 ditch	bulrushes	II-III	M(M1)	A 3 B	2	3	4	2
		10 stream	pondweeds	II-III-IV	Z(EAU)	A 2 E	2	3	2	1
		11 marsh	cattails	I-II	M(M1)	A 3 B	4	4	5	3
		12 clay plain	bur-oak forest	II	T(6)	A 3 A	4	4	5	4
			maple forest			A 5 A				
		13 floodplain	elm-ash forest			A 3 A	4	5	5	5
	F. River	14 levee	sand	I	(Sn)	A 1 D	4	2	1	1
			poplar screen	II	(6)	A 5 B	4	3	3	3
		15 shore	silt	I	S (AGn)	A 1 E	4	2	1	1
			willow scrub	II		A 5 B	4	4	3	2
			alder scrub				4	4	4	3
		16 river	pondweeds	II-III-IV	Z(EAU)	A 2 E	2	4	3	3
B rural (transformation)	Culling	17 woodlot	maple, birch, pine woods	II	T(7)	B 2 A,E	4	3	4	2
	Plantation	18 orchard	apple orchard		H(G)	B 2 D	3	3	4	2
		19 sugarbush	maples		T(7e)	B 2 E	5	5	3	4
		20 lumbered forest	pine grove		T(7)	B 2 A	5	4	3	3
		21 plantation	trees		T2(10)	B 2 F	3	4	4	1
		22 nursery	trees, shrubs, flowers		T2(C2)	B 2 B	3	4	4	1
	Cultivation	23 horticulture	vegetables, small fruits		H (C1,F)	B 1 B-G	2	1	5	4
		24 special crops	tobacco, flax, etc.		A(C)	B 1 E-H	2	1	5	1
	Rotation	25 mixed farming	vegetables, cereals, hay	II-III	P (C,B,H)	B 1 I-J B 3 A	2	1	4	4
	Ploughing, abandon	26 fallow and abandoned	goldenrod old-field	II	A (J,K)	B 1 M(x)	5	2	2	4
		27 sod farm	grasses		H(Pel)	B 1 A	1	2	4	1
	Grazing	28 pasture	bluegrass-clover sward	III	K(P)	B 3 A,B	4	2	3	3
	Upkeep	29 garden, park	vegetables, flowers	II	O(C3)	B(j) B 5 C	1	1	5	4
		30 farmyard	buildings	V,I	Z(Z)	B 5 A	1	5	4	2
		31 farmhouse	house			B 5 A	1	5	4	3

C industrial (substitution)	1. Extraction	32 quarry	limestone, sandstone	I-V	(Xc)	C 1 J	4	3	5	1
		33 gravel pit	rosettes of evening primrose	I	E (Xg)	C 1 K	5	2	2	2
		34 sand pit	sumac scrub		(Xs)	C 1 L	5	2	1	2
	2. Transport	35 road	gravel, asphalt	V	B?	C 2 E	2	3	3	1
		36 airport	runways		?(TR)	C 2 B	1	4	4	2
		37 station	building		?(5)	C 2 C	1	5	4	1
		38 transmission line	pylons, wires		?(////)	C 2 F	1	4	3	1
		39 railroad	rails, sidings		?(5)	C 2 C	1	5	3	1
		40 clearing	débris		A(TR)	C 2 J	1	2	1	3
	3. Power	41 mill	dam, building		B(X)	C 3 E	3	3	5	1
	4. Manufacturing	42 factory	building	V,III-IV	B(X)	C 4	1	2	5	2
D urban (substitution)	Services	43 dump	garbage	V,I	(5a)	D 1 B	1	2	1	3
		44 hardware dump	hardware			D 1 C	1	2	1	2
		45 parking lot	pavement			D 1 D	1	2	1	1
	Recreation	46 place	pavement			D 1 A	1	3	1	1
		47 park	greenery	V,II	(4)	D 2 D	1	5	2	2
		48 playground	sports equipment	V	(4)	D 3 B	1	2	3	2
		49 racetrack	track, stand		O (4)	D 3 D	1	5	2	1
		50 marina	wharves		(4)	D 3 C	1	2	3	2
		51 golf	lawn	II	(4)	D 2 C	1	1	1	1
	Construction, upkeep	52 residence	houses	V	(4)	D 4	1	3	1	2
	Sales, service	53 commerce	buildings		(Z)	D 5	1	2	4	4
	Information, control	54 administration	buildings	V-VI	B (5)	D 7	1	2	3	2
	Information	55 institution	buildings		(5)	D 6	1	3	3	4

TABLE VII
The escalation of human impact (see Dansereau 1969, 1970, 1971a, 1973).

REVOLUTION	PHASE	STAGE	IMPACT	Social organization of man	Economy	Clothing	Shelter	Land occupation panel
VI. COSMIC	E CLIMATIC-COSMIC	8. EXOBIOLOGICAL ESCAPE	escape from gravity	isolated individual	power	extra-specialized	metal, plastic, mobile	E. COSMIC
V. CYBERNETIC		7. CLIMATIC CONTROL	geological and atmospheric alteration	technocracies	power	specialized	metal, synthetic, mobile	
	D INDUSTRIAL	6. URBANIZATION	agglomeration of habitat	dense societies	consumption, control	fabrics	stone, brick, wood, synthetic, permanent	C. INDUSTRIAL / D. URBAN
IV. INDUSTRIAL		5. INDUSTRY	substitution (mineral), fabrication	concentrated societies	dependent, transforming	fabrics	stone, brick, wood, synthetic, permanent	
III. AGRICULTURAL	C SETTLEMENT	4. AGRICULTURE	cultivation, selection, substitution (biological)	tribes, societies	production, from autarkic to dependent	rudimentary, skins, tissues, fabrics	stone, wood, permanent	B. RURAL
II. DOMESTIC	B NOMADIC-PASTORAL	3. HERDING	fire, pasturing, transhumance, propagation	tribes, societies (sometimes nomads)	subsistence, autarkic to open	rudimentary, skins, tissues	rocks, sticks, skins, wood, moss, temporary	
I. INSTRUMENTAL	A PRIMITIVE	2. HUNTING AND FISHING	ablation, displacement, fire	tribes (often nomads)	subsistence, autarkic or somewhat open	rudimentary	rudimentary	A. WILD
		1. GATHERING	ablation, submission	small tribes, hermits	autarkic or subsistence	none, rudimentary	none, rudimentary	

he has occupied is the very basis of the recognition of land-use or land-occupation types. *It seems to me both logical and useful to design land-occupation classifications by giving primary recognition to the energy expenditure and to the depth of change induced in various parts of the landscape.*

Thus, as I see it, land is primarily: (A) wild, (B) rural, (C) industrial, or (D) urban. I have already somewhat defined these terms in my comments on Figure 3 and Table VI, and will presently apply them to actual land-occupation by pointing back to the thresholds that are crossed at each one of the revolutions noted on Table VII. It will appear that *indigenous* processes characteristic of the wild state are superseded by *agrigenous* practices in the rural phase, by *fabrigenous* impacts in the course of industrialization, and finally by *urbigenous* processes.

A further consideration is derived from the above conspectus of human escalation, and it concerns the *dynamics of landscape*.

The idea of vegetational change and its underlying modifications of soil and microclimate, as well as its overlying shifts in animal occupancy, is very dear to ecologists and has been the object of a good deal of research (Odum 1969, Knapp 1974). The accumulation of unsaturated resources is largely responsible for the invasion of new occupants better equipped to tap them and the consequent decrease in numbers and eventual elimination of the original dwellers. The reverse is also known to be true, to the effect that an over-exploitive community will deplete the resources to the point that its members lack the hardiness or frugality that incoming invaders may possess.

Both of these mechanisms (progressive and retrogressive) are certainly involved where man is the "successor." Moreover, within man's dominion, different groups of men replace one another on a given site. Our concern lies very close to the many ways in which this is achieved, as we trace the various levels of efficiency in ecosystematic strategy when a primeval forest becomes a cereal field; when the latter is turned into an orchard; which is then replaced by a pasture; and finally by a residential development (see Figure 6B). Often the latter will fall from a valuable, rather low-density, neighbourhood to a slum and be razed to give way to a commercial centre.

The lessons we have learned in following the pathways of natural succession, with its various thresholds of change and plateaus of stability, should stand us in good stead when the engineer, architect, or planner who effects the change is neither termite nor beaver, but man. The noöspheric impact, as we have seen, is potentially many times larger when man is involved, but the detection of impacts on the six trophic levels lends itself to the same kind of analysis in an industrial or urban milieu as in a wild landscape (see Figures 6C, 6D).

The processes concomitant with succession in a wild landscape are related, among other things, to:

1) the *presence/absence of agents* endowed with adequate tapping devices;
2) the *diversification/simplification* of resources and agents in the ecosystem(s);
3) the *increase/decrease of productivity* at one or more of the trophic levels;
4) the *accumulation/exhaustion* of surpluses or reserves;
5) the *stability/shift of critical factors* and of controlling forces;
6) the *fast/slow turnover of interlocking cycles;*
7) the *resilience/vulnerability of the ecosystem(s);*
8) the *durability/sporadicity/ephemerality* of the ecosystem(s).

These criteria have been applied more often than otherwise to "natural" sequences (Odum 1969) such as the filling-in of a bog, the silting of a floodplain, the invasion of field by forest, etc. In several earlier publications (especially 1956, 1974, 1975) I have discussed and illustrated these points. I do not propose to restate these cases except as they affect land-use.[5]

Innumerable examples can be sought to test the ways in which man's control of natural ecosystems—and singularly the application of his knowledge of dynamics and of succession—has consisted in *riding the wave of pedogenic and/or vegetational change*, or, on the contrary, in *stemming the tide of a turnover*. Such are, for instance, management of natural forest or grassland for sustained yield. Such are the harvesting of birds' or turtles' eggs and of clams and oysters.

Running up the scale, we are led to ask ourselves *how the impact is effected.* A few examples follow (figures refer to escalation stage as on Table VII).

1. *Gathering* of fungi, leaves, fruit, nuts, roots, bulbs, rhizomes for food, and of bark, boughs, fibre, leaves for building shelters (by Pygmies in Central Africa or by Amerindians) induces very slight changes; these ablations are carried out in a state that can well be called *submission;* they do not necessarily require instruments of any kind, although to be sure such instruments are inevitably present when the gathering activity exists side-by-side with a more "advanced" way of life: blueberry picking in Maine or Lac St-Jean, oyster harvesting on the Atlantic coasts. The land-occupation types where this stage of human intervention prevails belong in the wild land panel (A).
2. *Hunting* and *fishing* may well remain at a low level of intensity and require a very minimum of technology. As practiced, until recently, by the Inuit, it consisted in exploiting animal surpluses, required considerable migrations at times, but can hardly be said to have involved management. The Prairie Indians and other Amerindians used not only spears and arrows but fire, and this appears as a deliberate attempt to manage the environment: in the grass-

[5] A recent book in the "Vegetation Handbook" series (Knapp 1974) contains a multidimensional review of the entire question of vegetation dynamics. My own contribution to the ecological impact study of Mirabel airport (1976) contains much detail on this subject, and I am making use of some of it in the present contribution (see especially Table VI and Figures 3, 5, and 6).

buffalo-Indian triangle is revealed a calculated tampering with the processes of soil/vegetation dynamics. After fire (that channels the movements of the buffalo herd), short-grasses are soon replaced by mid-grasses and eventually by tall-grasses, a cycle that grazing also sets back. This kind of land occupancy also fits into the wild land panel (A).

3. *Herding* is initiated by domestication, a technique that will lead to genetic engineering and that was revolutionary from its early beginnings inasmuch as it tampered with heredity at the same time that an increasingly conscious environmental management programme came to light. The taming and mustering of secondary producers (herbivores) fastened upon grazers, not browsers, and required increasingly large areas of grassland. In the Mediterranean countries and in the European mountains, forested land was *set back* in the natural successional series. The subalpine pastures are possibly the most striking example of this, especially where transhumance is involved. The treeless alpine level has a low productivity potential for grass and grasslike plants, whereas the warmer (and often wetter) subalpine storey, when stripped of its low forest or woodland, runs to luxuriant meadows and even prairies. This stage in succession is maintained by the high pressure of summer grazing. On the other hand, in the Mediterranean lands, virtually no lush grassland occupies a successional stage where the evergreen hardwoods have been removed, and the prevalence, in some areas, of browsers (especially goats) on the scrubby matorral and garigue is an adaptation to the lowered primary production potential that results from abusive exploitation. The areas thus characterized belong to the rural panel (B).
4. The *agricultural revolution*, that required spatial stability and a less narrowly empirical planning, devised a number of ways of harnessing the natural dynamics of landscape. The central problem that farmers have to solve is the survival and continued yield of a small number of plants and animals that are made to exploit ecosystems containing some resources that these (usually exotic) organisms may not be equipped for. Whereas, in the extreme instance of hydroponics, there is a measured adequation of resources needed and actual assimilation by the desired plant. In ordinary agriculture there is, as likely as not, a certain deficiency of these and a surplus of unused and unusable materials that create a veritable ecological vortex that draws in the so-called weeds and pests. This is compensated by drainage, amendments, and fertilizers, and by cultivation and spraying. The practice of rotation, early developed in swidden farming in the tropics and highly standardized in Europe, is a manner of planned succession intended to insure consecutive uptake and feedback by crops of widely varying requirements. It must also be pointed out that the successional/dynamic frame of agriculture, in any given region, shows a different rise or fall of potential and of adaptation according to the life-form of the crop plant and to that of its predecessor in the natural sequence: wheat replaces bluestem or fescue in Saskatchewan; it replaces elm or maple in lowland Quebec! The cocoa-tree (an Amazonian understory species) is inserted as a subordinate member of the rainforest in West Africa and elsewhere; the coffee plant is seen in variously open and closed stands in several forest, woodland, and savana zones. Quite obviously agriculture is at the centre and is usually the main component of rural landscape (B).
5. *Industrial* interventions in the landscape are very numerous. They are essentially of five kinds: 1) *extraction* (or harvesting); 2) *redistribution;* 3) *harnessing for power;* 4) *processing of raw materials* through *manufacturing;* 5) *services.* The place of operation of an industrial plant (industrial location) is conditioned by raw material, power, transport, labour, and market. The order of precedence of these constraining forces continues to vary from place to place and from time to time. The relation of the industrial plant to the resources of the landscape is therefore variously stressful: the drain upon air, water, and other mineral elements and the discharge of the same into the local ecosystems often exert major influence. The mineralization of the Sudbury (Ontario) region provides a dramatic example of the over-burdening of level I to the detriment of virtually all others. The eutrophication of Lake Erie is a simplification at level II and an over-productivity that threatens the depletion of levels I and III-IV. Industrial elements (C) in the landscape are more often than not scattered throughout the mosaic.
6. *Urbanization* starts with the compound, and the village, surrounded or variously permeated by wild or rural intrusions or relicts. In the town, the city, the megalopolis, such persistent plots may be eliminated altogether. The point relevant to my present consideration is the ecological character of urbanization. Residential, commercial, and other buildings rest upon a mineral base (excavated or not) that is indigenous, and they undergo weathering much as a cliff might do. The city nevertheless utilizes the ambient air-mass. It is mostly constructed with materials from far away (at least from one or more other ecosystems) and clearly dependent upon adducted elements of irrigation, heat, light, power (I), food (II, III, IV), clothing (II, III, IV), and manufactured supplies (V) as well as architectural and engineering plans and labour and behaviour-determining information (VI). It is, however, producing consumable and investable supplies (V), information and command (VI) in massive quantity. Cities variously occupy former wild, rural, or industrial land; each street and edifice has supplanted some previous affectation. Is the substitution complete or

incomplete? What compensations have to be programmed in order to prevent an *offensive return* of formerly prevalent forces? What management devices insure protection against cold, heat, erosion (I), weeds, moulds (II), animal pests (III-IV), undesirable structures (V), alien controls (VI)? All effects of the urbigenous processes result in occupations that put them in the urban panel (D).

7. *Climatic control* is a dimension of man's power that strikes far above the ecosystem and even the immediate landscape, at the major frame of regional dynamics (see Table V). Cloud-seeding and atomic explosions displace air and rock masses on a truly geological scale, one that is larger than flooding and fire. Much in the way that deglaciation has brought in its wake the latitudinal shift of tundra-taiga-boreal forest-deciduous forest in North America and in Europe and the explosion of Krakatoa has dimmed the atmosphere of the planet, it is the high orders of magnitude (see Table V) which gravely upset the resource pattern. Carbon dioxide and dust concentrations may cause regional drought and even planetary climatic change. By definitions previously applied in the present contribution, aeronautic channels and various occupancies of the atmosphere are to be ranked as *industrial* (C) and could well be mapped as such in a three-dimensional map. Unless a fifth panel (E) should be set up for stages 7 and 8?
8. As for *exobiological escape*, it is hard to assess, at this early date, the noöspheric impact's repercussions on actual land-use. It can certainly be said that new worlds are being conquered. Moon-landings have added a major category of land-occupation and so have space-platforms and artificial satellites.

A NEW CONSPECTUS OF ECOLOGICAL LAND-OCCUPATION (ELO)

The following proposal adheres, therefore, to the principles defined above and seeks a re-ordination of land-occupation types along strictly ecological lines, as far as the ultimate categories are concerned, and on broader environmental lines for the major categories.

The taxonomic outlook

All classifications must be judged essentially by two criteria: *trueness* to their object and *practicality*.

As the one-time disciple of a solipsist who had spelled out his philosophy in the year of my birth (Hochreutiner 1911), I was much exposed to the idea that "natural" classifications did not exist, that all taxonomy was a matter of convenience, of adequacy to the small compass of our mind, and of our need to separate objects in order to study them. Nevertheless, I have adhered to the best taxonomic tradition if, in the act of imposing my own inner order upon the outside world, I have never given up striving for a match with the objects themselves, confiding in my knowledge of genetics to reflect the affinity of plants in a nomenclatorial scheme, in my knowledge of structure and dynamics to devise a framework for vegetation, etc. Unattainable points of arrival provide motivation and orientation, indeed a sort of polarization which is useful in maintaining a grasp of the object of study. This grammar of taxonomy, depending upon the temperament of the proponent of a system and the needs of its users, is made to shift between theoretical grounds and pragmatic constraints. An oscillation between the presumption of objectivity and the insights of subjectivity is a necessary exercise that yields good results if it is undertaken with lucidity.

In the present instance it seems to me the trueness to the nature of things is better served in my proposed scheme, which is geared to environmental phenomena, than are most of the existing systems of classification. A glance back to Tables I, III, and IV shows the equivalents with my new categories (Table VIII) of the World Land Use Survey, of the British Land Use Survey, and of the Canada Land Inventory. Subsequent tables that will be offered in the present series of papers will provide further adaptations and adequations where widely different areas are being tested.

Having already argued for the ecological meaning of my proposition and for the logic of its subordinate categories, I must turn to the numerous features of its applications and practicality.

An ideal classification appeals to an easily-grasped logic, it is simple, contains as many mutually-exclusive categories as possible, lends itself to universal and rapid application, and leads to readable recording. Such is the Linnean (1753) system for plant and animal taxonomy; the Raunkiaer (1934) life-form system; such are the international geological and pedological systems (in: U.S.D.A. 1960); such is the Köppen climatic system (Köppen and Geiger 1954); and such is Küchler's (1967) system for recording vegetation.

When improvements upon these well-tested and well-worn schemes have been proposed, in the hope of a closer approximation to the real (objective) nature of the object of study and of its behavioural features, they are often achieved at the expense of simplicity, readability, memorization. Thus, Du Rietz's (1931) classification of life-forms has not supplanted Raunkiaer's; Thornthwaite's (1948) climatic classification has not replaced Köppen's, nor has Bagnouls and Gaussen's (1957), in spite of their greater significance and precision; the pedological categories of the "7th approximation" (U.S. Department of Agriculture, Soil Survey Staff, 1960) have not fully replaced the Dokuchaiev-Marbut scheme (Marbut 1935) although they reflect a better compromise between morphological and functional features. These systems may be truer but they require an effort that defeats the capacity of attention, the memory, or the eye of most users.

I could speak with some feeling on this subject, inasmuch as my own proposal of an adjustable symbolic scheme for representing vegetation structure (Dansereau 1951, 1957, 1958, 1968a, Dansereau, Buell, and Dagon 1966) has not been generally adopted. In the words of the author of a recent ecology textbook (Colinvaux 1973): "It has not come into wide use . . . partly for the reason that people are seldom ready to learn another's new language but more because it has been realized that refined description gives little help to answering grand ecological questions like why the plants are shaped as they are and why they live as they do." I am bound to quote this entire statement. Whereas I fully agree with the first part, I find the second unfair, inasmuch as the method in question is not aimed at a "grand explanation" but proposes a means of defining one of the dimensions of vegetation the better to cast it against other dimensions, and *then* to risk answering the form-and-function riddles. The ever-vexing circular reasoning that has plagued biogeographical research can only be circumvented if we devise methods of separating the objects, features, and criteria between which we seek a correlation! That is why I am aiming this first contribution towards land-occupation and not land-use; towards land-occupation and not land-potential or capability, although the ultimate goal is unequivocally land-use, and although the planner requires guidance on land potential. All of which will be considered, in the light of the present scheme, only when the descriptive foundation has been laid.

Such a statement, in fact, raises the whole issue of how classification can be expected to relate to problematics. *If we do not devise separate means of tackling form and function, anatomy and physiology, how shall we advance in our study of their mutual impacts?* An early trainee in the Aristotelian-Thomistic philosophy, I am bound to adhere to Jacques Maritain's (1934) "Distinguer pour unir" wherein lie the "degrees of knowledge" (or the levels of knowledge?).

I find it inescapable to pose such a question in the present context, inasmuch as every new classification incorporates existing knowledge about both form and function in its premises, and then tries to separate them anew. This paradox shows up in my present proposition in that the depth of alteration (a functional consideration) is the basis for my major categories, but the shape, texture, and extent of occupancy (a morphological category) constitute the ultimate criterion of the minor unit.

It would not be proper to pursue this topic at length and to offer further reflections on the merits of simplicity and readability vs. accuracy. Nor will I indulge in an apologetics of "significance." Instead, I shall proceed to outline the applications of my scheme, and in so doing possibly point out the recurring cycle of accurate description and functional interpretation.

Four dominants of landscape

It is thus on the basis of the prevailing processes, dynamic status, and degree of human control that elements composing the landscapes of the world can be assigned to four principal panels, according to the energy charge with which they are laden.

PANEL A. *Wild lands* essentially obey the laws of nature; their component ecosystems being under the sway of long-established heredity/environment contests, display *indigenous processes* of stabilization and change. Although they need not be *unused* by man, and may even be *indirectly managed*, they are not under his immediate and visible influence. *Primary and secondary productivity dominate* and there is virtually no actual consumption by man. Trophic activities at levels I to IV predominate.

PANEL B. *Rural lands* are *much transformed but sparsely occupied* by man. The indigenous and other spontaneous flora and fauna are usually eliminated (or else subjected to systematic culling) and replaced by chosen useful species and varieties. The dominant *processes* are *agrigenous*, geared to *agricultural yield*, which involves a simplification of agents intended to bolster to the extreme *primary* and/or *secondary productivity* of chosen plants and animals. Strict management, cultivation, breeding, harvesting, consumption, storage, and export are the main operations. Trophic levels I, II, and III are heavily weighted, but *investment* (V) has priority.

PANEL C. *Industrial lands* are marked by *very heavy investment*, *sophisticated information*, very *dense occupation*, and *intense use*. The component ecosystems are dependent upon *import* of raw materials, *efficient processing*, and *massive export*. *Fabrigenous processes* geared to *technology* are in command, allowing virtually no spontaneous activity at levels II, III, IV, whereas large investments (V) prevail subject to fluctuating (usually external) controls (VI). The productivity in industrial space is strictly tertiary.

PANEL D. *Urban land* is quite *densely built-up* and harbours a numerous and *concentrated human population*. *Urbigenous processes* are the inescapable solutions to metabolic problems of dense congregations of men; favouring inner diversification, they are meant to satisfy all human needs (physiological, psycho-social, economic, cultural) and therefore command a great variety of investments (V) that must submit to various means of control (VI). Shelter, storage, exchange, communication are the dominant processes leading to massive occupation by artifacts. Consumption (and indeed, survival) in urban spaces is dependent upon the tapping of other ecosystems having a strong phytotrophic (primary) and zootrophic (secondary) productivity and also upon the tertiary yields of industry.

One is tempted to add a fifth panel (E) encompassing atmospheric and extra-terrestrial zones, although the pathways of aerial navigation, the temporary occupancy of space-platforms and space-capsules, the ephemeral moon-landings, may well lack the permanence of the four other panels. Nevertheless, in the compass of Table VII, they provide *habitats* that are constructed, equipped, and powered in a way quite unlike the others.

The ELO scheme and its formulae

A new scheme for classifying the land-occupations of the world is presented in Table VIII. It is based on the ecological views that have been detailed above. Its major divisions (or *management regimes*) follow the principal steps in the escalation of man's power over environment (Table VII) and recognize as divisions of the *first order* the four *panels* defined above: A. Wild; B. Rural; C. Industrial; and D. Urban.

The second order reflects the *kind of exploitation* (extraction, processing, etc.), and this also is amenable to linear progression of a sort, or at least to assemblage in homogeneous *blocks*. It is primarily based on *process*.

The *third order* is the *type* of occupation (quarry, orchard, etc.), which is characterized either by a *resource* or an *agent*.

A denominator is given to these digits, based upon the *trophic level* that bears the heaviest energy burden (see Figures 2 and 3), and is numbered accordingly: I to VI.

Emerging categories may thus be assembled in a formula that contains the essential information. In the upper line, A, B, C, or D (regime) refer to one of the major *panels;* the *blocks*, showing the *kind of exploitation*, are numbered in arabic figures, whereas the *type of occupation* is represented by a capital letter. The dominant *trophic level*(s) is given as a denominator. The whole formula for a *land-occupation type* reads as follows:

$$\frac{\text{C 1 J}}{\text{I}}$$

which is spelled out:

C for *industrial* land (regime) (panel),
1 for predominance of *extraction of mineral* raw materials (kind of exploitation) (block),
J for *quarry* (type of occupation),
I for predominance of *minerotrophy*.

A more complex formula involving lower-case letters, such as $\frac{\text{C 1 Ja}}{\text{I}}$, would refer to a *limestone* quarry that identifies the resource. The full formula for the maple sugarbush reads $\frac{\text{B 2 Ea}}{\text{V, II}}$, and this means

B *agricultural land* (panel),
2 predominance of *woody plant exploitation* (block),
E *tapping* (process),
a *maple* (identity of agent),
V, II predominance of *investment* at the *phytotrophic* level.

I have made an attempt to allow for all the possible subdivisions known to me as of potential world-wide occurrence in the three orders, although extensive discussions and tests have given me warning that yet other groupings can well arise at the third- or fourth-order levels. It also will be argued that some lower-case units should be raised to the third order.[6]

There clearly emerge many fourth and fifth orders, and in a number of instances I have given examples thereof, as witness maple sugarbush above, as a subdivision of trees tapped for various purposes (resin, latex, etc.). There would seem to be an almost unlimited number of them if one scans the whole planet for application of this scheme. I will hardly attempt this now (although I am confident that it can eventually be achieved), but I feel bound to develop my application to the fourth and fifth subdivisions in a good number of instances so as to get down to the concrete level where such a comprehensive classification stands some chance of practical recognition.

I therefore propose that the term *land-occupation type* be applied to potentially universal or at least widespread spatial occupation, such as coral reef $\frac{\text{A 6 C}}{\text{III, IV}}$, fur farm $\frac{\text{B 4 B}}{\text{IV}}$, quarry $\frac{\text{C 1 J}}{\text{V, I}}$, parking lot $\frac{\text{D 1 D}}{\text{V, I}}$, involving three symbols and their trophic denominator. In fact, recognition can often be given to a further subdivision, as in volcanic ash bed $\frac{\text{A 1 Aa}}{\text{I}}$, burned-over forest $\frac{\text{B 2 Ab}}{\text{V, II}}$, cotton textile mill $\frac{\text{C 4 Ic}}{\text{V, II}}$, theatre $\frac{\text{D 6 Ft}}{\text{VI, V}}$, where four symbols occupy the upper line.

The example cited above for maple sugarbush decidedly belongs to a lower category that can only occur as a regional unit. Such would also be true for a number of crops. If cereals appear as $\frac{\text{B 1 I}}{\text{V, II}}$, different kinds will require an additional symbol, such as $\frac{\text{B 1 It}}{\text{V, II}}$ for wheat, $\frac{\text{B 1 Ih}}{\text{V, II}}$ for barley, $\frac{\text{B 1 Iz}}{\text{V, II}}$ for maize, $\frac{\text{B 1 Ia}}{\text{V, II}}$ for oats, and so on.

Lest it be inferred that the categories recognized in Table VIII are a sort of last word in land-occupation classification, let me make my purpose clearer by developing a few examples revealing the broader reach of some three-digit land-occupation types.

In the *wild* panel (A), *rock outcrop* is part of block 1, and reads $\frac{\text{A 1 B}}{\text{I}}$. It can be subdivided according to qualities of the rock, thus: $\frac{\text{A 1 B}}{\text{I}}$ rock outcrop

a limestone	*or*	a abrupt
b granite		b flat
c sandstone		c smooth
d gypsum		
e . . .		

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[6] Since I made my original proposal in 1973, maps have been drawn by my collaborators, assistants, and students in Montreal, Waterloo, and Auckland (New Zealand), and such diverse areas as northern New Zealand, coastal British Columbia, central Alberta, southern Ontario, southern Québec, the Gaspé Peninsula, the Magdalen Islands, and the Azores have been sampled. The results of this application are discussed in Part II "Mapping Methods and Problems" by Gilles Paré.

In the course of these studies the classification was shifted and modified a good deal. Table VIII, finalized in January 1976, is the tenth version, actually. It will be allowed to stand for some time, as far as I am concerned, so that it may be thoroughly tested.

TABLE VIII
Ecological land-occupation (ELO).

Panels (A. Wild, B. Rural, C. Industrial, D. Urban) show the *regime* of land-occupation in the order of increasing management by man

Blocks (1, 2, 3,...) indicate the progression (from bottom to top) of energy input, and the shift from one group of processes to another

Types (A, B, C, D, E,... or Aa, Ab, Ac...) are the exact *kinds* of occupation of a wide geographical range

Trophic levels: I. Minerotrophy, II. Phytotrophy, III. Zootrophy (herbivory), IV. Zootrophy (carnivory), V. Investment, VI. Control (see Figure 2)

Method: P : airphoto reading sufficient (1:20,000 or less)
T : field-work necessary (visual inventory, analysis, survey)
P-T: airphoto reading possible. Field-work desirable for verification
T-P: field-work preferable. Airphoto reading possible

The *formula* for a unit area reads, for example:

$\frac{A\ 3\ D}{II}$ = bog $\frac{B\ 2\ Ea}{V,\ II}$ = maple sugarbush

$\frac{C\ 2\ Eg}{V,\ I}$ = gravel road $\frac{D\ 3\ B}{V}$ = playground

MOBILE ELEMENTS

In A, B, C, D:		*In B, C, D:*	
(a) Trees in a row	P	(f) Channel	P-T
(b) Hedge, hedgerow	P	(t) Parking lot	P
(c) Fence	T	(u) Construction	P-T
(d) Pylons	P-T	(w) Irrigation	T-P
(g) Pasture	P	(x) Abandoned	T-P
(j) Garden/kitchen garden	P		
(l) Lawn	P		
(n) Snow	P	*In A only:*	
(q) Grove	P	(p) Unmanaged park	T
(s) Path, driveway	P-T	(r) Fully-protected reserve	T

PANEL A. WILD

Blocks	Trophic Levels	Types	Method
6 Animal aggregation	III, IV	A Mammal herd	T-P
		B Bird colony	P-T
		C Coral reef	P-T
		D Shell bank	P-T
5 Predominance of woody plants on upland	II	A Forest	P
		B Parkland	P
		C Savana	P
		D Scrub	P
		E Tundra	P
4 Predominance of herbaceous plants on upland		A Prairie	P
		B Meadow	P
		C Steppe	P
		D Desert (see A 1)	P
		E Crust	P
3 Wetlands		A Swamp forest	P-T
		B Marsh	P
		C Saltmarsh	T-P
		D Bog	P
2 Water	I, II, III, IV	A Sea	P
		B Estuary	P
		C Lagoon	P
		D Salt lake	T
		E Flowing water (river, stream, cataract)	P
		F Still water (lake, pond)	P
	I	G Ice	P
		H Snow	T
1 Raw minerals		A Volcanic elements	P
		B Rock (outcrop, cliff, flat)	P
		C Gravel	P
		D Sand (beach, dune, spit)	P
		E Silt	T-P
		F Clay	P
		G Salt flat	T-P

PANEL B. RURAL

Blocks	Trophic Levels	Types	Method
5 Construction & maintenance	V	A Yards and outbuildings	P
		B Recreation space	T-P
		C Greenhouses	P
	V, II, I	D Clearing	P
4 Breeding	V, III, IV	A Wild animals (see D 2 A)	T
		B Fur-bearing animals	T
		C Draft and riding animals	T
		D Butchery animals	T
		E Dairy animals	T
		F Wool-bearing animals	T
		G Pets	T
		H Poultry	T-P
		I Pisciculture	T-P
		J Apiculture	T-P
		K Silkworm orchard	T
		L Earthworms	T
3 Pasture	V, III	A Improved pasture (enclosed, permanent in rotation)	P-T
		B Unimproved pasture (itinerant, extensive)	P-T
2 Woody-plant exploitation	V, II	A Lumbering (selective cut, burn, clear-cut)	P-T
		B Nursery	P
		C Vineyard	P-T
		D Orchard	P
		E Tapping (sugar, rubber, resin, bark, cork)	T
		F Plantation	P
		G Fruiting shrub	P-T
1 Cropping of herbaceous plants		A Sod	P-T
		B Fruiting plants	P-T
		C Foliage plants	P-T
		D Roots, tubers, bulbs	T
		E Fiber plants	T-P
		F Medicinal plants	T-P
		G Aromatic plants	T-P
		H Oil plants	T-P
		I Cereals	P-T
		J Fodder and silage	P-T
		K Mushrooms	T
		L Flowers	P
	V, I	M Fallow	T-P

PANEL C. INDUSTRIAL

Blocks	Trophic Levels	Types	Method
5 Services	V, II, III, IV	A Cleaning	T
		B Storage	P-T
		C Washing	T-P
	V, I	D Garage	T-P
		E Repairs	T
		F Filtration plant	T-P
		G Reservoir	P-T
4 Manufacturing	V, III, IV	A Wool	T
		B Leather, skins	T
		C Oil, fat	T
		D Meat	T
		E Fish and invertebrates	T-P
		F Dairy products (casein, cheese, butter, cream, milk)	T
	V, II	G Wood (pulp-and-paper, sawmill, furniture)	P-T
		H Fruit and vegetables	T
		I Fiber (textiles)	T
		J Spirits (distillery, brewery)	T
	V, I	K Jewelry	T
		L Rock and sand	T
		M Clay (brick, ceramics)	T
		N Metal and mineral	T
		O Petroleum	P-T
		P Coal	T-P
		Q Mineral water	T
3 Energy		A Solar plant	T
		B Nuclear plant	T-P
		C Thermal plant	P-T
		D Hydroelectric plant	P-T
		E Hydraulic mill	P-T
		F Windmill	P-T
2 Transport and communications	V, I	A Telecommunication	P-T
		B Airport	P
		C Railroad and station	P
		D Port and shipyard	P
		E Road and highway	P
		F Transmission line	P
		G Ducts (pipeline, aqueduct, pumping station)	P-T
		H Bridge	P
		I Lighthouse	P
		J Clearing and filling operations	P
1 Extraction	V, III, IV	A Bones	T
		B Manure (guano, manure)	T
	V, II	C Sod (see B 1 A)	P-T
		D Peat	P
		E Litter (straw, compost)	T
		F Muck, humus	T
		G Algae	?
	V, I	H Mine	P-T
		I Salina	T
		J Quarry	P
		K Gravel	P
		L Sand	P
		M Clay and silt	P-T
		N Petrol	P-T
		O Gas	P-T

PANEL D. URBAN

Blocks	Trophic Levels	Types	Method
7 Administration, public service	VI, V	A Governmental	T
		B Public	T
		C Private	T
6 Institution		A Financial	T
		B Military	T-P
		C Religious	T
		D Educational	T-P
		E Medical	T-P
		F Cultural	T
5 Commerce	V	A Hostelry	T
		B Restaurant	T
		C Stores (shopping centre, shops)	T
		D Market	T
		E Warehouse	T-P
4 Residence		A Single-family (mansion, cottage, bungalow, row house, semi-detached, hut, shack)	T-P
		B Multifamily (duplex, triplex-multiplex, apartment house, highrise)	T-P
3 Open spaces		A Stadium (open, closed)	P
		B Playground	P
		C Marina	P-T
		D Racetrack	P
2 Green spaces	V, III, IV, II	A Zoo (see B 4 A)	T-P
	V, II	B Botanical garden	P-T
		C Golf links	P
		D Park	P-T
		E Cemetery	P
1 Paved or unplanted spaces	V, I	A Square, plaza	T-P
		B Dump	P
		C Junkyard	P
		D Vacant lot	P

In the *rural* panel (B), plantation is $\frac{\text{B 2 F}}{\text{V, II}}$ and can be subdivided according to the qualities or identities of the species planted, thus: $\frac{\text{B 2 F}}{\text{V, II}}$ plantation

a evergreen	*or*	a pine
b semideciduous		b spruce
c deciduous		c larch
d succulent-leafless		d maple
		e oak
		f . . .

Again, in the *rural* panel (B), *dairy animals* are $\frac{\text{B 4 E}}{\text{V, III}}$, and can be further qualified as:

a Holsteins	*or*	a stabled
b Jerseys		b pastured
c Ayrshires		
d Charolais		
e . . .		

In the *industrial* panel (C), *fish and invertebrate factory* is $\frac{\text{C 4 E}}{\text{V, III, IV}}$, but it can be subdivided as to nature of resource or nature of operation, thus: $\frac{\text{C 4 E}}{\text{V, III, IV}}$ fish and invertebrate factory

a tuna	*or*	a drying
b cod		b salting
c mackerel		c smoking
d herring		d marinating
e lobster		e canning
f oysters		f . . .
g clams		
h . . .		

In the *urban* panel (D), a *governmental administration* unit is $\frac{\text{D 7 A}}{\text{VI, V}}$, and will comprise:

a post office	*or*	a federal
b fire station		b provincial
c police station		c municipal
d welfare bureau		d international
e information		
f court house		

Also in the *urban* panel (D), residence (D 4) is first subdivided according to type of occupation: $\frac{\text{D 4 A}}{\text{V}}$ = single family, and is further subdivided into:

a mansion
b cottage
c bungalow
d rowhouse
e semi-detached
f shack
g hut

whereas $\frac{\text{D 4 B}}{\text{V}}$ = multifamily, and is subdivided into

a duplex
b triplex-multiplex
c apartment-house
d high-rise

Within this block 4 (compare with A 5) an adjustable coefficient can be used connoting building materials, or style, such as

a rock	*or*	a Colonial
b carved stone		b Gothic
c brick		c Victorian
d mortar		d Georgian
e concrete		e New England
f shingle		f Western
g wood		g Californian
h . . .		h . . .

It is scarcely possible to give the fourth order a truly world-wide character, and the examples provided above are not so comprehensive as they are intended to be in the instance of the third order. Thus, a shack, a mansion, a high-rise apartment house can and do occur all over the world, but some of the building materials and styles of architecture have regional occurrence only and the above enumeration may well meet virtually all Canadian cases but not constitute a universal enumeration.

So much for the rationale of the classification and for its symbolism, which will be considered again in relation to mapping.

Ecosystem equivalents of land-occupation types

I have argued here and elsewhere (1971a, 1975) against the widely held opinion (Evans 1956, Margalef 1968, 1974, Odum 1971, 1975, Duvigneaud 1974) that ecosystems are of any size, that the concept is applicable to circuits of energy flow at all orders of magnitude, from tropospheric circuits to metabolism of a small pool inside the pitcher-plant. Although I do not fail to recognize this functional dimension as a basic and highly significant fact, I have been at some pains to winnow out of the total environmental matrix a certain order of dependence and an imbrication of successive controls (Dansereau 1956, 1957, 1971a, 1974, 1976). In Table V I have revised an earlier projection (1957, 1972a), as I believe that recognition of several orders of magnitude in the environment is a prerequisite to an ecological definition of land-occupation types.

The adequation of such types to veritable ecosystems has already been attempted in Figures 1 and 3. The latter is based on the ball-of-arrows (Figure 2), and I propose to fill in this model in order to summarize the ecological characteristics of several other land-occupation types.

Three questions will arise concerning each and every type:

a) What are its inner dynamics?
b) What are its connections and tensions with other regional types?
c) In what categories of a supraregional order is each one likely to be found?

I cannot attempt to answer these three questions for all of the types listed in Table VIII, but will make a brief sampling in each block of all four panels, in order to probe the perspective and the purpose of this classification. The following discussion is accompanied by Figure 4, which comprises the four panels: A, B, C, D. The balls-of-arrows of Figure 4 are patterned after those of Figures 2 and 3.

In wild lands (Figure 4 A)

A *rock outcrop*, $\frac{\text{A 1 B}}{\text{I}}$, is a purely minerotrophic ecosystem, virtually devoid of all activity at levels II-VI. It is principally subject to weathering processes and to a very faint biological impact, since it is amenable to some occupation by algae, mosses, and lichens. Occasionally the latter may be conditioned by bird lime (allowing a transition to A 4 E). Rock outcrops can and do occur all over the world, although they are conspicuously absent from such regions as the larger loess plains.

A *lagoon*, $\frac{\text{A 2 C}}{\text{I-IV}}$, has four levels of great activity: (I) the silting and sorting of mineral particles with shifting tides; the variations of salinity, temperature, and water level provide for a rich segregation of mineral resources into niches; (II) zonation of vegetation belts composed of aquatic halophytes follows such a patterning; which in

A. WILD LANDS

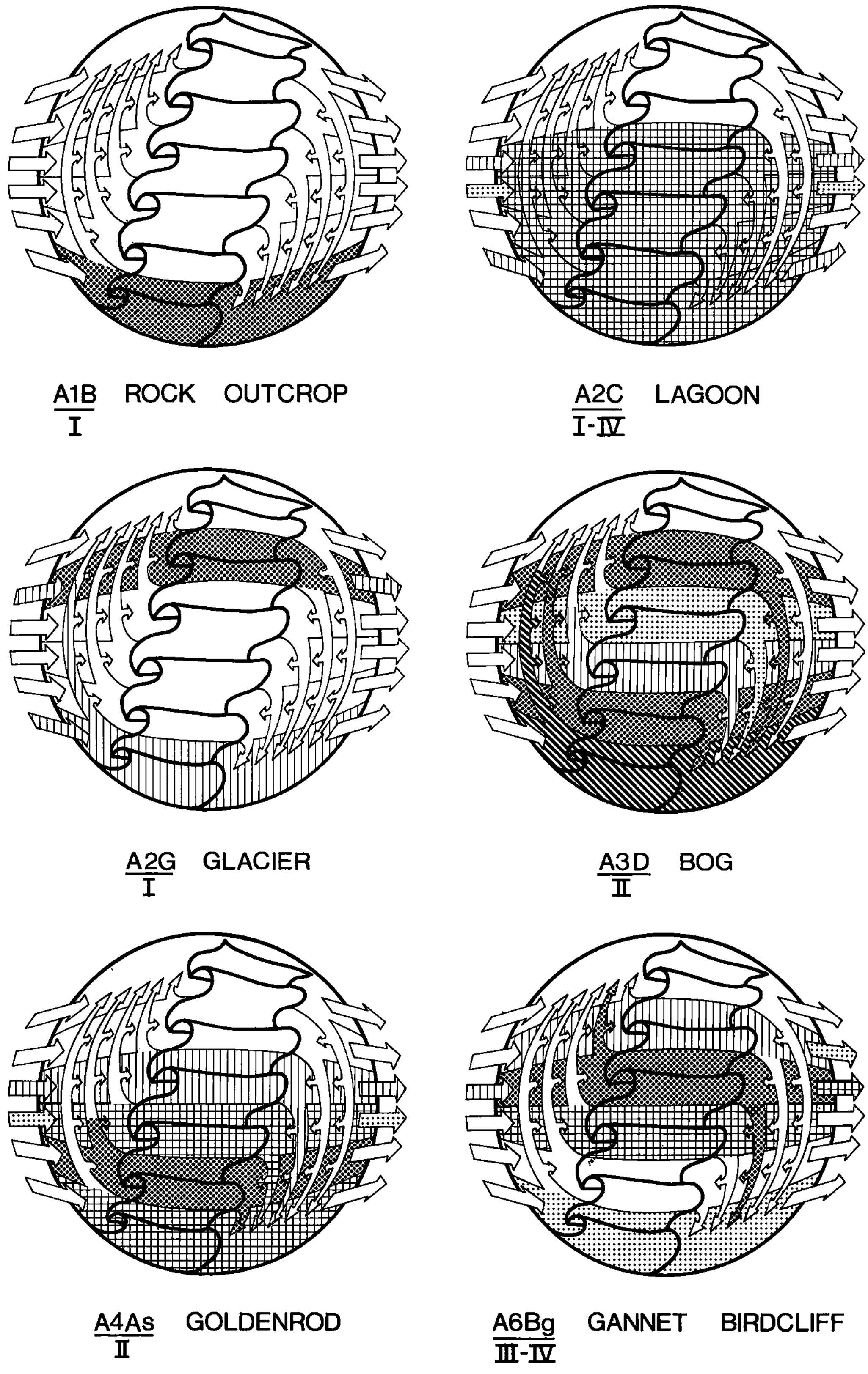


FIGURE 4 A. The wild lands. Balls-of-arrows (see Figure 2) exhibiting relative weight of trophic activity, as in Figure 3. (For an example of block A5, see Figure 3: maple forest, which is A 5 A / II .)

turn (III) serves as shelter and food to many phytophagous invertebrates and vertebrates that are preyed upon (IV) by a number of somewhat more mobile carnivores. Lagoons occur only where sand spits or other barriers allow an inland penetration of salt water, and a silting process favourable to the accumulation of organic ooze.

Solid, permanent *ice*, $\frac{\text{A 2 G}}{\text{I}}$, is even less hospitable than the rock outcrop to life of any kind, least of all to permanent settlement. Temperature and precipitation cause fluctuations in volume and in outflow of melt-water to neighbouring ecosystems. Permanent ice is restricted to high mountains and high latitudes, although some mountain glaciers flow down to very low altitudes.

A *bog*, $\frac{\text{A 3 D}}{\text{II}}$, only develops in closed drainage systems that allow virtually no lateral movement of water and therefore no influx of minerals other than water; the indefinite but incomplete decomposition of plant (and animal) remains takes place under anaerobic conditions, so that dead organic matter forms the entire non-living substratum, which plants (II) of a highly specialized physiology (oxyphytes) are able to exploit. The low primary productivity hardly allows an important mass of phytophages (III), even less of carnivores (IV), to subsist. Bogs are extremely stable unless the water level is lowered or the drainage is opened up (which would lead to replacement by marsh: A 3 B). Bogs do not form in the warmest, driest, and coldest zones, but require a combination of cold, rather high precipitation, and blocked drainage.

A *goldenrod prairie*, $\frac{\text{A 4 As}}{\text{II}}$, occupies a (I) well-drained, fairly deep and fertile soil; it consists of many kinds of leafy and grasslike herbs (II), some with rather deep roots; it offers shelter and food to innumerable insects, birds, and small mammals (III) that harvest a great crop of root, stem, leaf, and grain and prey (IV) upon each other. It is under constant menace of invasion and shading out by woody plants (cherries, hawthorns, birches, pines). Goldenrod prairies are a transition stage in agricultural areas ("old fields") of Eastern North America, where they are replaced by scrub (A 5 D) or savana (A 5 C).

The *maple forest* (shown in Figure 3) is $\frac{\text{A 5 Aa}}{\text{II}}$. It has very active soil-processes (I) and of course an extremely high phytotrophic productivity (II); abundant and diverse harvest thereof by phytophagous animals (III) and a good number of predators (IV), not all residents. The investments and reserves (V) in soil, in plants, in hibernating or overwintering animals are quite high also. This well-balanced ecosystem is largely self-controlled, being amenable to change, under wild conditions, only if the prevailing climate should undergo a major shift.

A *gannet birdcliff*, $\frac{\text{A 6 Bg}}{\text{III, IV}}$, consists of extremely numerous and crowded breeding birds that fairly inhibit all pedogenic processes (I) by covering the substratum with their excrements; this antibiotic action inhibits all plant growth (II) and, of course, other phytophagous animal life as well. The birds are subject to parasites and to occasional predators (IV). They use the cliff as a breeding ground, the adults plunging down to sea for seaweed to garnish their nests and fish to feed themselves and the young. The concentrated nitrates and phosphates of their guano are washed off by rain into neighbouring and unoccupied crevices or ledges where, thus diluted, they greatly enrich the soils of these other ecosystems. Thus the permanence of the bird colony is assured by an import of food from the sea and an export of nutrients to grassy patches and meadows (A 4 B), not to mention the seasonal abandonment of the site. Gannets, boobies, and their relatives form these dense agglomerations in tropical, temperate, and cold zones.

In rural lands (Figure 4 B)

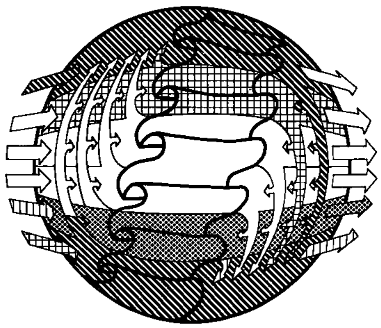
A *sugarcane field*, $\frac{\text{B 1 Cs}}{\text{V, II}}$, is heavily dominated by close-growing *Saccharum officinarum*, a plant of very high efficiency (II), if the supply of water and minerals (I) is abundant. The plant/soil relationship needs fertilizer and sometimes irrigation from outside sources, since it reinvests relatively little material and exports a great mass of plant tissue. The animal levels (III and IV) are as totally neutralized as possible through the application of pesticides (V). Capital investments (V), regulations, and market fluctuations (VI) are very influential. Of course, sugarcane grows only in moist tropical areas.

A *sod farm*, $\frac{\text{B 1 A}}{\text{V, II}}$, is geared to production of grass (II), but soil (I) as well as live vegetable material is harvested and taken out of the ecosystem and has to be compensated for. Some soil faunal activity, especially earthworms (III), is beneficial, whereas carnivores (IV) find next to nothing to prey upon. Investments in machinery and labour (V) are quite heavy and the main controls mostly lie outside the rural zone. Sod farms do best in cool-moist areas with a warm summer.

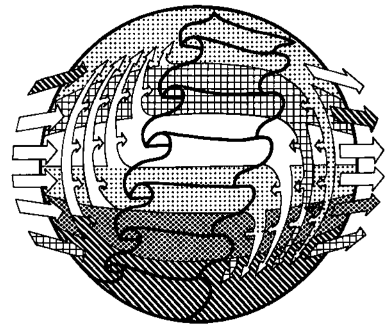
A *pine-resin grove*, $\frac{\text{B 2 Eb}}{\text{V, II}}$, consists of close-growing pine trees (II) that are tapped (V) for their resin, which is processed for the production of turpentine. A number of insects (III) are active, but carnivores (IV) are virtually absent. A fairly extensive equipment (V) is necessary, and the market demands (VI) for the product fluctuate. Warm-temperate marine or at least coastal climates (Bordelais, South Carolina) seem to offer the best conditions to such species as *Pinus pinaster*, *P. caribaea*, *P. longifolia*.

A *closed pasture*, $\frac{\text{B 3 Aa}}{\text{V, III}}$, harbours grazing animals (III) whose product (milk, meat, hide) is exported. As a rule, vegetable food (II) has to be brought in. The soil potential (I) may be high, and yet trampling and excessive manuring may inhibit phytotrophic processes (II). Carnivores (IV) are carefully kept out, but parasites may be present. Fencing, feeding, breeding (V) weigh heavily on

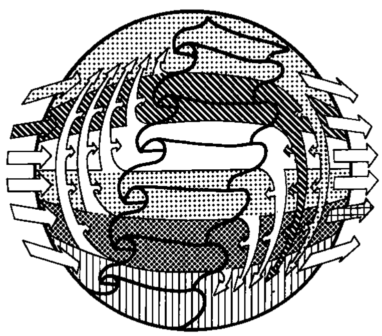
B. RURAL LANDS



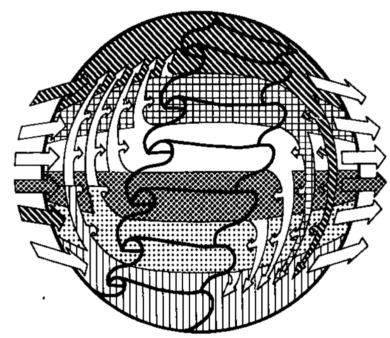
B1Cs SUGARCANE FIELD
V, II



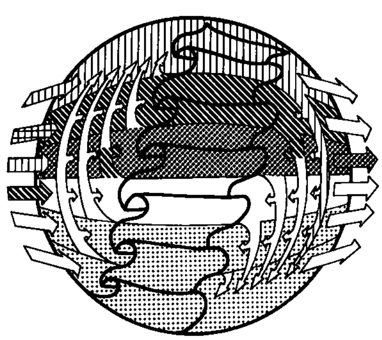
B1A SOD FARM
V, II



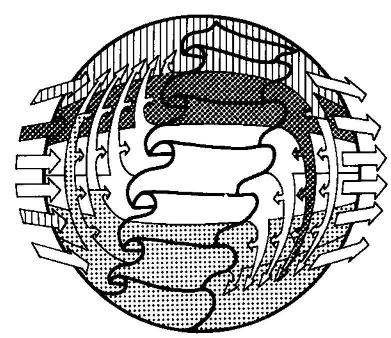
B2Eb PINE-RESIN GROVE
V, II



B3Aa CLOSED PASTURE
V, III



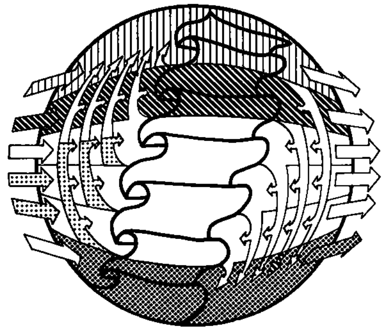
B4Ba FOX FARM
V, IV



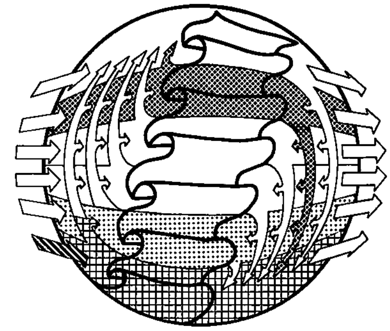
B5Aa FARMHOUSE
V

FIGURE 4 B. Rural lands. Balls-of-arrows (see Figure 2) exhibiting relative weight of trophic activity, as in Figure 3.

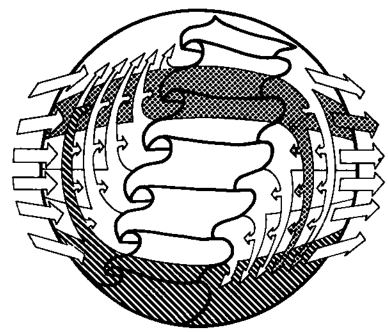
C. INDUSTRIAL AREAS



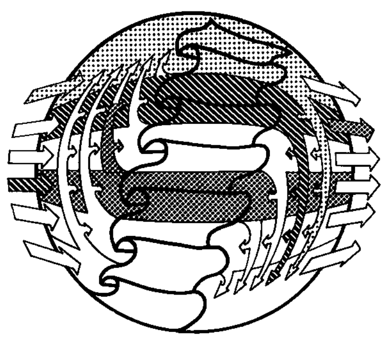
C1Ha / V,I — UNDERGROUND MINE



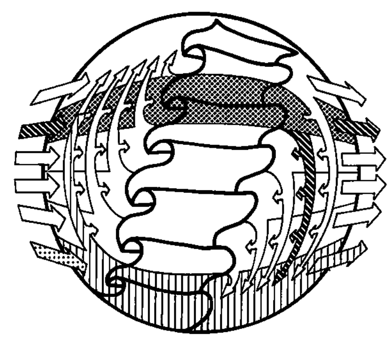
C2C / V,I — RAILROAD



C3D / V,I — HYDRO-ELECTRIC COMPLEX



C4Fb / V,III — CHEESE FACTORY



C5D / V,I — GARAGE

FIGURE 4 C. Industrial areas. Balls-of-arrows (see Figure 2) exhibiting relative weight of trophic activity, as in Figure 3.

this kind of pasture. On the other hand, market demand (VI) may well cause fluctuations of the grazing and mustering activities. As likely as not, a closed pasture is a unit in beef-farming (A 4 D), dairy-farming (A 4 E), sheep-raising (A 4 F), etc.

A *fox farm*, $\frac{\text{B 4 Ba}}{\text{V,IV}}$, shows little dependence on soil (I) and vegetation (II) as such; although they are important, in a general way, as dry, even, substratum and as screen and shelter. But, it is the well-fed (IV) and well tended (V) carnivore (IV) whose pelt is being exported to which the ecosystem is geared. Cages, kennels, feeding devices, exercise pads (V) have to be provided. The market (VI) notoriously fluctuates and causes the abandonment of many fox farms that will revert to scrub (A 5 D). A cool climate, with not too warm summers, is most favourable.

A *farmhouse*, $\frac{\text{B 5 Aa}}{\text{V}}$, cannot be built on just any substratum (I): good carrying capacity, efficient drainage are necessary; vegetation (II) will, by and large, be ornamental, providing shade and decoration rather than food. The building itself (V) will be constructed out of imported materials and will contain almost exclusively imported furnishings, the choice of which witnesses social and economic influences (VI). According to the region, the type of farming and the value of its yield, climatic and edaphic tolerances variously combine with preferred architectural style and building materials to suit the pattern of the building.

In industrial areas (Figure 4 C)

The *underground mine*, $\frac{\text{C 1 Ha}}{\text{V, I}}$, functions only at the minerotrophic level (I), thanks to heavy investments (V) in machinery and labour. The extracted materials are in no way compensated. The disposal of the product is controlled (VI) by active and occasionally fluctuating economic forces. There is literally no biological activity (II, III, IV), unless the human workers are considered, whose metabolic processes require air and water (I) and vegetable (II) and animal food (III) and clothing. The location of mines depends exclusively upon geological strata, although depth below soil level and geographical accessibility are also factors. Of course, climate at ground level also imposes constraints on the operating techniques. An abandoned mine may eventually be used for storage (C 5 B) or even as a reservoir (C 5 G).

A *railroad*, $\frac{\text{C 2 C}}{\text{V, I}}$, demands a total clearing of previous occupation, down to the mineral level (I). Investments (V) are heavy and, perforce, long-term, and maintenance is constant. It is the investment as such that fairly controls the system. Some invasion by vegetation is inevitable, and in some situations desirable and deliberate (e.g., *Equisetum arvense*, *Robinia pseudoacacia* as consolidators of the embankment). The railroad bed and the upkeep practices will vary a good deal according to physiography, topography, and climate.

A *hydroelectric complex*, $\frac{\text{C 3 D}}{\text{V, I}}$, consisting of a dammed watercourse and an energy-producing plant, is strictly geared to the mechanical channelling (V) of contained water (I) for the massive export, by transmission, of electricity. All other levels are inhibited. This ecosystem can be developed only in areas of fairly high and virtually constant water availability. Therefore, the dry regions present an obstacle, except where long-distance channelling is possible (Egypt), and so do the very cold regions.

The *cheese factory*, $\frac{\text{C 4 Fb}}{\text{V, III}}$, gets its raw material as a product of herbivorous animals (III), by transforming (V) milk brought in from farms and exporting cheese. Some pressure of market control (VI) and technical improvements (V) affect virtually all levels, eliminating carnivorous animals (IV) and other pests such as insects (III) and moulds (II) from the premises (I). Normally, such an industry is located within or near the periphery of a dairying zone, which, in turn, is best situated in a cool, moist climate with high-yielding pastures.

A *garage*, $\frac{\text{C 5 D}}{\text{V, I}}$, is a highly simplified ecosystem, dealing in services (V) to a constantly incoming and outgoing flow of mechanical devices (trucks, automobiles, motorcycles). The metabolism of air, water, petroleum fluids (I) is fairly high and efficiently cuts down biological activity (II, III, IV). Heating and cooling conditions may well be different in Aklavik, Chicago, New Delhi, and Punta Arenas, but the ecological structure is not likely to vary.

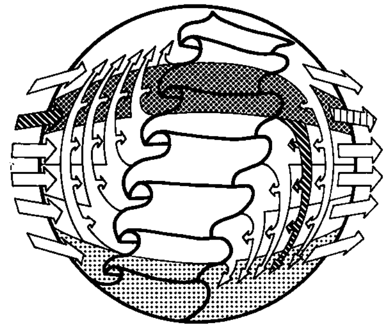
In urban areas (Figure 4 D)

A *junkyard*, $\frac{\text{D 1 C}}{\text{V, I}}$, represents primarily an investment (V) of derelict (although partly recuperable) mineral objects (I). The substratum is thus pre-empted and unable to foster any kind of vegetable (II) or animal (III, IV) productivity. Its very uneven inputs and outputs are entirely due to outside forces. Inasmuch as, contrary to a dump (D 1 B), it contains no bioreducible materials it can occupy any site at all, under any climate.

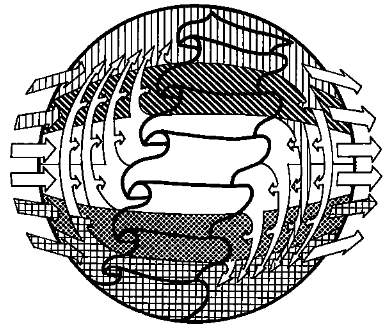
Golf links, $\frac{\text{D 2 C}}{\text{V, II}}$, owe their existence to a highly productive low sward of grasses (II) deliberately sown and managed (V) so as to maintain the soil potential (I). Social benefits for health and recreation are at the origin of the forces (VI) that maintain the investment (V). Sprays, cultivation, and other maintenance practices keep the links free from most forms of animal life (III, IV), except man. This ecosystem is incompatible with very flat and extremely hilly land and with very cold, very wet, or very dry climate.

A *swimming pool*, $\frac{\text{D 3 Ba}}{\text{V}}$, is a body of water (I), which is managed (V) by constant renewal, cleaning, disinfection, etc. This generally involves a minimum of shrub or grass (II) decoration, to fully suit the purpose (VI) of the

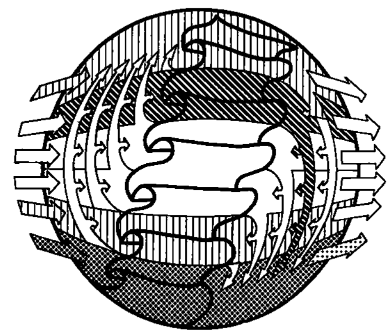
D. URBAN AREAS



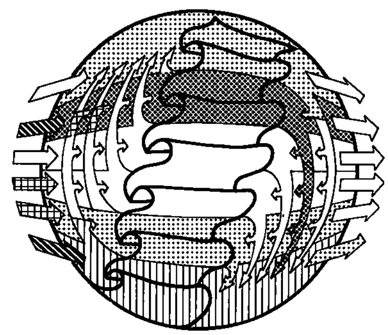
D1C JUNKYARD
V,I



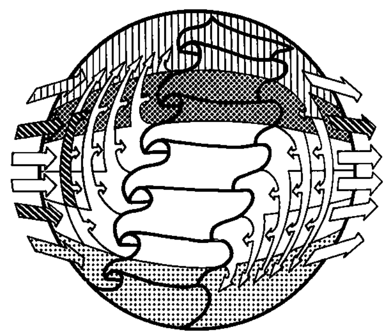
D2C GOLF LINKS
V,II



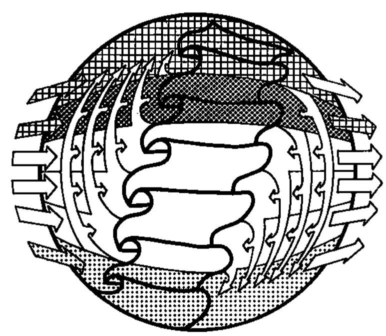
D3Ba SWIMMING POOL
V



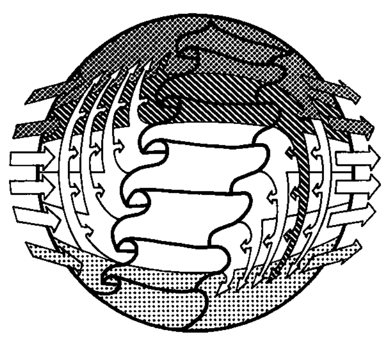
D4Ae SEMI-DETACHED HOUSE
V



D5Ct TOBACCO SHOP
V, II



D7Aa POST-OFFICE
V, VI



D6Ca CHURCH
VI, V

FIGURE 4 D. Urban areas. Balls-of-arrows (see Figure 2) exhibiting relative weight of trophic activity, as in Figure 3.

owners and users. Animal life (III, IV) is carefully eliminated. Outdoor swimming pools, in recent years, have been built in all parts of the world that have a warm season, even a short one.

A *semi-detached house*, $\frac{\text{D 4 Ae}}{\text{V}}$, harbouring two families is an investment (V) in imported brick, mortar, piping, wood, glass, metal, etc. The pre-emption of largely excavated soil (I) leaves space only for ornamental plants and grass (II), excludes virtually all animal life (III, IV), although plant and animal food in good quantities enter the homes. Controls (VI) include design, architecture, rental or ownership conditions, municipal regulations on construction, taxes, mortgage, etc. The pressure and dearth of space typical of certain urban densities on the one hand, and architectural traditions on the other, condition this type of land-occupation.

A *tobacco shop*, $\frac{\text{D 5 Ct}}{\text{V, II}}$, is a very specialized unit, dealing in a vegetable product (II) constantly imported, stocked, stored (V), and exported. It requires a minimum of ground space (I) and building (V). It is somewhat at the mercy of outside controls (VI): market, medical recommendations, etc. As an independent, self-contained unit (or ecosystem), it has become rare and its functions are more frequently included as a very minor subsystem in a drugstore, general store, restaurant, hotel lobby, etc.

A *church*, $\frac{\text{D 6 Ca}}{\text{VI, V}}$, is, by definition, under noöspheric forces (VI) since worship and rules of moral and social behaviour are its raison d'être; they can be presumed to affect, and indeed direct, all of its functions in form, frequency, attendance, etc. Material as well as informational and personnel investments may be of outstandingly high value and strength. The relations of the church to other ecosystems of the local landscape have more or less influence on the prevailing functions and investments (school, newspaper, real estate, etc.).

A *post office*, $\frac{\text{D 7 Aa}}{\text{V, VI}}$, is a crucial centre of information and communication (V, VI) in human settlements of all sizes, and it is the latter that determines the site (I) occupied as well as the diversification of services (V). External traffic much exceeds internal, and the unit as such is under total control from a regional or national centre. Structure, territory, personnel thus depend less on circumjacent ecosystems or on regional climate than on wide-ranging socio-economic factors.

These thumbnail sketches of one ecosystem in each of the *blocks* of all four *panels* give some idea of the structure and dynamics of *land-occupation types* considered as ecosystems.

LAND-USE PROSPECTIVES

Having illustrated, in Figures 4 A, B, C, D, the differential trophic loads of several land-occupation units (types), we must now consider their potential. Taking our cue from the Canada Land Inventory, and referring to the limiting factors which it uses as "sub-classes" (as negative modifiers for the positive values of potential), I think it is consonant with the present system to consider potential itself in terms of trophic level. Thus, a very low minerotrophic potential is present in a bog, and a high one in a swamp if the contemplated relay of energy is phytotrophic productivity (level II). Likewise if it is zootrophic productivity (levels III and IV). If, however, it is some other kind of investment (level V), such as agriculture, the potential of bog is still very low, and that of swamp is high only under reservation of a *correction* (namely drainage). If, instead, housing or road-building are involved, the potential is definitely low and any such affectation requires not only correction but *transformation*.

Figure 5 thus shows how, in the Mirabel area (New Montreal International Airport), there may be a considerable displacement of trophic weight when a *relay* occurs from one land occupation to another. The two ecosystems that replace one another may also stand in a different dynamic position as far as relative dependence (or *autarky*) is concerned. The three pairs shown in Figure 5 correspond to units recorded in Table VI (from Dansereau 1976).

The *potential* of land is, in a sense, of more interest to the planner than is the present, and possibly short-term, utilization. For this reason, the Canada Land Inventory has produced, at this time, a tremendous number of maps showing the capability of land for forestry, agriculture, wildlife (ungulates and waterfowl), and recreation, but it has printed for general distribution very few land-use maps because it assumes that they are already out-of-date when published. This is not the policy in Britain, apparently, since the "first land utilization survey" (see Table II), virtually completed in the fifties, has been followed by the "second land use survey" (Table III), still in course of publication. It is obvious that comparison will be very useful indeed, yielding valuable data on kind and rate of change.

Five principal considerations arise with respect to land-use vs. land-potential:

1) How does the present affectation of the land compare with its *alternate uses* in the past and in the future?
2) What is the *true vocation* of the land and how can it be assessed?
3) What is the estimated (and/or demonstrated) *productivity* of the land for each affectation?
4) What are the principal *limitations* for all and any particular affectation?
5) What *opportunities* and *constraints* do the larger (regional, climatic) units offer?

The prediction and planning that are necessary for a valid prospective are conditioned by a clear sorting of these five questions and a critical decision on the parameters which are relevant. I propose, of course, to adhere to the ecological criteria defined above.

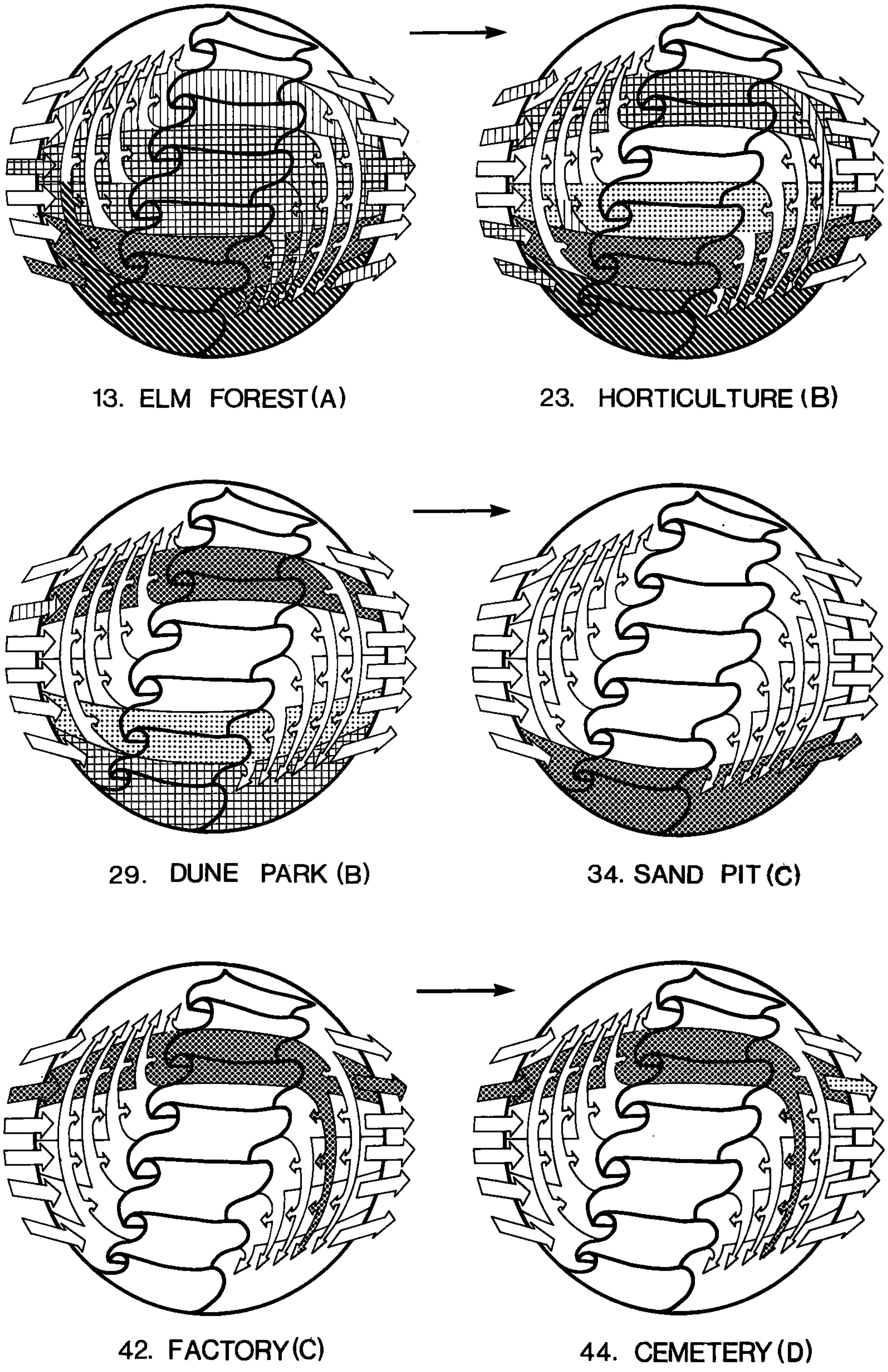


FIGURE 5. Three examples of shift in trophic weights (see Figures 3 and 4) in the course of succession. The numbers assigned to ecosystems are those given in Table VI.

Alternate uses

Where land-use inventory has been repeated at appropriate time intervals, especially if this has been carried out with a uniform methodology, the kind of change, its quantity, rate, and orientation can be measured.

Thus, in the Mirabel area (Clibbon 1972, 1975, Dansereau, Clibbon, Paré 1975), maps of land-use in 1930, 1966, 1971, when compared, show the regression of the agricultural ecumene, the fluctuations of wind erosion, the displacement of horticultural exploitation, etc. Jean Gottmann's (1961) maps of the great Washington-New York-Boston megalopolis show the increase in green spaces and forest in the 1950-1960 decade.

An even more useful compilation, from an ecological point of view, consists in recording the kind of change and the time that it has taken: for instance, from abandoned pasture to thicket to forest, or else from general farming to horticulture to residential building. The former is a succession where man releases the lots to wild forces and the latter is one where additional investments and increased control change the affectation altogether and upset the existing distribution of relative trophic-level weights (see Figures 3, 4, 5).

Looking at an objective, well-recorded land-use map, the student or the planner will question the appropriateness of the present affectation of a given lot if he finds that it is occupied by the wrong exploitation system and therefore set outside its *vocation*, if its *productivity* is too low, if it contains obvious *limitations*, or if it is entirely out-of-place within the *regional* dynamics (at a higher order of magnitude in the environment).

The question of adequate and inadequate uses and of present and alternate uses therefore hinges upon the determination of *potentials*.

The point of departure is bound to be wild land. The somewhat diffuse and certainly not very systematic nor complete knowledge that we have of natural ecosystems (in Canada as elsewhere) is the real basis for the assignment of vocation and productivity.

The kinds of wild vegetation once prevalent in a section of the Montreal Plain, summarily recorded in Table VI, are assumed to have a *constant* and often *stable* relationship to certain conditions pertaining to the minerotrophic level (I). Thus maple forest is highly productive on the moraines whereas elm-ash forest is found only on the flood plain and pine forest on sandy crests and beaches, leatherleaf mats occur only in bogs, and dense cattail stands in marshes. Without running through the whole gamut of the plant-communities that occupy (or have occupied) these ecosystems, it can be said that the physiographic sites that have been mentioned provide opportunities that promise an ecological *vocation* best fulfilled respectively by maple forest, by elm-ash forest, etc. It will also turn out, as a rule, and within the given bioclimatic area, that these exploiters will achieve their best performance (their highest productivity) there. The sugar maple on the drier (pine) site or on the wetter (elm) site will not do so well; the leatherleaf, in fact, is unable to occupy any other site.

It is well to insist once more upon an extremely important notion here: wild lands will differ, at all times and in all places, from others (rural, industrial, urban) in the fact that their exploiting populations have obtained their present tapping and cycling capacity through *genetic adjustment* to the non-living and to the living parts of the ecosystem in which they participate. It must be added that this applies in part to man, wherever the forces of natural selection have had time to segregate regional races (as witness some arctic, high-mountain, desert, and wet-tropical human populations). In other words, the full sway of *indigenous* forces is really different in kind from the other processes.

When it comes to rural, industrial, and urban vocations, the strategy is quite different, inasmuch as technology cancels out a number of environmental opportunities and adversities, and man's management practices incessantly condition the channelling of chosen productivities. Again, *agrigenous*, *fabrigenous*, and *urbigenous* processes do not present the same self-perpetuating adjustments that indigenous ones do.

Vocation and succession

It is therefore fairly easy to ascribe a definite wild vocation to a given site if, at this time, it has been stripped of its primeval plant cover and animal population—providing no irreversible change has taken place at the minerotrophic level, such as a permanently lowered water table or ablation of a substantial layer of the substratum. Even in such instances, however, it may (in a progressive or retrogressive way) conform to another site-type already contained in the regional wild repertory.

In the Mirabel zone (Table VI), for instance, what areas (as evaluated by their present or potential plant cover [II] and their underlying substratum [I]) are amenable to which ones of the rural *vocations* indicated under numbers 17 to 31?

17. *Woodlots* will be found or could be developed on wild 2, 3, 4, 5, and possibly 12, 13.
18. *Orchards* on 2 only.
23. *Horticulture* is on 4, 12, 13, and maybe on 11, often on 21.
25. *Mixed farming* is mostly on 12 and 13, but can occur on 2, 4, 11, and frequently on 23, 26.
26. *Fallow* and *abandoned land* is likely on 12, 13, and of course on 23, 28, 29.
28. *Pastures* on 4 and 12; not so well on 2 that is too stony, on 5 that is too dry, on 13 that is too wet.
29. *Gardens* are on 12, and of course on 21 and 22.

There are indicated a number of successions from wild to rural land and quite a few shifts from one rural land-use type to another. This is an ongoing and, so to speak, cumulative process, as we consider industrial land-use types.

32. *Mines*, or *quarries* can only develop on 1, although they often involve the stripping and destruction of several other types.
33. *Gravel pits* come on 1, 2, and 3.
34. *Sand pits* are dug on 4, 5, and 6.
35. *Roads* cross 1, 2, 3, 4, 5, and 12, and occasionally 11, 13; also 17 to 30.
41. *Mills* are on 14 and 15.
42. *Industrial plants* can be constructed on 1, 2, 3, 4, and 15, but also on almost any of 17 to 30.

The cumulation continues with the urban land-use types.

51. *Golf courses* are mostly on 3, 4, 5, but can overlap on 19 and 21.
52. *Residences* are being built directly on 4 and 12, rarely on 2, but more likely on 17 to 23 (maybe 24), and on 25 to 29 (not very likely on 30).
53. *Commercial buildings* are rather scarce on 4, 22, and even 2; not very common on 17 to 27, but most likely on 28 to 30.
54. *Administration buildings*, and
55. *Institutional structures* are found on 32 to 39, 41 to 51, and of course 54 succeeds 55 and vice-versa.

What is involved here are really two major levels of integration: (1) the wild (A), and (2) the others (rural [B], industrial [C], urban [D]). The first is under the sway of permanent natural forces that tend to a series of juxtaposed and only relatively dependent equilibria. The three following regimes work increasingly *against* the first, while obligatorily harnessing some of its forces or countervailing them.

Therefore, if one speaks of vocation about the pine forest on its sandy crest and about the cattail in its marsh, these *wild ecosystems obey well-coordinated and time-tested forces springing primarily from regularly alternating minerotrophic processes and permanently adjusted biological responses. Such self-regulation has broken down in agriculture, industry, and urbanization which depend utterly on fluctuating noöspheric forces.*

The vocation of a particular site for pasturing, manufacturing, or residence is geared to productivity of grass, to power, to supply of new materials, and to carrying capacity, to be sure, but also to quality of introduced grazer, to market fluctuations, and to architectural information and social requirements of man. Moreover, the particular kind and amount of energy which is needed by the processes that will allow a relay is very important. Figure 6 makes an attempt to identify such processes in examples taken from all four panels. These are taken from the EZAIM (Mirabel) study (Dansereau 1976).

In each of the four panels, the block-drawings represent a precise land-occupation type. The *regime* (A, B, C, D) is at the base of the individual diagram, and the circled number refers to the corresponding ecosystem listed and characterized in Table VI. The *parent-rock*'s texture (rock, gravel, sand, silt, clay, water) occupies all or only the lower part of the square, whereas the *soil* layers or their replacements lie above this. Four to six diagrams are thus shown in a linear sequence from left to right, illustrating, in the wild landscape (Figure 6 A), two spontaneous and natural lines of succession, and in the other three the replacements that are due to deliberate human interference.

Without belabouring the view that the dynamics of the wild panel (Figure 6 A) differ very much in kind from those of the other three, it is well to draw attention to the fact that the former are strung on environmental gradients, whereas the latter are in a very real sense *disconnected episodes* in a time sequence that has little to do with their inner tensions and productivity and everything to do with *human decisions* that may or may not derive from the pre-existing dynamics.

The most important feature of these replacements of one land-occupation by another is the *identification of the process that is responsible for a relay.*

Lumbering, ploughing, sowing, fertilizing are typical rural processes (Figure 6 B); they are capable of breaking into wild land and, if eventually stopped, to allow the site to return to the wild. Thus, a major *threshold* will have been crossed twice, in opposite directions.

Excavation, drainage, clearing, paving, outfitting are industrial processes (Figure 6 C) that will bite into either wild or rural sites and may sometimes, if discontinued, favour a return to a wild or a rural occupation, although most probably a different one from the primeval.

Construction, demolition, adduction, and traffic are urban processes (Figure 6 D) that may break into a wild, a rural, or an industrial matrix. No examples are offered here of reversion, for that is rare indeed, although not unknown.

Productivity and potential

The yield of agricultural fields was no doubt at the origin of this notion. One plot was sure to produce more bushels, pounds, tons to the acre than another. Labour was likewise estimated, first physical, then mental (Victor Hugo and Dickens were more productive than Baudelaire and Whitman). Investments of all kinds are subjected to this criterion. In land-use studies it has two applications: (1) how much more productive is one plot than another of the same category for a given crop? (2) for what crop (or what use) is a given plot most productive?

Foresters and agronomists have provided, through the years, a great wealth of data. The publications of FAO show an attempt to draw some of these observations together, but they also bear evidence to the difficulty of reliable comparisons. Rodin and Basilevič (1968) and more recently Whittaker (1970) and Lieth (1972) have compiled a sampling of the yields of the world's principal plant formation-classes. The more systematic, uniform, and well-coordinated measurements of primary productivity in aquatic and terrestrial environments initiated by the International Biological Programme will give us a much more precise evaluation and certainly better grounds for correlations of plant-mass (II) and soil qualities (I). It is well to point out that the I.B.P. has concerned itself almost exclusively with wild (or nearly wild) ecosystems

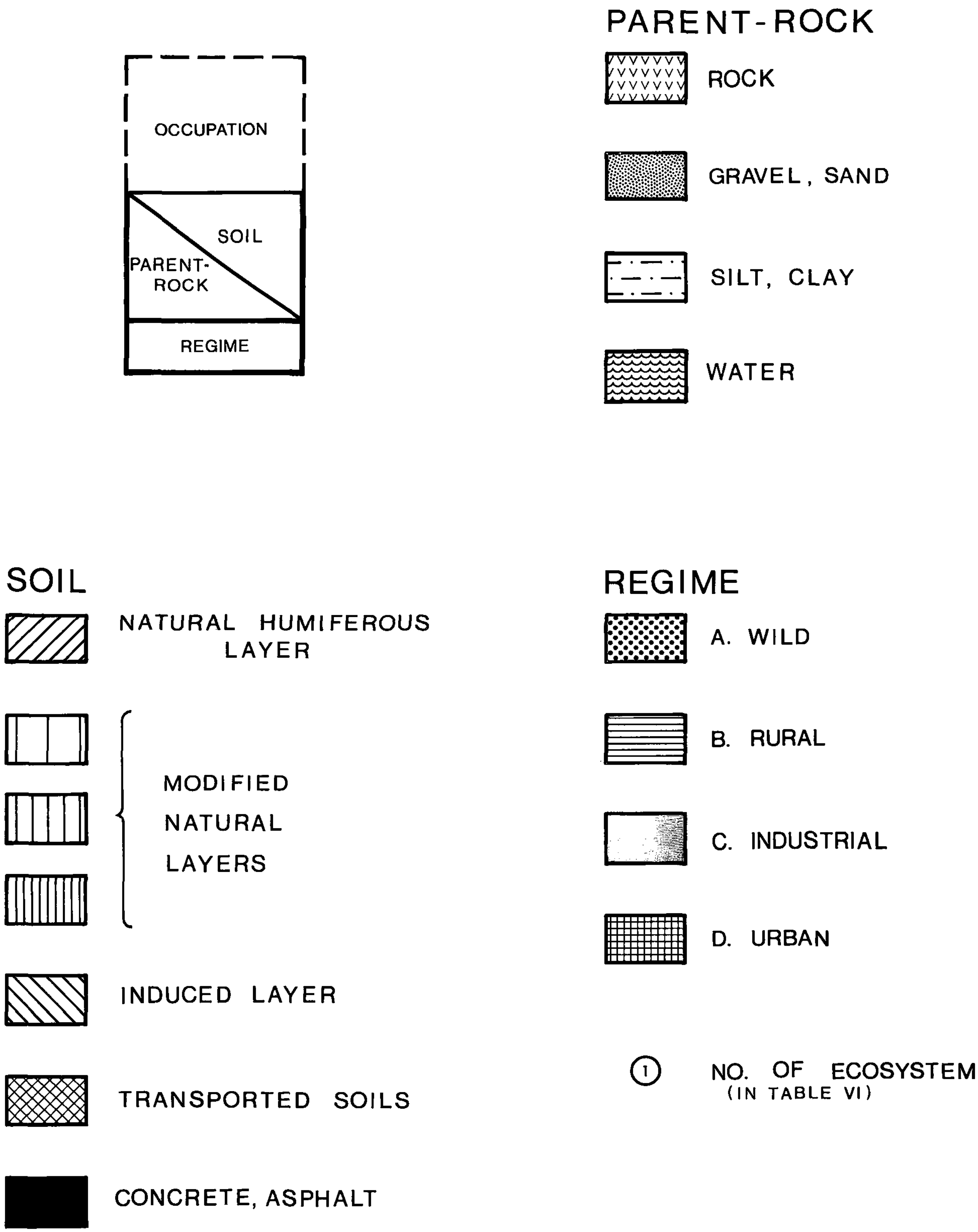


FIGURE 6. Some examples of succession in the Montreal Plain, indicating prevailing processes in each relay (Dansereau 1976).

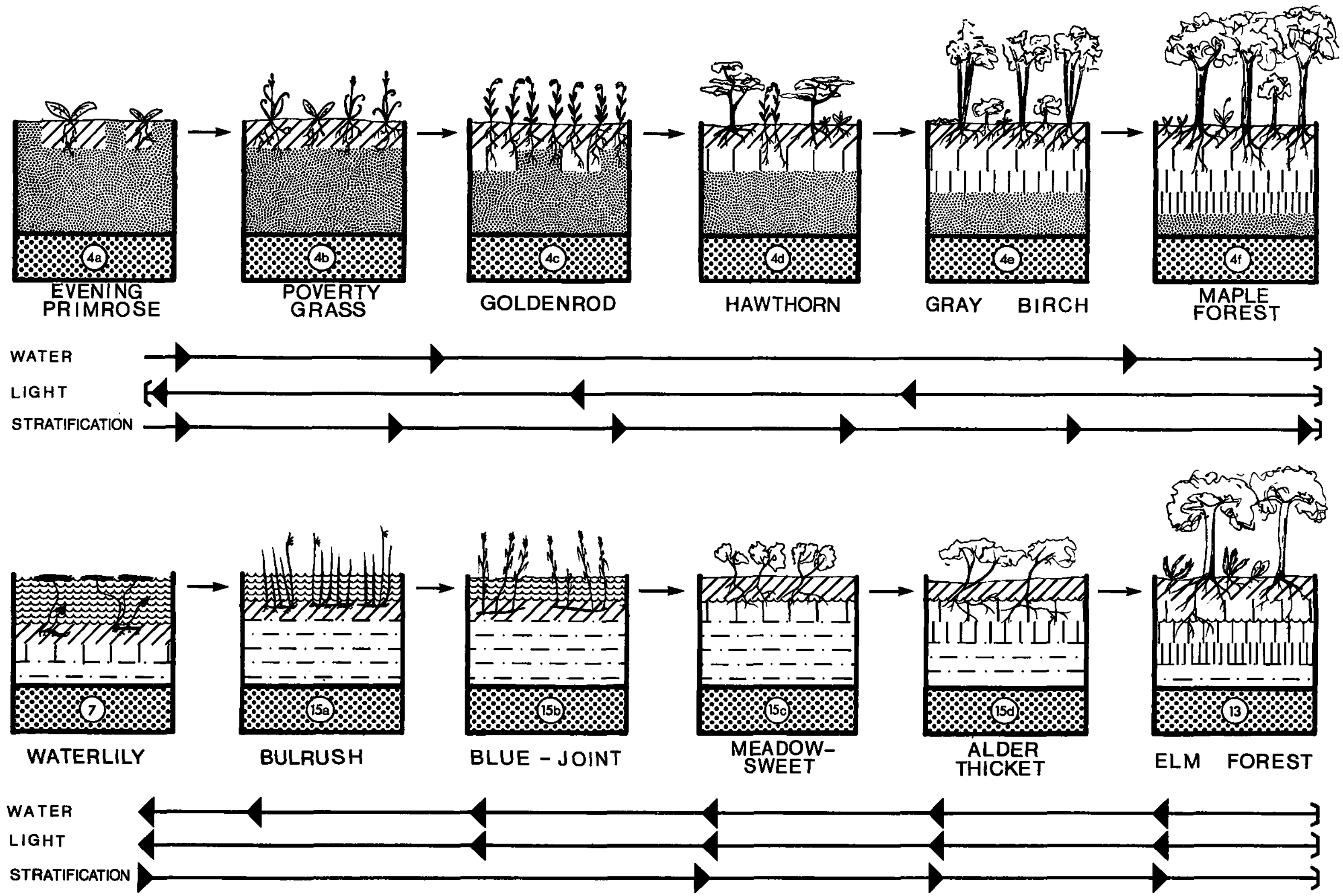


FIGURE 6 A. *Wild panel.* Indigenous forces at play in two lines of succession: above, a xerosere; below, a hydrosere.

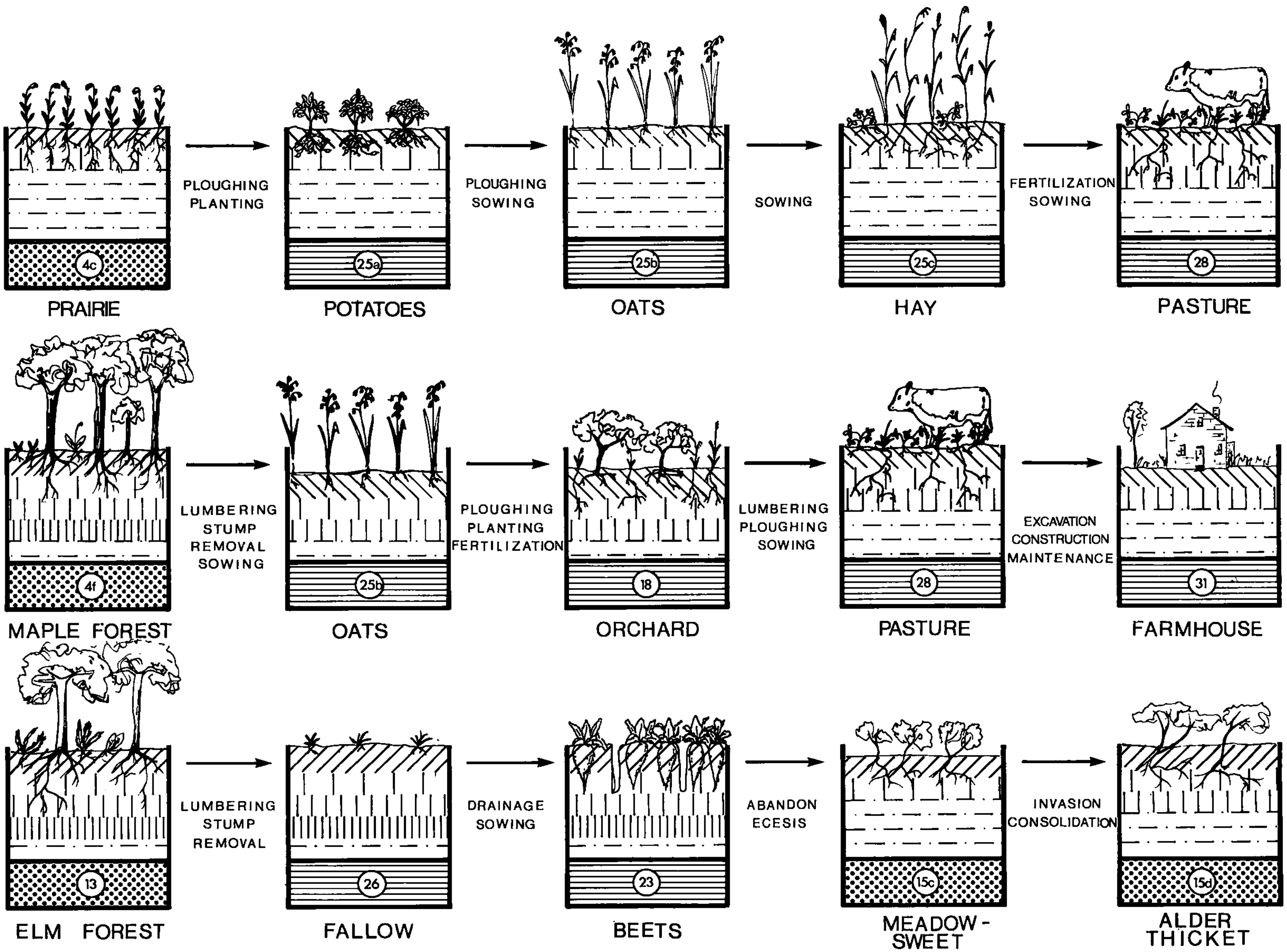


FIGURE 6 B. *Rural panel.* Three lines of replacement initiated on a wild site.

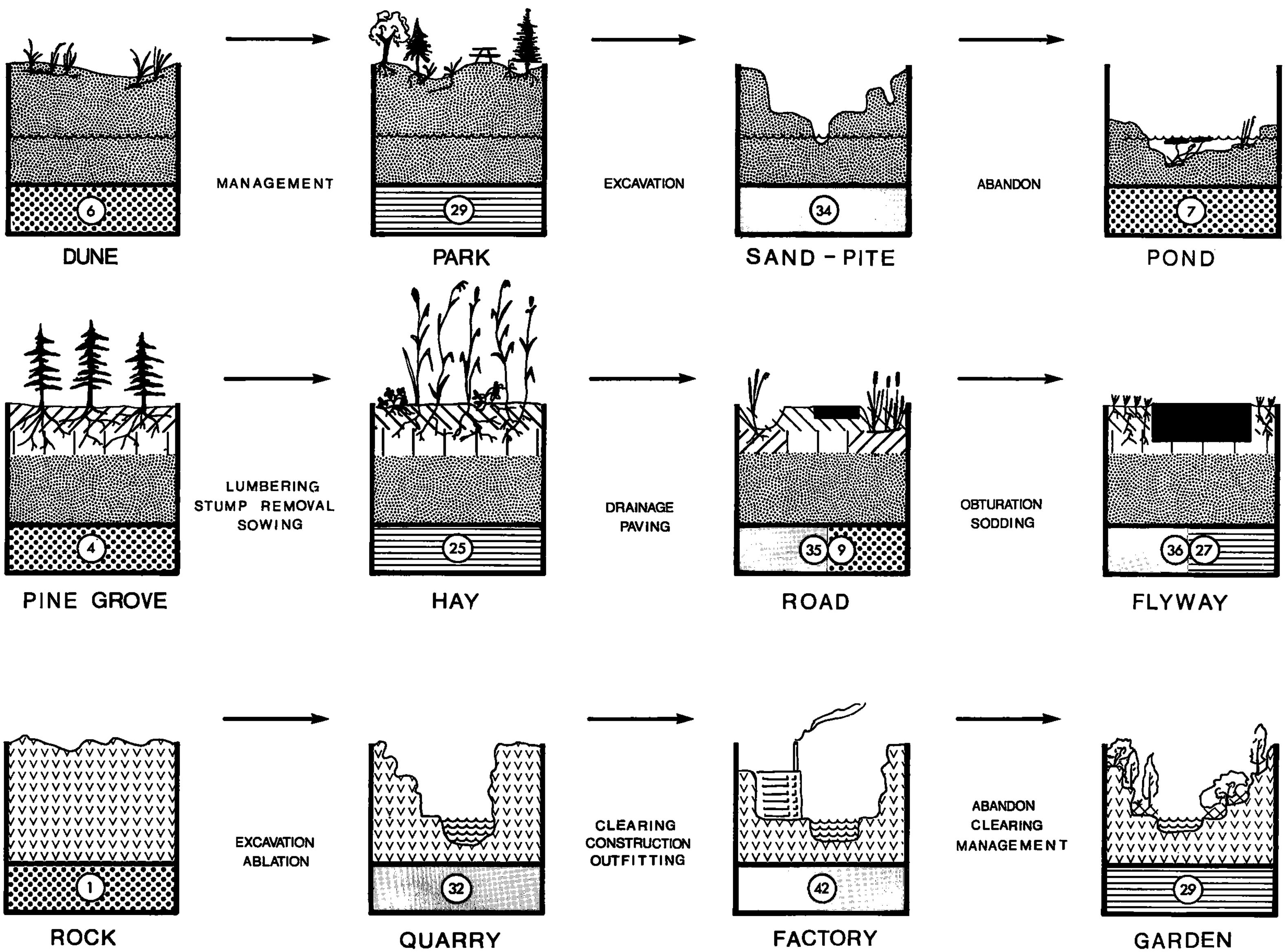


FIGURE 6 C. *Industrial panel.* Three lines of consecutive land-use, involving mainly fabrigenous processes.

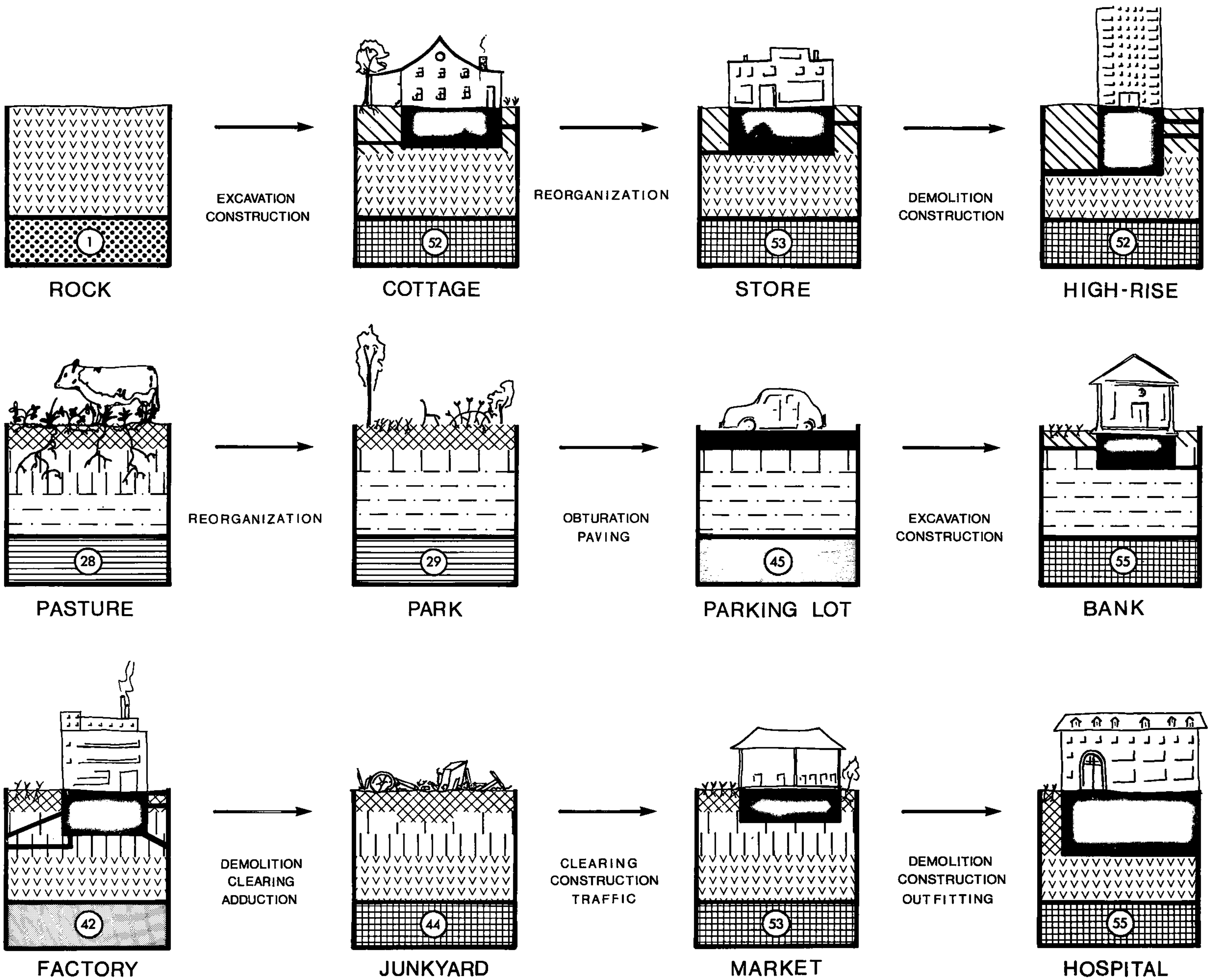


FIGURE 6 D. *Urban panel.* Three lines of successive land-use under progressive urbanization.

and that an application of the same standardized methodology to agricultural land remains to be undertaken, possibly by the new Man and the Biosphere (MAB) international programme.

The scales of capability that have been devised—for instance by the Canada Land Inventory for forestry, agriculture, and wildlife—are essentially based on *productivity* (within each vocation) of lumber, of crop dry-weight, of ungulate and wildfowl abundance and health.

It is easily seen that, for the most part, *forestry potential* (at least in most of North America, but less so elsewhere) is very close to wild potential. Canadian plantation-forestry has not reached the degree of advancement that would often allow the designation of a high potential for a tree species (indigenous or exotic) that does not naturally occur on a given site (viz., the pattern of the Black Forest of Germany, the Monterey pine forest of New Zealand, or the Eucalyptus forests of Brazil and of the Ruanda).

Wildlife potential lies even closer to the wild landscape. The ungulates (in different parts of Canada) have fairly well-known food habits, short- and long-range migration routes, and needs for shelter and reproduction, all of which can be assigned to a gamut of wild ecosystems. Where the units are well spaced and in good condition, the potential is high; where the contacts and spacings or the state of conservation are poor, it is low. Wildfowl abundance and health are tied to waterways and marshland.

Agricultural potential is not weighted towards all possible uses of land for cultivation, although the planner may well seek such a perspective. It is primarily measured in accordance with long-prevailing practices and crops that are not only well adapted to local or regional climate and soil but also congenial to the local or regional population. Growing strawberries and melons, raising sheep, rabbits, and pheasants present very good possibilities in the Montreal Plain, but either market opportunities or psycho-social obstacles would seem to stand in the way. On the other hand, evaluation of classes of land for mixed-farming is a well-explored field with a great wealth of factual experience to back it. Land now occupied by a messy goldenrod prairie or a hawthorn savana, but consisting of a deep, well-drained marine clay, will be given a high rating for mixed farming. A moraine (once high-potential maple forest) stripped of its woody cover is of very low grade for pasture, but a good orchard site.

Recreation is hardly measured in similar quantitative terms. The meaning of recreation and leisure time, in fact of work-and-play, has shifted as rapidly as that of education and culture (adult education, permanent education, social therapy). It is against this fluctuating background of values that recreation is being mapped. To isolate *outdoor recreation* and to assume that pure air and water, varied relief and "scenery," abundant plant and animal life have a high potential is easier to do than to attempt a non-linear array of recreation opportunities that will meet the expressed (but mostly latent) needs of our now-predominantly urban society. Introducing accessibility (actual and potential), need for equipment, and other parameters is a task now undertaken mostly by urban-centred studies.

Industrial potential and *urban potential* have not been so systematically mapped (in Canada) as the four areas mentioned above. However, some of the basic features have been considered. For instance, a carrying capacity map of the Gaspé Peninsula has been drawn, whereas prospective industrialization and urbanization there seem rather remote. This is analogous to the high recreation potentials allotted to areas in Northern Quebec that have virtually no access.

Actually, forestry, wildlife, and agricultural potentials are exclusively measured in terms of immediate site quality, referring to the possible yield at the minerotrophic (I), phytotrophic (II), and zootrophic (III-IV) levels. But recreation, industrial, and urban potentials (within the constraints of levels I-IV) are largely determined by level V and VI factors, not related so much to site qualities as to factors that belong to a higher unit of environment and to existing investments (roads, buildings) that are endowed with intrinsic strength of expansion.

Limitations

The negative or inhibitory features present in the landscape are a necessary coefficient of productivity categories. In the Canada Land Inventory scheme they are introduced as "sub-classes," or as mobile modifiers, much in the same way as Köppen and Geiger's (1954) lower-case coefficients of climate. Such properties of the soils as excessive or deficient drainage, very coarse or fine texture, low or high "fertility" are, of course, among the outstanding arrays of segregative forces in the wild environment: wet ground is "favourable" to cattails, "unfavourable" to beeches; a steep slope is propitious to certain algae, mosses, and ferns, adverse to most tree species.

The seemingly complex formulae which are developed by this kind of capability mapping are, in fact, readily readable even to an inexperienced eye, if only the observer will take care to master the key. Thus: $2\,\frac{7}{P}\,3\,\frac{3}{T}$ means a 7 to 3 ratio for classes 2 and 3; stoniness limitations in class 2 and topographic limitations in class 3. This is a very useful stenography that fully embodies the CLI logic. In proposing a substitute formula, at this time, I am concerned with the ecological placement of these limiting factors, as I believe it makes a difference to what trophic level they are referred. For instance, limitations ("sub-classes") affecting general agricultural and forestry practices are virtually all confined to the minerotrophic level (I); the wildlife limitations are of immediately phytotrophic (II) with secondary zootrophic (III-IV) emphasis. As for recreation (as plotted by the Canada Land Inventory), its grading rests in part on the forestry (II) and wildlife (III-IV) inventories but, for the planner, a number of level V and level VI limitations are obviously in order.

Moreover, forestry and agricultural potentials will be seen to reside essentially *within* the ecosystem concerned, whereas some agricultural and most industrial, urban, and recreational potentials are to be sought *outside*. This brings us back to earlier considerations of relative autarky and trophic loads.

We will be led, in further contributions, to examine the whole question of potentials and of the kind of knowledge required to classify capability, and also the validity, the comparability, and the reliability of regional and extra-regional extension of the classes. Inasmuch as all such extrapolations, however, are implicitly based upon earlier perceptions of inter-trophic correlations, we shall continue to dwell principally on the framework of land-occupation categories in the first three contributions in the present series.

The compass of higher orders

Some of the acknowledged limitations are climatic. A regional climate which is adverse to tuliptree is excellent for yellow birch (northern Michigan). An area or a plot edaphically well suited for corn has too cold a climate (e.g., the Gaspé Peninsula). A region that produces large quantities of raw-material (bauxite, wool) lacks the power or labour facilities for manufacturing (Guyana, Tibet). A landscape that has ideal setting and natural amenities for urbanization is too remote from transport facilities or population supply (Philippine mountains).

We get many clues from the presence/absence, life-cycle, abundance, productivity, and behaviour of many plants and animals in wild lands. The yellow birch grows on wetter soils in the climatically warmest and driest part of its range (Dansereau and Pageau 1966) whereas the silver maple shows no amenability to any such compensations; bur-oak usually grows on somewhat imperfectly drained (but not permanently wet) clay; hemlock favours cool northern slopes and ravines in its southernmost geographical reach (in the Appalachians) and relatively warm southern slopes and open ravines near its northern limits, whereas it covers many different topographical sites in-between. This calls attention to a shifting climatic/-edaphic ratio, so that a yellow-birch vocation, a silver-maple vocation, a bur-oak vocation, a hemlock vocation are all predicated on two levels.

Foresters have established a large number of such edaphic/vegetational links, usually through a well researched regional monograph. However, the validity of such correlations as modified by shifting edaphic/climatic ratios is far from being fully tested. And when a key species, such as the bur-oak in the Montreal Plain, is at the very edge of its total natural range, the reliability of its extrapolation as an indicator must be questioned, especially if witness-stands are lacking.

Paul Rey's (1960) bioclimatic compensation scheme could well provide (especially where forest-tree dominants are concerned) a useful index of climatic/edaphic strategy. This system takes into consideration the time-scale and permanent trends of climatic change which may have affected certain stocks genetically. I raised this question some years ago with reference to the very influential post-glacial pine period and the decline of pine dominance in Quebec (Dansereau 1956).

It remains to apply these concepts to rural, industrial, and urban occupation-types.

At all events, the possibility is very great that an area large enough to accommodate more than one bioclimatic zone (e.g., the Azores, the Gaspé Peninsula), not to mention a wide range of them (California, Canada, Australia), needs a land-use classification where all universal categories (e.g., forest type, pasture type, industrial plant, residential development) are framed separately under each regional climatic zone.

The justification for such a probe lies in the fact that the forces that animate ecosystematic cycling, at each trophic level, originate and/or are triggered off at different orders of magnitude.

The *site*, bearing a *land-occupation type* (as understood and defined herein), is the receptor of cumulative influences and impacts, some of them as remote as the rays of the sun (in the *cosmos*), as rain from the atmosphere (in the *planet*), as the migrant birds (common to the whole *region*), as the drainage system (typical of the *landscape*), and as the proximity, contact, emanations, etc., of the contiguous and neighbouring occupation-types that make up the neighbourhood *mosaic*.

Figure 7 shows all of these natural concentric units, and it includes yet another, of a different kind and shape, the *country*. This unit (whose frontiers are often known to expand or contract) is shaped by *political* forces that often cut across natural boundaries. Whereas New Zealand, Australia, Madagascar, Japan contain in their entirety several regions, Canada, Ghana, the U.S.S.R., Czechoslovakia, Thailand, Switzerland have frontiers that cut through natural regions. None of the Benelux and the former Baltic States even contain one entire region.

Superimposed upon this concentric pattern are five lines bearing roman numerals that correspond to the trophic levels of Figure 2. It shows the points of origin and/or modification of the resources and processes that eventually reach the occupation-type (at centre).

Line I follows the progress of *minerotrophic* elements. Energy, light, heat originate in the cosmos and are transmitted (in various forms, places, and times, and not without loss) to the atmosphere of the planet, to the regions, landscapes, mosaics, and occupation-types. The incident arrows indicate a capacity of transformation, or indeed of production, originating in the planet, region, landscape, or mosaic. Whereas, for instance, heat emanates from the sun, it may well be stored and transformed on the planet, in a certain region (as coal, petrol, cellulose), or even generated by combustion, electricity, muscular exertion, etc. Water originates in the atmosphere and hydrosphere, and soil in the lithosphere, and they have been respectively circulated, transformed, and stored on the site.

Line II shows the pathway of *phytotrophic* forces. Since

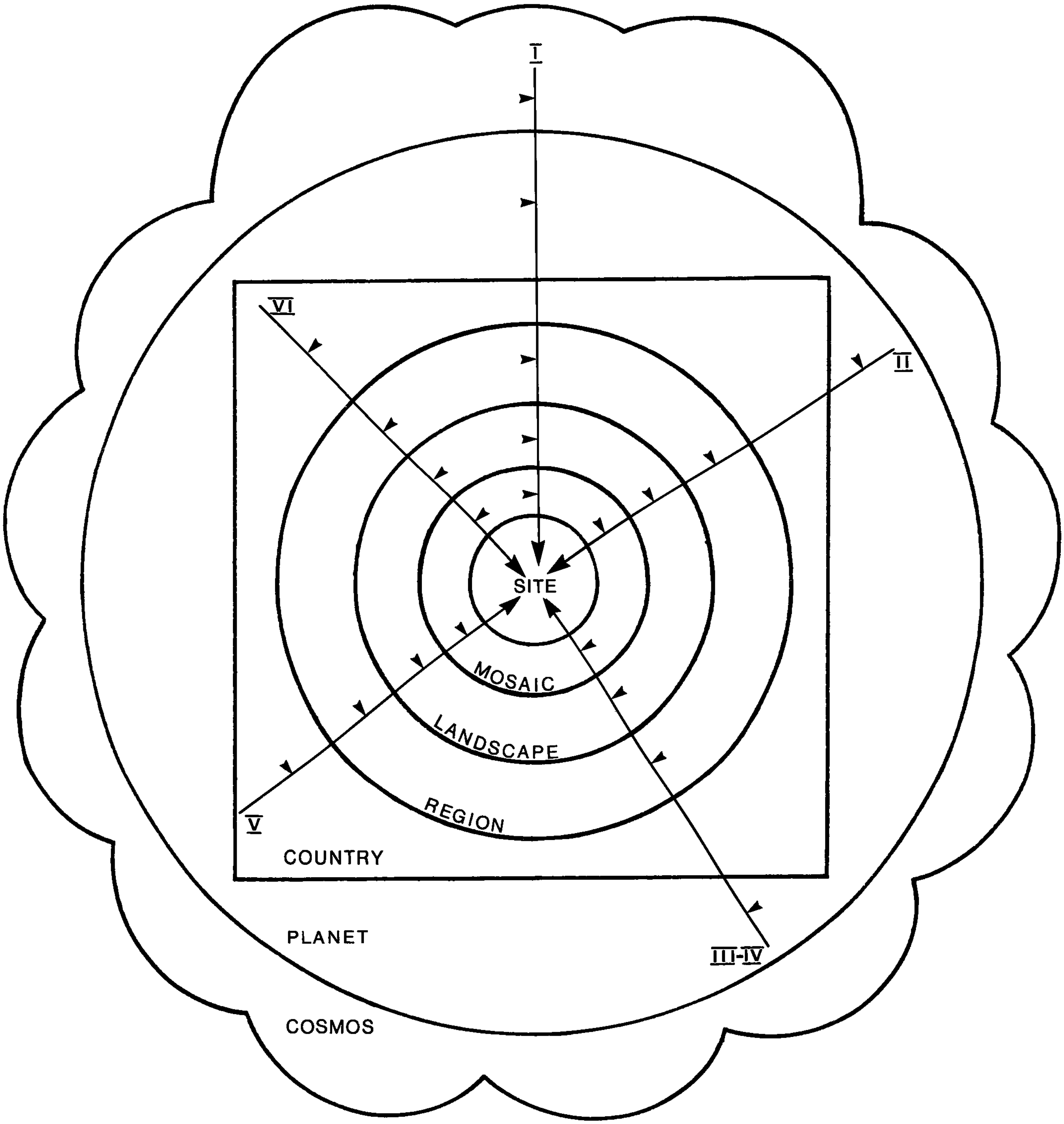


FIGURE 7. The major orders of magnitude of the environment and the centripetal convergence of impact at each trophic level upon the ultimate site (where the occupation-type lies). The roman numerals refer to Figure 2.

plants have migrated all over the planet, they assemble in segregated patterns of adaptation in different regions, display differential forms of exploitation and domestication in different landscapes, and are the object of a more or less deliberate utilization in different settlements. Much plant material from regional or extraregional sources finds its way onto the site.

Line III-IV follows a very similar trajectory, since the *zootrophic* elements (phytophagous and carnivorous animals) are capable of playing roles similar to those of plants, although predominantly as food and clothing, more rarely as building stuff.

Line V is very different, however, since *investments* are directed in a definitely utilitarian way as allowed, stimulated, and inhibited by socio-economic forces originating in the country (or state), rather than in the region! Thus, transfer of capital (from New York to Ethiopia; from Arabia to Canada; from Switzerland to Argentina) for building purposes is directed to the most favourable regions, settled in the most amenable landscapes.

Line VI is even more likely to make direct hits from a high unit to the occupation-type, since legislative *control* on taxation and subsidies is at the very least extra-regional.

In the framework set by Figure 7, it is possible to operate from the periphery inwards and to account for the constraints suffered on the site now affected to a given occupation-type. It is in response to such constraints (whose remoteness, strength, duration, etc., can be known) that soils have developed pedogenetic patterns, plants and animals morphogenetic shapes and habits, buildings peculiar architectural and technological devices, institutions appropriate structures and regulations.

Conversely, the question of impact of the said occupation-type upon higher orders of environment is seen to radiate outwards. Not only may the fumes of a factory pollute the neighbourhood mosaic, but they may extend to the landscape, the region. It is now considered more than likely (Davitaya 1968, Wilson and Matthews 1971) that world industry is capable of inducing macroclimatic shifts.

Table V has already outlined the dependence of niche upon layer, upon belt, upon habitat, and the containment of the latter within a region, a zone, a province. Figure 7 presents an illustration of these imbricated orders of magnitude, and it reflects the same principles of *cumulative constraints.*

In the several contributions that will form parts of the present series, these higher orders will be carefully noted and their power of releasing or inhibiting the productivity of the component recorded land-occupation types will be assessed.

II. Mapping Methods and Problems

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INTRODUCTION

The taxonomic criteria once established, in the first contribution, above, it remains to transfer their dynamic implications on maps within the technical limitations of present-day cartography. At that level one encounters the ponderous problems of scale and of symbol. What elements are really "mappable"? How can one best accumulate information and retain legibility? How can cartographic documents be produced that will lend themselves to ready and efficient interpretation, without exceeding reasonable costs of production? It is mainly to such questions that this second contribution responds.

CARTOGRAPHIC STYLES

As fully defined above (Table VIII), the ELO system rests upon three orders of magnitude: the panels (A, B, C, D), the blocks (1, 2, 3, . . .), and the types (A, B, C, . . .). To this formula is added a denominator based on the trophic level (I to VI, as in Figure 2) where the energy impact is heaviest (Figures 3, 4, and 5). The mapping process must therefore reflect as clearly as possible the characteristics of all three orders of magnitude and also follow the more or less linear progression that goes with a growing intensity of energy expenditure.

Colour

The four basic colours assigned to the *panels* run the gamut of the spectrum: blue for wild lands (A), green for rural occupation (B), yellow for industrial development (C), and red for urban establishment (D). What we have in mind is colour at the saturation point, neither "washed" with white nor "muddied" with black (Bertin 1973). Such a choice therefore rests on essentially chromatic criteria and does not really follow the *linear* progression of human impact. However, "warm" colours (greater wavelengths), such as red and yellow, do correspond to activities wherein the energetic impact is higher (industrialization and urbanization). As a matter of fact, red is already much used in cartography for urban elements. Likewise, green, a blend of blue and yellow, is quite suitable to the rural environment, result, after all, of technological activities in a relatively "natural" landscape. As for blue, it would seem to symbolize fairly well the wild environment. Actually, in choosing this sequence, we did not intend to limit ourselves to purely conventional factors. We hoped, somehow, to be in accord with a colour symbolism that already has significance in many parts of the world and under several frames of reference. Thus, Bertin (1973) mentions that water, the sea, the rivers are never drawn in red, and that heat and drought hardly convey a blue sensation. Gaussen (1958) offers a similar argument. As for vegetation it is, not unexpectedly, represented in green. Ice and snow are associated with "cold" tones, such as blue. We have therefore opted for a selection of colours in harmony, as much as possible, with the symbolic aspect, although we have given priority to readability and have tried to avoid the garish colours that would really clash with the very elements to be represented.

The logic of the system, as already argued, requires that the intensity of land use, and therefore its impact on the surrounding landscape, follow an order of increasing values from bottom to top. This cannot possibly mean that such a scale runs in mathematical or geometric, or even roughly proportional, rates from one block to the next. In fact, it has already been pointed out that the sequences may not even be linear. For instance, in the rural panel (B), the shift in cycling activities from block 1 (herbaceous cover) to block 2 (woody cover) is no doubt less than from block 2 to block 3 (pasture). It would be difficult, if not impossible, in the absence of actual energy measurements, to devise a very realistic cartographic scale. We have therefore opted for a more or less even progression from pale to dark tints, as shown in Table IX.

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In all but one case, each block has its own colour. The exception occurs in the wild panel, where forest (A 5 A) and parkland (A 5 B) are separated from savana (A 5 C), scrub (A 5 D), and tundra (A 5 E).

It has to be granted, of course, that the lumping, in the first place, of a number of *types* into a block, that the assignment of a given type to a block (or occasionally to a panel), may well not be acceptable to all users. Although the progressive increase of energy expenditures from one block to the next must not be taken too literally, we firmly believe in the reality and usefulness of such a gradation. Where, as in the wild and urban panels, the blocks are numerous, map-reading has to be more careful. It is unusual, however, to find all of the blocks of a panel represented on any single map. It seems to be recognized that the human eye cannot retain more than six or seven alternatives of a colour or a textural scale. It is partly for this reason that we have set up the ELO scheme in panels of seven blocks and less.

Black-and-white

The cost is so high that colour reproduction cannot always be used in publications. (The present memoir, in its original version, contained some 30 maps in colour and had to be cut down to three!) At all events, a parallel system in black-and-white is needed. This is shown in Table X.

The main textures for the panels are *crossed lines* (or *grids*) for the urban (D), *shading* for the industrial (C), *horizontal lines* for the rural (B), and *stippling* for the wild (A). The general gradation, here as in the colour scheme, will run from very light in block 1 to very dark in the uppermost block.

Thus, in panel A (wild), the scale is rendered by a stippling wherein the diameter of the dots increases with the energy charge. In the rural panel (B), it is the thickness of the horizontal lines, and therefore the decreasing area of the white intervals that shows progression. In the industrial panel (C), it is the deepening of shading from light gray (10%) to nearly black (70%). This amounts to 20% between each block, except between 2 and 3 where it is only 10%. Finally, in the urban panel (D), the grill becomes more and more closed. To obtain this effect, we have had to use two types of weaves for blocks 5, 6, and 7.

It is worth noting that previous classifications (e.g., CLI) do not include *all* land, e.g., roads, etc., lakes, etc., are "background" and not part of the scheme, whereas ELO attempts to record and classify all occupation.

Symbols

Colours and textures will show only *panel* and *block* elements. And therein are found the major dynamic features in the land mosaic. It remains, however, to map with ultimate precision the *land-occupation type*, which is determined, as had been amply demonstrated above, either by a resource (such as wool in $\frac{\text{C 4 A}}{\text{V, III}}$) or an agent (such as nuclear plant in $\frac{\text{C 3 B}}{\text{V, I}}$). Cartographically the type is identified by a capital letter (A, B, C, etc.), starting anew with A in each block. Such a procedure has the advantage of flexibility should new occupation types be inserted. This may indeed be desirable: although we have aimed at the full scope of a world order, we fully expect that wider sampling will reveal some gaps that need to be filled. This would hardly pose any problem, since we have never reached beyond the letter P (in C 4 P). The system is, of course, open to a fourth order (a, b, c, . . .) as proposed above.

In the drafting of maps, the procedure remains fairly simple. The full symbol (for instance for orchard) reads as follows: $\frac{\text{B 2 D}}{\text{V, II}}$. The first digit of the formula (panel) is provided by either colour or texture. The second digit (block) is revealed by shade of colour or intensity of texture. It would be feasible to eliminate both of these symbols from the map itself. However, because of the constant need to refer to the legend of the map, we prefer to transcribe the block number (2) on the map, even if it seems superfluous to transcribe the panel letter (B). As for the trophic level, it can be ascertained by reference to Table VIII.

Mobile elements, as we have called them (see Table VIII), are land-occupation types that either cannot be intrinsically ascribed to one of the four panels for strictly ecological reasons, and/or generally have a punctual or linear dimension. Table XI has plotted those 17 elements by distinguishing two main groups: *geographic* and *functional* units. The functional qualifications (with their lower-case letter in parentheses) are simply appended to the formula that symbolizes the type. Thus, an irrigated sod is shown, on the light green or sparsely striated background of B 1, as 1 A(w). As for the geographic units, we recommend the use of the block colour where the element is normally found with the letter symbol in parentheses. Thus, parking lots (t) will always be shown in yellow, whether they occur in urban, industrial, or even rural areas, since they are the *product* of *processes* related to transport and communications (panel C, block 2).

Table XI gives the coordinates of these mobile elements and allows a ready reference to Tables VIII, IX, and X, for mapping purposes.

As will be demonstrated presently (Figures 9, 10, 11, and 12), the symbols to be superimposed upon maps already bearing colour or texture indicative of panel and block are more readable and more useful if cast on a transparent overlay sheet. The small size of individual cells, the scale of the map, the diversity of the mosaic all tend to make such a practise more amenable, as it avoids marring and confusion.

PROBLEMS OF SCALE

It is scale that limits the possibilities of showing detail on a map, since it reflects the ratio of actual dimension

PANELS

BLOCKS

Panel	Block	No.	Land occupation
A-WILD	6	901*	ANIMAL AGGREGATION
A-WILD	5	906	PREDOMINANCE OF WOODY PLANTS ON UPLAND
A-WILD	5	902	PREDOMINANCE OF WOODY PLANTS ON UPLAND
A-WILD	4	903	PREDOMINANCE OF HERBACEOUS PLANTS ON UPLAND
A-WILD	3	904	WETLANDS
A-WILD	2	919	WATER
A-WILD	1	920	RAW MINERALS
B-RURAL	5	908	CONSTRUCTION AND MAINTENANCE
B-RURAL	4	909	BREEDING
B-RURAL	3	911	PASTURE
B-RURAL	2	910	WOODY-PLANT EXPLOITATION
B-RURAL	1	913	CROPPING OF HERBACEOUS PLANTS
C-INDUSTRIAL	5	946	SERVICES
C-INDUSTRIAL	4	943	MANUFACTURING
C-INDUSTRIAL	3	917	ENERGY
C-INDUSTRIAL	2	915	TRANSPORT AND COMMUNICATIONS
C-INDUSTRIAL	1	914	EXTRACTION
D-URBAN	7	925	ADMINISTRATION, PUBLIC SERVICE
D-URBAN	6	923	INSTITUTION
D-URBAN	5	922	COMMERCE
D-URBAN	4	926	RESIDENCE
D-URBAN	3	929	OPEN SPACES
D-URBAN	2	928	GREEN SPACES
D-URBAN	1	927	PAVED OR UNPLANTED SPACES

*numbers of eagle prismacolor pencils

TABLE IX. Ecological land occupation. Key to the colour range proposed for mapping. The numbers correspond to Eagle Prismacolour pencils.

PANELS

BLOCKS

Panel	Block	No.	Land occupation
A-WILD	6	112	animal aggregation
A-WILD	5	113	predominance of woody plants on upland
A-WILD	5	114	predominance of woody plants on upland
A-WILD	4	115	predominance of herbaceous plants on upland
A-WILD	3	911	wetlands
A-WILD	2	907	water
A-WILD	1	909	raw minerals
B-RURAL	5	111	construction and maintenance
B-RURAL	4	110	breeding
B-RURAL	3	78	pasture
B-RURAL	2	77	woody-plant exploitation
B-RURAL	1	75	cropping of herbaceous plants
C-INDUSTRIAL	5	63	services
C-INDUSTRIAL	4	61	manufacturing
C-INDUSTRIAL	3	59	energy
C-INDUSTRIAL	2	58	transport and communication
C-INDUSTRIAL	1	57	extraction
D-URBAN	7	110+110	administration, public service
D-URBAN	6	122+924	institution
D-URBAN	5	122+67	commerce
D-URBAN	4	928	residence
D-URBAN	3	158	open spaces
D-URBAN	2	157	green spaces
D-URBAN	1	956	paved or unplanted spaces

TABLE X. Ecological land-occupation. Key to the textures to be used when mapping in black-and-white. The LT numbers refer to the Letratone sheets produced by Letraset. In the industrial panel, the percentage of shading is also given.

TABLE XI
Principal characteristics of mobile elements.

Elements	Symbol	Predominant blocks	Trophic levels	Possible location (panels)				Mode of occupation	
				A	B	C	D	Spatial or punctual	linear
a) Geographic units									
parking lot	(t)	C 2	V, I		X	X	X	X	
pylons	(d)	C 2	V, I	X	X	X	X		X
path, driveway	(s)	C 2	V, I	X	X	X	X		X
channel	(f)	C 2	V, I		X	X	X		X
fence	(c)	B 5	V, II, I	X	X	X	X		X
garden	(j)	B 2	V, II	X	X	X	X	X	
lawn	(l)	B 1	V, II	X	X	X	X	X	
trees in a row	(a)	A 5[(a)]	V, II	X	X	X	X		X
hedge, hedgerow	(b)	A 5[(b)]	V, II	X	X	X	X		X
grove	(q)	A 5[(a,b)]	V, II	X	X	X	X	X	
snow	(n)	A 2	I	X	X	X	X	X	X
b) functional units									
construction	(u)	C 4	V		X	X	X		
unmanaged park	(p)	B 5	V	X					
fully protected reserve	(r)	B 5	V, VI	X					
irrigation	(w)	B 5	V, I		X	X	X		
pasture	(g)	B 3	V, III		X	X	X		
abandoned	(x)	n.a.	n.a.		X	X	X		

(a) same colour or texture as A 5 A, A 5 B.
(b) same colour or texture as A 5 C, A 5 D, A 5 E.

of an object vertically projected on a flat surface, or of linear distance from one point to another.

It is current to speak in terms of small, medium, and large scale. These designations are only relative, of course, and lead to some confusion. We therefore feel that we must clarify such a vocabulary or, at the very least, adapt it to our present purpose. The guiding principle lies in the convention that the larger the scale denominator, the smaller the scale (Miller 1968, Fuechsel 1974). Thus a map at 1/25,000 is on a larger scale than one at 1/50,000. The greater the distance or surface represented on a given map surface, the smaller the scale: a map of 1 mile to 2 inches is on a larger scale than one at 8 miles to one inch. What, then, is a large, a medium, a small scale? Table XII records the opinions given by three authorities (Tricart 1972, Fuechsel 1974, Strahler 1975). There does not seem to be any firm international agreement on small-medium-large scales. Tricart's (1972) division (adopted by the Institut Géographique National de France), seems much more useful to us, and we shall adhere to it in the following discussion.

It is well to remember that the same material projected on a large scale shows potentially more detail than on a small scale. Thus, on a very large scale, actual stands (even individual trees) can be shown; on a small scale, the plant community; on a yet smaller one, the formation (e.g., forest). This loss of *information* implies simplification and interpretation. It is consonant, of course, with increasingly large taxonomic units. In our case: type, block, panel. *From small to large scale: increase of precision; from large to small scale: increase of generalization.* (See Figures 1 and 7, and Table V.)

Large scales (1:25,000 downwards)

The category of large scales defined by the Institut Géographique National de France (Tricart 1972) needs to be subdivided, in our opinion. The first subdivision which we are calling "very large" would range from 1:10,000 to greater enlargements: 1:5,000, 1:2,000, etc. Such very large scales are sometimes referred to as *plans* rather than maps, and they are mostly used for purposes of high precision locations and allocations: drawing cadasters, development plans, drainage and sewer projects, etc. In fact, such plans allow the representation of much detail without resort to exaggeration or symbolization. Thus, the exact walls of a house, the entrance to a courtyard, etc.

TABLE XII
Scales of maps, according to various authorities.

SCALE	Fuechsel 1974	Strahler 1975	Tricart 1972	This paper
General or very small			1,000,000 and more	1,000,000 and more
Small	1,000,000 and more	600,000 - 100,000,000	100,000 - 1,000,000	100,000 - 1,000,000
Medium	63,360 - 1,000,000	75,000 - 600,000	25,000 - 100,000	25,000 - 100,000
Large	63,360 and less	75,000 and less	25,000 and less	10,000 - 25,000
Very large				10,000 and less

Dickinson (1969, p. 56) says that such documents are meant to "be worked on rather than with." The mapping of ELO categories of the third and even fourth order of magnitude poses no problem at such very large scales.

The second subcategory of large scales runs from 1:10,000 to 1:25,000. Such scales are frequently resorted to for regional studies: 1:10,000, 1:12,000, 1:15,840, 1:20,000, and 1:25,000 are commonly used. As a matter of fact, they frequently correspond to current series of airphotos. Mapping of wild (A) and rural (B) panels poses no particular problems at these scales. However, the industrial (C) and urban (D) panels are more advantageously mapped at larger scales.

Medium scales (1:25,000—1:100,000)

The 1:50,000 is no doubt the most widely used in this category. The Surveys and Mapping Branch of the Department of Energy, Mines, and Resources of Canada uses it very much indeed. It has replaced the one-mile-to-an-inch series: 1:63,360. The latter, however, is still frequently encountered in Anglo-Saxon countries, whereas the French Army uses 1:80,000, and airphotos are frequently 1:40,000. The manuscript maps of the Canada Land Inventory are 1:50,000.

Such is the scale that we have also adopted in our tests of medium scales on Canadian territory. We encountered no difficulty in mapping wild (A) and rural (B) *types*, but could hardly show more than *blocks* in the industrial (C) areas and only *panels* in the urban (D).

Small scales (1:100,000—1:1,000,000)

At this order of magnitude, maps hardly show localities at all, but regions. These *chorographic* maps can only reveal *generalized* land-occupation (wooded land, cultivated land, urban development, etc.). In this category, the Canadian national cartographic service uses 1:125,000, 1:250,000, and 1:500,000. It is at the scale of 1:250,000 and 1:500,000 that the Canada Land Inventory publishes its capability maps (forestry, wildlife, agriculture, recreation). On this scale, we hardly find it useful, or indeed feasible, to map anything beyond the *blocks* (second order of magnitude) for panels A (wild) and B (rural) and beyond the panel itself (first order of magnitude) for industrial (C) and urban (D) occupations. It is nevertheless difficult to fix hard and fast rules in this respect, for the situation will vary from one region to another. Thus, one could probably map *types of occupation* (third order of magnitude) at 1:250,000 in a uniform region in the Western Canadian Plains, whereas this would hardly be possible in the Montreal or Toronto metropolitan zones where the occupation mosaics are quite complex. Moreover, the possibilities of the method will vary according to kinds of landscape. For instance, it is easier, at first glance, to map wild areas than urban areas on a small scale. The same is true of blocks. Thus, also, for the rural panel, the types of block 1 (exploitation of herbaceous plants) generally occupy larger surfaces than those of block 5 (construction and maintenance), and therefore lend themselves more readily to small-scale mapping. We conclude that, for such scales, the user of the ELO can suit his method to the region under study.

General maps (1:1,000,000 and higher)

Such very small scales can hardly show anything more than major land divisions: countries or even continents. The 1:1,000,000 scale is much used, the world over. Lebault (1966) states that it has been chosen for the International Map of the World and adopted in many atlases, particularly for densely populated countries, and moreover is standard background for numerous studies on population, soils, vegetation, etc., endorsed by the International Geographical Union. The national cartographic survey of Canada uses that scale in the framework of a world project sponsored by the United Nations, and intended to cover the whole globe (Sebert 1973). As for the Canadian National Atlas, it contains maps mostly on the scale of 1:17,000,000. On such very small scales only the panels of the ELO system could be shown and even so, maybe only by symbols. Thus, Lebault (1966) points out that at the scale of 1:12,000,000 local uncertainty is 9/10 of a millimeter and that, in order to represent a medium-sized city, one must use a conventional circle of no more than one millimeter in diameter. So that, on a map of 1:40,000,000, a radius of 6 to 7/10 of a millimeter would correspond to a surface of 30 to 40 kilometers.

SAMPLED ZONES: SELECTION CRITERIA AND MAIN CHARACTERISTICS

The choice of zones that were sampled (see Table XIII) was meant to test the Ecological Land-Occupation system (ELO) throughout the Canadian territory. This involves recognition not only of biophysical variations "a mari usque ad mare" but of socio-economic landscapes as well. Ideally, one should have explored a great number of regions (hundreds, perhaps) and have spotted them according to approved sampling methods (random, stratified, systematic, etc.). An apology for not doing so is hardly needed: time, personnel, budget, accessibility, documentation would allow no more extensive a test than we have in fact made.

The actual sampling has ranged between 62° Long. W (Magdalen Islands, Québec) and 124° Long. W (Victoria, B.C.), and from 42° Lat. N (Niagara) to 54° Lat. N (Edmonton), thus running across major geological, physiographic, climatic, and vegetational landscapes. It also encompasses very diverse socio-economic zones: urban, industrial, agricultural (dairying, beef cattle-raising, cereals, horticulture, fruit-growing, etc.).

We have eschewed the process of statistical sampling and made the best of available sources and personnel. We already had rather a considerable amount of material from our own recent studies (1970-1974) in the Magdalen Islands and at the new Montreal International Airport Zone, Mirabel (Clibbon 1975, Dansereau, Clibbon and

TABLE XIII
List and principal characteristics of maps drawn according to the ELO system.

	Area	Province	Year	Scale	Original	Translation *	Author	Panel by dominance order	Reference to grid of Fig. 8
1	Cap-aux-Meules**	Québec	1972	1:15,840	X		G. Paré	A^2 B^1 D^1	29
2	Halifax	Nova Scotia	1965	1:50,000		CLI	G. Paré	A^2 D^2	26
3	Percé (natural area)	Québec	1975	1:10,000	X		M. Chamberland	A^2 B^1 D^1	29
4	Village of Percé and surroundings	Québec	1975	1: 5,000	X		M. Chamberland	D^3 A^1	16
5	Village of Percé (central part)	Québec	1975	1: 5,000	X		M. Chamberland	D^4	1
6	La Pocatière	Québec	1967	1:50,000		CLI	R. Lapointe	A^2 B^1 D^1	29
7	A l'Aigle Island (Sorel)	Québec	1974	1:15,840	X		J. Lalancette	A^4	35
8	St. Ignace Island (Sorel)	Québec	1974	1:15,840	X		J. Lalancette	B^2 A^1 D^1	23
9	Bouchard Island (Sorel)	Québec	1974	1:15,840	X		J. Lalancette	B^3 A^1	25
10	Westmount	Québec	1968	1:12,000		CECM	N. Nantel	D^4	1
11	Montréal-Nord	Québec	1968	1:12,000		CECM	N. Nantel	C^3 D^1	4
12	Jetté farm (Mirabel)	Québec	1975	1: 6,500	X		L. Carrières	B^3 A^1	25
13	Laframboise farm (Mirabel)	Québec	1975	1: 6,500	X		L. Carrières	B^4	15
14	Mirabel (St-Janvier sector)	Québec	1971	1:20,000		EZAIM	G. Paré	B^2 A^2	31
15	Mirabel (Lachute sector)	Québec	1966	1:20,000		CLI	P. Dugas	A^3 B^1	34
16	Mirabel (Lachute sector)	Québec	1971	1:20,000		EZAIM	P. Dugas	A^3 B^1	34
17	Mirabel (Lachute sector)	Québec	1975	1:20,000	X		P. Dugas	A^3 B^1	34
18	Oka	Québec	1966	1:50,000		CLI	S. Gagnon	B^3 A^1	25
19	Val-David, municipality	Québec	1975	1:12,000	X		L. Girard	A^2 B^1 D^1	29
20	Val-David gravel pit sector	Québec	1975	1: 6,000	X		L. Girard	D^2 A^2	26
21	Martin farm, Waterloo	Ontario	1975	1: 5,200	X		D. Nixey	B^4	15
22	Waterloo, South Dumphries Twp.	Ontario	1975	1:15,840	X		A. Hanna	B^3 A^1	25
23	Waterloo, Wilmot Twp.	Ontario	1975	1:15,840	X		A. Hanna	B^3 A^1	25
24	Waterloo, Woolwich Twp.	Ontario	1965	1:15,840	X		A. Hanna	B^2 A^1 D^1	23
25	Niagara	Ontario	1965	1:50,000		CLI	G. Paré	A^2 B^2	31
26	Winnipeg	Manitoba	1965	1:50,000		CLI	G. Paré	B^3 A^1	25
27	Saskatoon	Saskatchewan	1965	1:50,000		CLI	G. Paré	B^3 A^1	25
28	Edmonton (Dobbs sector)	Alberta	1975	1:15,840	X		G. Paré	B^3 A^1	25
29	Edmonton (Looking-Back Lake)**	Alberta	1975	1:15,840	X		G. Paré	B^2 A^2	31
30	Saanich, Sydney**	British Columbia	1975	1: 6,000	X		G. Paré	B^2 C^1 D^1	8
31	Saanich (industrial sector)	British Columbia	1975	1: 3,000	X		G. Paré	C^4	5
32	Saanich (residential sector)	British Columbia	1975	1: 3,000	X		G. Paré	D^4	1

*Original data and maps by:
CLI = Canada Land Inventory
CECM = Commission des Ecoles Catholiques de Montréal (Atlas)
EZAIM = Ecologie de la Zone de l'Aéroport International de Montréal

**Maps included in this paper.

Paré 1975). We were able to draw from several other ongoing projects located in the St. Lawrence Islands below Montreal, at Val-David in the Laurentians, and at Percé, in the Gaspé Peninsula. We also used existing maps that had been drawn by applying other systems and that lent themselves to *translation* into ELO categories. Most notable, of course, was the Canada Land Inventory, at all times a steady point of reference for us. Table IV lists the equivalents between CLI and ELO. Seven areas mentioned on Table XIII are the result of such translations. The Commission des Ecoles Catholiques de Montréal's atlas (1969) was also an excellent source. Finally, we have been fortunate in obtaining the help and guidance, in several parts of Canada, of geographers with considerable field knowledge for our own field work and airphoto readings. Although we have made additional attempts to map areas outside of Canada, by the "translation" of maps, our only original application of the ELO system was carried out in New Zealand.

One of the objects that we had in mind, of course, was the need to apply ELO to landscapes that differed significantly in the relative importance of the elements of the system itself. Thus, whereas it is useful to sample the Maritimes, the Prairies, the West Coast, it may be even more important to show areas that are predominantly filled by the blocks of one panel (A, B, C, D), and other areas that run the gamut of uneven coverage by A, B, C, or D, or even exclusion of one or more of them.

Figure 8 is an attempt to project the various combinations of A, B, C, D elements in their order of relative importance. Although this is best done by actual planimetric measurement, we have plotted much broader units, for the present purpose of orientation. Therefore, we have kept five alternatives only: 0=absence (or almost) of panel; 1=25% and less coverage; 2=25-50%; 3=50-75%; and 4=75-100%. Thus a map containing more than 75% wild (A) coverage is A4; one with 50% industrial, 25% wild, and 25% rural is C2, A1, B1, etc.

Among the 32 areas studied, six are nearly homogeneous: Ile à l'Aigle (No. 7) is A4, the two farms—in Waterloo (No. 21) and Mirabel (No. 13)—are B4, an industrial section near Victoria (No. 31) is C4, Westmount (No. 10), the village of Percé (No. 5), and a residential ward in Victoria (No. 32) are D4. A very frequent formula is B3 A1.

It is seen that many combinations occur, although, in such a restricted sampling, not all of the possible ones. Enough, however, to demonstrate the adaptability of the method to a diversity of landscape mosaics.

CARTOGRAPHIC METHOD

Collection of data

The method of data collection does not really differ from that which is generally in use, and which requires careful reading of the best and most recent airphotos available and as much knowledge as possible of actual field conditions.

Table VIII has indicated, opposite each type, whether it can be identified directly from airphotos or whether additional information (generally a field check) is necessary.

Photo-interpretation

The resort to airphotos to delimit the cells of land-occupation offers many advantages, among them the reduction of time-consuming and costly ground work. The technique of photo-interpretation is of course subject to many difficulties and variations related to photographic emulsion (black-and-white, colour, infra-red), scale, season and time-of-day, cloudiness, type of film, and, of course, the capability of the photo-interpreter (Gagnon 1974). For all of these reasons, it is hardly possible for us to propose a fixed set of rules for the application of photo-interpretation to the ELO system. It seems useful, however, to present a method based on the criteria best suited to land-occupation surveys.

1. It is preferable that the scale of the photo be less than 1:20,000. In fact, the scale usually runs from 1:10,000 to 1:20,000.
2. Vertical photos in black-and-white are the most usual and accessible, at least in Canada.
3. Photos were taken below 55° Lat. N, whereas, farther north, obliquity of solar incidence and greater humidity lessen the contrasts.
4. Photographic flights were made between June and September, preferably in late July to early August.
5. Gagnon (1974) points out that because of soil moisture, studies of land-use are favoured by photos taken when the sun is low; this is a favourable but not an indispensable factor.
6. Finally, we take for granted that the interpreter has the necessary basic qualities: good eyesight, both general and specific knowledge of land-occupation, capacity for analysis, deduction, classification, etc.

It is with due consideration of these six criteria that we have assigned, in Table VIII, one of four methods of photo-interpretation to each one of the *types:*

- P: photo-interpretation adequate;
- T: field check necessary;
- P-T: photo-interpretation possible; field check desirable;
- T-P: field work preferable; photo-interpretation possible.

Table XIV shows that almost 33% of occupation types can be mapped from unaided photo-interpretation. In some cases, this percentage can conceivably be boosted to 72% by adding P-T and T-P categories. It will be noted, once more, that the usefulness of photo-interpretation varies with the panels: 70% for A, 18% for B and C, and 20% for D. As for mobile elements (see Table XI), 50% of them can be spotted by direct airphoto reading. This is to say that wild areas lend themselves best to airphoto interpretation. Thus, landscapes of the A4 or A3 classes (see Figure 8) can be mapped down to the third order (panel/block/type) with a minimum of field work. This is particularly interesting, inasmuch as such regions are sometimes difficult of access.

For tasks undertaken at the scale of a province or a country, photos by satellite are excellent working instruments. During the last decade, teledetection (or *remote sensing*) has developed enormously in the United States. In Canada the ERTS programme (Earth Resources Technology Satellite) inaugurated in the summer of 1972 provides constantly renewed images of all parts of the country.

The methods of interpretation have progressed very rapidly and have been the object of many studies in various fields of investigation (forestry, agriculture, wildlife, etc.). As far as land-use is concerned, Anderson's contributions (1971, 1972) have led to most interesting classification schemes, the more so since they are compatible with previously proposed systems. We believe that the ELO method could eventually be used as a base for remote-sensing detection, since it offers a gamut that lends itself to translation from other classifications (see Tables I, III, IV).

		C_0					C_1				C_2			C_3		C_4
		D_0	D_1	D_2	D_3	D_4	D_0	D_1	D_2	D_3	D_0	D_1	D_2	D_0	D	D_0
A_0	B_0					1				2			3		4	5
	I				6				7			8		9		
	E 2			10				11			12					
	I 3		13				14									
	B_4	15														
A_1	B_0				16				17			18		19		
	B_1			20				21				22				
	B_2		23				24									
	B_3	25														
A_2	B_0			26				27				28				
	B_1		29				30									
	B_2	31														
A_3	B_0		32				33									
	B_1	34														
A_4	B_0	35														

FIGURE 8. Matrix for the grading of maps according to their diversity, in terms of percentage blocks, as follows:
0 = ≙U
1 = 0 - 25%
2 = 25 - 50%
3 = 50 - 75%
4 = 75 - 100%
Figures (1-35) are located in all theoretically possible combinations; shaded squares refer to our own maps (see Table XIII).

TABLE XIV

Occurrence and percentage of frequency of the four methods of data collection for ecological land-occupation (see Table VIII).

METHOD \ PANEL	A		B		C		D		Mobile elements		Total	
	Occurrence	%	Occurrence	%	Occurrence	%	Occurrence	%	Occurrence	%	Occurrence	%
P	23	69.7	7	18.4	10	18.2	8	27.6	8	47.0	56	32.6
T	2	6.1	11	29.0	23	41.9	10	34.5	3	17.6	49	28.5
P-T	4	12.1	10	26.3	16	29.1	3	10.3	4	23.6	37	21.5
T-P	4	12.1	10	26.3	6	10.8	8	27.6	2	11.8	30	17.4
TOTAL	33	100.0	38	100.0	55	100.0	29	100.0	17	100.0	172	100.0

P: photo-interpretation adequate
T: field check necessary
P-T: photo-interpretation possible; field check desirable
T-P: field work preferable; photo-interpretation possible

Field survey

It is not always possible to make direct readings of ecological land-occupation types from airphotos. Thus, 28% of ELO types require field study (Table XIV). This need is higher for industrial (42%) and urban (35%) affectations, whereas it is very low in the wild sectors (6%). Field checks, however, are at least desirable (P-T) in 21% of cases and highly recommended (T-P) in 17%. The variation between panels runs from 10 to 29%.

Translation of information maps

After the data of land-occupation have been inscribed directly on the airphotos, they must be transferred to a suitable base-map. This can be effected by traditional methods or by using computers, according to the nature and object of the research. For regional types of study, where the information to be processed is relatively limited, we suggest the first method.

Conventional procedures

More often than otherwise the translation of data from the airphoto to the map consists either in tracing the outlines on transparent (herculene) paper or in drawing them upon a standard base map. This procedure has been used by the Canada Land Inventory teams who used Canadian Topographic Survey maps (1:50,000 and 1:-250,000). In both cases, one must mind the distortions which variously affect airphotos and carefully make the necessary corrections.

The delimitation of *punctual* or *linear* occupation types (Table XI) will not usually pose any problem, at least if the minimum dimension of cell is about 5 mm in diameter, as it is always possible to work on a blow-up of the original document (photographic process or special apparatus).

However, some of the ELO types are *linear* (see Table XI), notably in block 2 (transport and communications) of panel C (industrial). In such cases, we suggest that conventional cartographic designs and symbols be used by superimposing the appropriate ELO colour or texture. It may be well to draw attention to the fact that these elements, in most land-use classifications, are not considered within the classification itself but as background, whereas in the thorough and systematic inventory of all occupation which the ELO system envisions, roads and power lines are altogether as "important" as pastures and industrial plants. For this reason we recommend that railroads $\frac{C\ 2\ C}{V,I}$, highways and roads $\frac{C\ 2\ E}{V,I}$, electric power lines $\frac{C\ 2\ F}{V,I}$, ducts (pipelines, etc.) $\frac{C\ 2\ G}{V,I}$, be represented by conventional geographic symbols already in use, for instance by the Canadian Topographic Survey (Sebert 1972). Other linear occupation types, such as trees in a row (a), hedgerows (b), sand spits $\left(\frac{A\ 1\ Da}{I}\right)$ can be drawn as closed lines, as it is generally admitted that such elements are at least slightly exaggerated on a map whose scale does not allow true representation.

Ultimate design of the map should meet the objectives of the user. If it is a working document, for limited circulation, it is enough to draw the colours (Table IX) manually, as well as the symbols. If the map is meant for publication, the author can use textures (Table X) for a black-and-white reproduction or else deliver his working document in manuscript form to the printer who will effect the preliminary work for printing in colour. The use of prefabricated textures (*Letrafilm*) can also yield very good results in the case of reproduction by photographic processes.

Mecanographic methods

The use of computers as cartographic instruments offers numerous advantages, foremost among them the possibility of manipulating an impressive amount of data. Among the best known programmes (LINMAP, NORMAP, NORI, etc.), SYMAP is no doubt most often favoured, at least for land-use purposes (see Marsan, in Dansereau, Clibbon, and Paré 1975). This system, however, offers only 6 or 7 shades, which severely limits its use for ELO mapping. It remains, however, that it would lend itself very well to mapping of one panel at a time (as, for instance, Maps 5.16b and 5.21 drawn by Marsan in Dansereau, Clibbon, and Paré 1975). Thus, four maps could well be drawn for the same area.

The clear structure of the ELO system is certainly amenable to automatic cartography, particularly on the national scale. It could well fit into the Canada Geographic Information System (CGIS) which is, in fact, meant to store, read, analyze, and compare various maps, among them the land-use maps produced by the Canada Land Inventory. We therefore believe that it would be useful to further explore the possibilities of the ELO in this direction.

CONCLUSION

The ELO system is first of all a taxonomic method of classifying land-occupation patterns according to the *dynamics of their component ecosystems.* It could even be applied to the analysis of a territory without necessarily resorting to cartography. But it is more consonant with the very logic of the system to seek expression in mapping, inasmuch as it is principally an instrument for planning. We are fully aware, of course, that numerous tests are needed to provide sharper focus and to produce more satisfactory applications of our cartographic proposals. It would be particularly useful to pursue experiments with automatic mapping processes and with remote sensing. On the other hand, we have found out, in the utilization of the ELO system by students and by land-expertise teams, what the actual cost of production may be. It would seem that such costs are closely linked to the nature and scope of the research: all things considered, we do not think that it would be more expensive to apply the ELO system than other current methods.

SOME SAMPLES OF CARTOGRAPHY

In order to properly illustrate the cartographic results obtained in the application of the ELO scheme, it would obviously have been desirable to present herewith most of the maps enumerated in Table XIII. This is hardly possible, because of the high cost of colour production, and we have chosen only four maps, three in colour and one in black-and-white. These maps are on large (1:15,840) and very large (1:6000) scales. They show contrasting units both as to geographic location (eastern and western Canada) and as to land-occupation itself. Thus, the sampling of Cap-aux-Meules, in the Gulf of St. Lawrence (Figures 9 and 10), shows a land mosaic predominantly wild (A), with a substantial coverage of rural elements (B) and a narrowly clustered urban development (D). At the other end of the continent, in British Columbia, the Saanich sector (Figure 12) shows a predominantly rural (B) landscape, tightly bordered by occupations of an urban (D) and industrial (C) character. Finally, the map of Looking-Back Lake (Figure 11), near Edmonton (Alberta), shows great predominance of rural (B) and wild (A) features, whose uniformity is only broken by oil wells (panel C, block 2). Further analysis of these three maps will allow some interesting conclusions concerning the new system (ELO).

Cap-aux-Meules (Québec)

(Figures 9 and 10, Table XV)

1. Principal characteristics

a. *Location.* Small municipality of Iles-de-la-Madeleine (Magdalen Islands), in the Gulf of St. Lawrence: 62° Long. W by 48° Lat. N.
b. *Scale.* 1:15,840.
c. *Physiography.* Appalachian and coastal.
d. *Geology.* Appalachian orogeny; Mississippian and Permo-Carboniferous deposits. Soils: podzolic and regolithic.
e. *Forest region.* Acadian (see Rowe 1972).
f. *Socio-economic activities.* Predominance of fisheries; residential development; commercial centre for the islands; subsistence agriculture.

2. Cartographic elements

All blocks of all four panels are represented, with the exception only of blocks 1 and 7 of the urban panel (D). As can be seen on Table XV, which lists all ELO types encountered on the archipelago as a whole (Paré 1974), even these blocks are to be found nearby. The striking feature is that nearly 70 ELO types are shown at this scale (1:15,840), including some of the fifth order, such as an old cut-over plot $(\frac{\text{B 2 Aab}}{\text{V,II}})$.

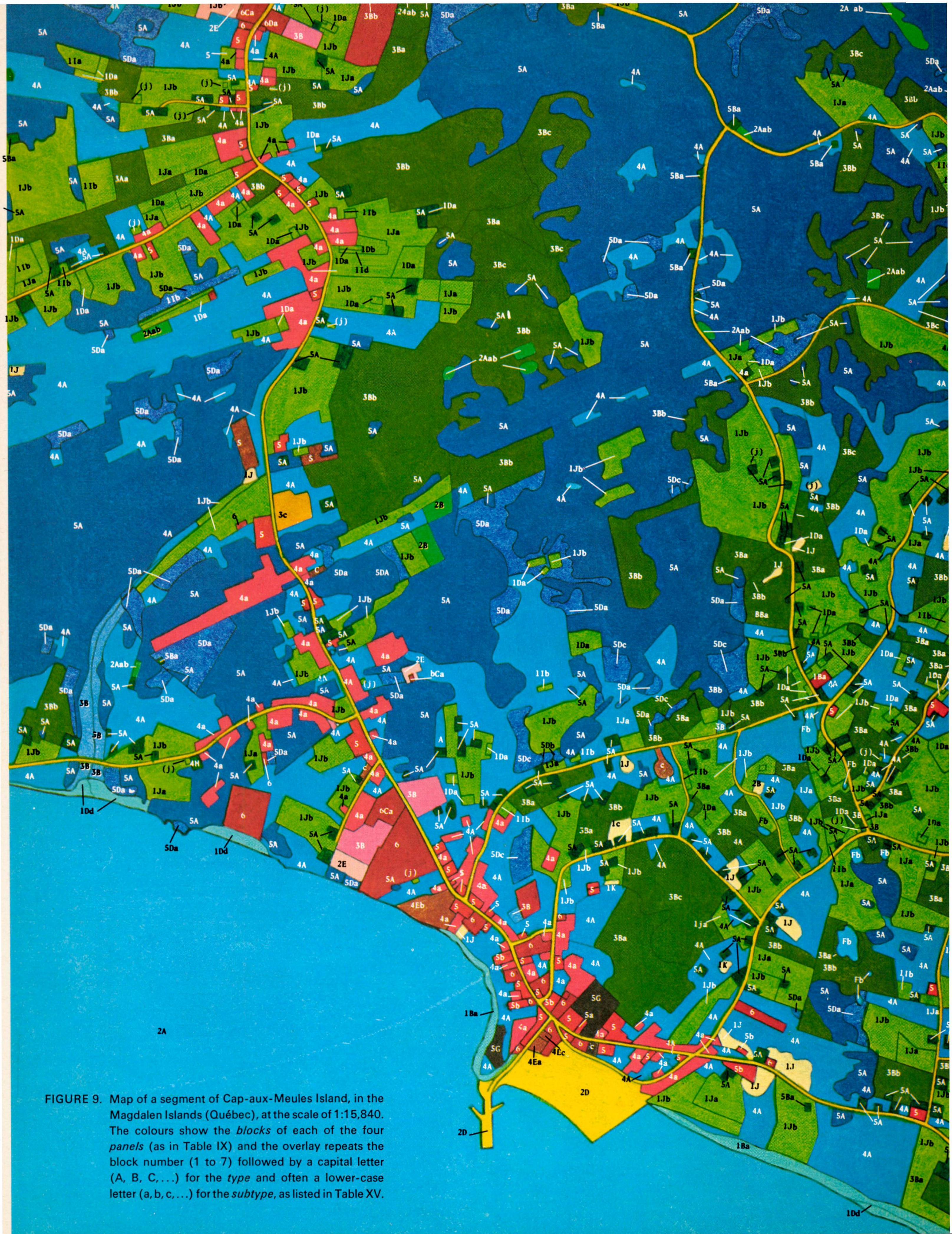

FIGURE 9. Map of a segment of Cap-aux-Meules Island, in the Magdalen Islands (Québec), at the scale of 1:15,840. The colours show the *blocks* of each of the four *panels* (as in Table IX) and the overlay repeats the block number (1 to 7) followed by a capital letter (A, B, C, ...) for the *type* and often a lower-case letter (a, b, c, ...) for the *subtype*, as listed in Table XV.

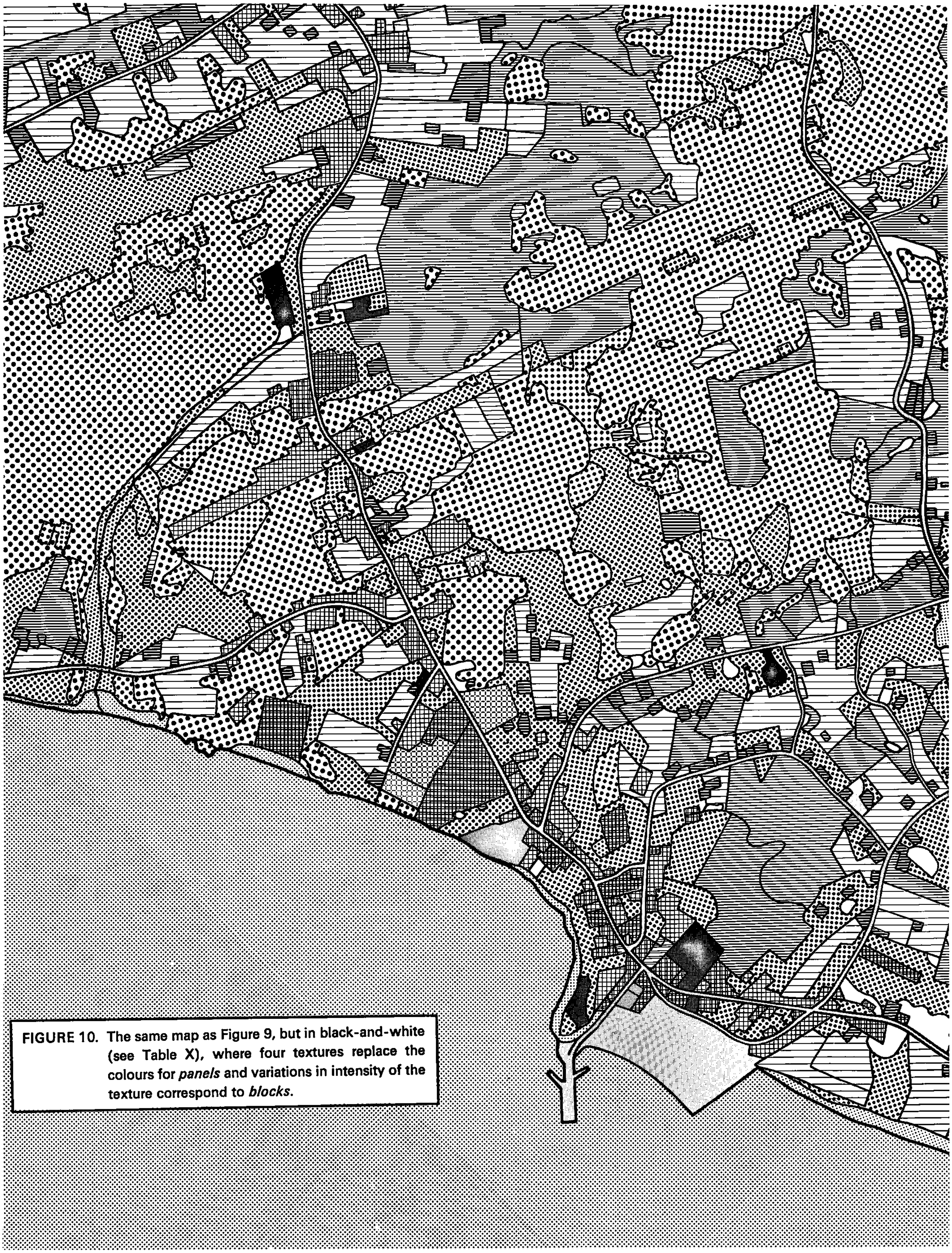

FIGURE 10. The same map as Figure 9, but in black-and-white (see Table X), where four textures replace the colours for *panels* and variations in intensity of the texture correspond to *blocks*.

TABLE XV

The ELO types (see Table VIII) present in the Magdalen Islands (Québec). The types present on the Cap-aux-Meules map (Figures 9 and 10) are marked by asterisks.

PANEL A. WILD

Blocks	Trophic Levels	Types
5 Predominance of woody plants on upland	II	A Forest* D Scrub* a evergreen* b deciduous c mixed*
4 Predominance of herbaceous plants on upland	II	A Prairie*
3 Wetlands	II	B Marsh* C Saltmarsh D Bog
2 Water	I, II, III, IV	A Sea* C Lagoon E Flowing water* a stream* F Still water* a lake b pond*
1 Raw minerals	V, I	B Rock* a cliff* b outcrop c scree and regolith D Sand* a dune b bare sand c blowout d beach and spit* e sand lightly or temporarily submerged

PANEL B. RURAL

Block	Trophic levels	Type
5 Construction and maintenance	V	A Yards and outbuildings* B Recreation space* a cottage* b camping c picnic grounds
4 Breeding	V, III, IV	H Poultry*
3 Pasture	V, III	A Improved pasture* a permanent* b in rotation B Unimproved pasture* a wet* b dry* c semi-natural* d communal
2 Woody-plant exploitation	V, II	A Lumbering* a clearcut* a recent b old* B Nursery* F Plantation
1 Cropping of herbaceous plants	V, II	B Fruiting plants a raspberries b strawberries D Roots, tubers, bulbs* a potatoes* b rutabagas c beets I Cereals* a wheat b oats* c barley d sweet corn* J Fodder and silage* a good quality* b poor quality*
	V, I	M Fallow

PANEL C. INDUSTRIAL

Block	Trophic levels	Type
5 Services	V, II, III, IV	B Storage
	V, I	G Reservoir*
4 Manufacturing	V, III, IV	E Fish and invertebrates* a canning* b smoking* c freezing*
	V, II	G Wood* a doors and windows* b lobster cages
	V, I	L Rock and sand a asphalt Q Mineral waters*
3 Energy	V, I	C Thermal plant*
2 Transport and communications	V, I	A Telecommunication a antennae B Airport a landing strip D Port and shipyard* E Road and highway* a major* b secondary* F Transmission line I Lighthouse J Clearing and filling operations
1 Extraction	V, II	C Sod*
	V, I	J Quarry* K Gravel

PANEL D. URBAN

Block	Trophic levels	Type
7 Administration	VI, V	A Governmental
6 Institution		C Religious* a church* D Educational* a school* E Medical* a hospital*
5 Commerce	V	A Hostelry* a hotel* b motel* c cabins B Restaurant* C Stores* a shopping center*
4 Residence		A Single-family* B Multifamily*
3 Open spaces	V	B Playground* a mini-golf b skating rink c tennis court* D Racetrack a horseracing
2 Green spaces	V, II	C Golf links D Park E Cemetery*
1 Paved or unplanted spaces	V, I	B Dump D Vacant lot

Mobile elements
(g) pasture (grazing)
(j) kitchen-garden*
(t) parking lot
(u) construction
(x) abandoned

A close look at Figure 9 shows that blue, green, brownish-yellow, and red allow ready recognition of panels A, B, C, D. The differences in shade do not generally create reading difficulties, although blocks 4 (residence) and 5 (commerce) of panel D (urban) may require very close scrutiny, especially of the smallest cells. It may also be difficult to separate the darkest blocks from one another. Finally, the superimposed formulae (figure and letter(s)) do not really get in the way, the less so since the transparent overlay may be easily lifted.

The results of mapping in black-and-white are also satisfactory, as witness Figure 10. The graphic density is neither too weak nor too strong. We have, in fact, remained within the limits of the ten signs per cm² prescribed by Bertin (1973). Moreover, in each unit, or cell, of land-occupation, points, lines, or crosses are large enough for clear identification. Bertin (1973) has figured that, at the elementary reading level, a significant form must have at least 2 mm and that its extent must be four times its width in order to be legible. It is worth noting, on the other hand, that the boundaries between cells are more distinct in black-and-white than in colour.

Looking-Back Lake (Alberta)
(Figure 11, Table XVI)

1. Principal characteristics

a. *Location.* A few kilometres SE of Edmonton, Alberta; 114° Long. W by 54° Lat. N.
b. *Scale.* 1:15,840.
c. *Physiography.* Interior plains.
d. *Geology.* Interior platform. Mesozoic. Sedimentary rocks, with weak folding.
e. *Forest region.* Boreal. Aspen parkland (Rowe 1972).
f. *Socio-economic activities.* Agriculture (cereals, hay, pasture). Oil fields.

2. Cartographic elements

This quadrangle is notable for the complete absence of any type belonging to panel D (urban). It can be divided in two sections: predominantly rural (B) in the western, and predominantly wild (A) in the eastern part, with a spattering of industrial plots (C) tied together by the road network. Looking-Back Lake itself is a natural buffer between the two areas. Most of the blocks of panels A and B are represented, whereas the industrial panel (C) has only two blocks (5. Services and 2. Transport and communications). On the other hand, there are some 20 different ELO types here, as against almost 60 at Cap-aux-Meules where the total land area is roughly the same.

From a purely cartographic point of view, the shades of green (panel B) show up quite well and the gradient is easily perceived. The blues (panel A) stand out well against the other colours, but the inner gradient is not so readable as it is in the green. Yellow, which shows driveways, roads, pipelines, etc., causes no problems of readability. Finally, the superimposed symbols are quite distinct, even where very small areas are involved. But, again, the overlay sheet can always be lifted for a final check.


N
2C
1JB
1Ja
1Jb
1Jc
1M
1Ib
1Ib + c
1Ia + b
2Aa
2E
2Ed
2Ga
2Gb
3B
3B (g)
3B (q)
3Ab
4A
5A
5A (g)
5D (g)
(a)
(s)
(q)

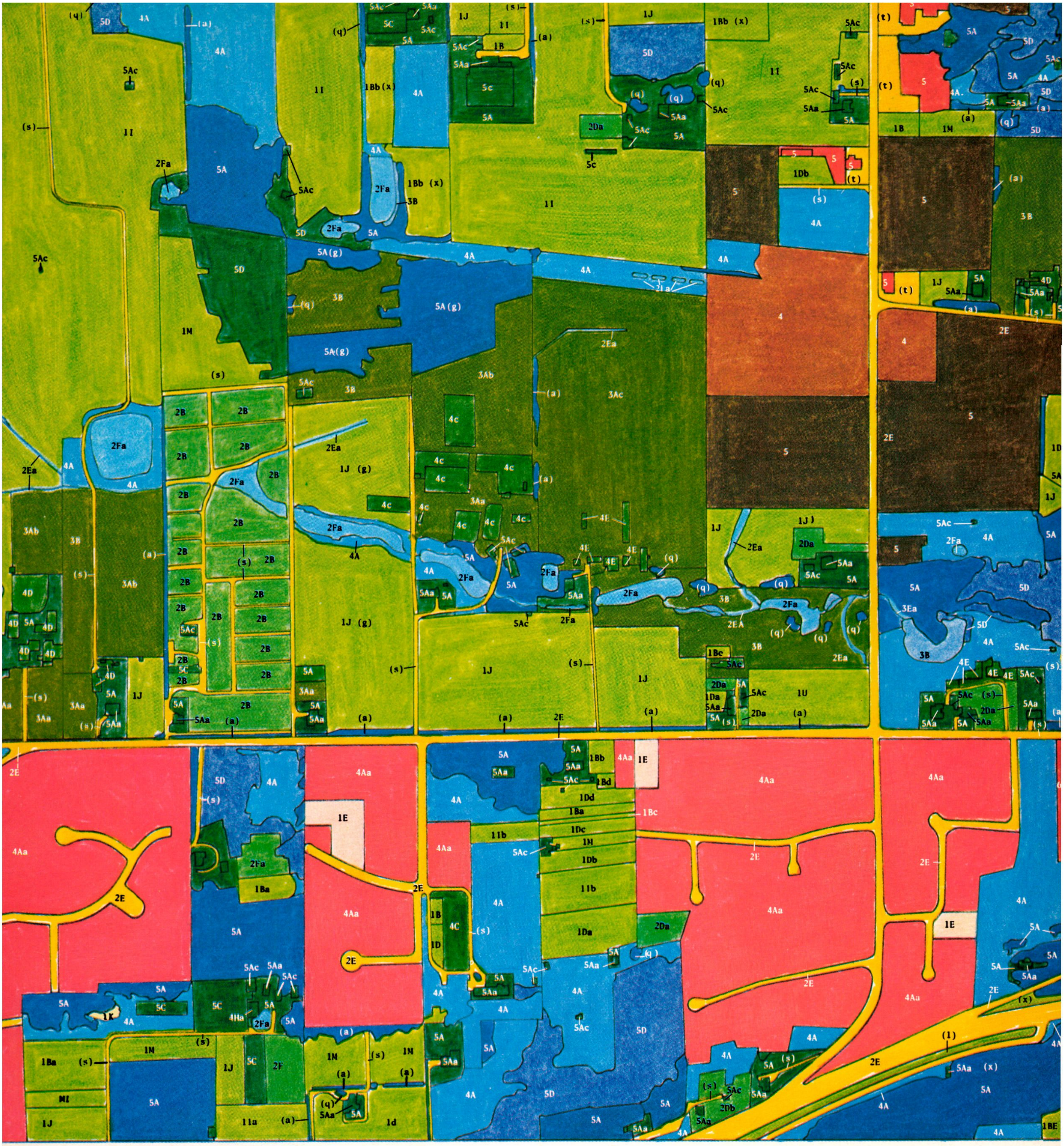

FIGURE 12. Map of the Saanich area, near Victoria (British Columbia), at the scale of 1:6,000. The colours show the *blocks* of each of the four *panels* (as in Table IX) and the overlay repeats the block number (1 to 7) followed by a capital letter (A, B, C, . . .) for the *type* and often a lower-case letter (a, b, c, . . .) for the subtype, as listed in Table XVII.

←

FIGURE 11. Map of Looking-Back Lake (Alberta) at the scale of 1:15,840. The colours show the *blocks* of each of the four *panels* (as in Table IX) and the overlay repeats the block number (1 to 7) followed by a capital letter (A, B, C, ...) for the *type* and often a lower-case letter (a, b, c, ...) for the subtype, as listed in Table XVI.

TABLE XVI

ELO types (see Table VIII) present in the Edmonton (Alberta) area. Types bearing asterisks are represented on the Looking-Back Lake map (Figure 11).

PANEL A. WILD

Block	Trophic Levels	Type
5 Predominance of woody plants on upland		A Forest* D Scrub*
4 Predominance of herbaceous plants on upland	II	A Prairie*
3 Wetlands		B Marsh*
2 Water	I, II, III, IV	C Lake* D Stream F Pond*

PANEL B. RURAL

Block	Trophic Levels	Type
5 Construction and maintenance	V	A Yards and outbuildings* B Recreation a Improved park
	V, III, I	D Clearing
3 Pasture	V, III	A Improved pasture* a enclosed b in rotation* B Unimproved pasture*
2 Woody-plant exploitation	V, II	A Lumbering* a clearcut*
1 Cropping of herbaceous plants	V, II	H Oil plants a colza I Cereals* a wheat b oats* c barley* d corn J Fodder and silage* a good quality* b poor quality* c Lucerne*
	V, I	M Fallow*

PANEL C. INDUSTRIAL

Block	Trophic levels	Type
5 Services	V, II	B Storage a grain elevator G Reservoir* a oil tanks*
2 Transport and communications	V, I	C Railroad and station E Road and highway* a gravel* G Ducts* a oilwell* b pipeline*
1 Extraction		H Mine a coal a open-pit

Mobile elements
(a) trees in a row*
(s) path, driveway*
(q) grove*
(x) abandoned
(g) pasture*

Saanich (British Columbia)
(Figure 12, Table XVII)

1. Principal characteristics

a. *Location.* Saanich Peninsula, near Sydney, on Vancouver Island; 124° Long. W by 48° Lat. N.
b. *Scale.* 1:6,000.
c. *Physiography.* Cordilleran region.
d. *Geology.* Cordilleran orogeny.
e. *Forest region.* Coastal (Rowe 1972).
f. *Socio-economic activities.* Truck crops and fruit-growing. Industrial and residential development.

2. Cartographic elements

In this quadrangle the very large scale allows detailed representation of wild (A) and rural (B) panel types. In the latter, block 5 (construction and maintenance) evokes some reading difficulties, for types A (yards and outbuildings) and C (greenhouses) occupy rather narrow spaces and it is hardly possible to show subtypes within these categories, even at such a high scale as 1:6,000. It has nevertheless been feasible to run down to the fourth order of magnitude $\frac{\text{B 5 Aa}}{\text{V}}$ without too much difficulty.

TABLE XVII

ELO types (see Table VIII) present in the Saanich area, near Victoria (British Columbia). Types bearing asterisks are represented on the Saanich map (Figure 12).

PANEL A. WILD

Block	Trophic Levels	Type
5 Predominance of woody plants on upland		A Forest* a evergreen a red cedar b Douglas fir b deciduous D Scrub*
4 Predominance of herbaceous plants on upland	II	A Prairie*
3 Wetlands		B Marsh*
2 Water	I, II, III, IV	E Flowing water* a stream* F Still water* a pond*

Mobile elements
(a) trees in a row*
(b) hedge
(j) garden
(l) lawn*
(q) grove*
(s) path, driveway*
(t) parking lot*
(u) construction
(w) irrigation*
(x) abandoned

PANEL B. RURAL

Block	Trophic Levels	Type
5 Construction and maintenance	V	A Yards and outbuildings* a house* a old b new (bungalow) b barn/stable* c shed* C Greenhouses* a vegetables b flowers
	V, II, I	D Clearing*
4 Breeding	V, III, IV	C Draft and riding animals* a horses* D Butchery animals* E Dairy animals* H Poultry* a pigeons*
3 Pasture	V, III	A Improved pasture* a enclosed* b long-term* c in rotation* B Unimproved pasture*
2 Woody-plant exploitation	V, II	B Nursery* D Orchard* a apple* b cherry* F Plantation* a holly-growing*
1 Cropping of herbaceous plants		B Fruiting plants* a raspberries* b loganberries* c tomatoes* d beans* e cucumbers* D Roots, tubers, bulbs* a potatoes* b rutabagas* c beets* d carrots* I Cereals* a oats* b corn* a sweetcorn* J Fodder and silage* a good quality b poor quality
	V, I	M Fallow*

PANEL C. INDUSTRIAL

Block	Trophic Levels	Type
5 Services*	V, IV, III, II	B Storage a paper b wood c fruits and vegetables d freezers e neon signs f aluminum g heavy equipment h storage yard
		E Repairs a heavy machinery
4 Manufacturing*	V, I	N Metal and mineral a aluminum a trailers b doors and windows
2 Transport and communications*		E Road and highway

PANEL D. URBAN

7 Administration	VI, V	C Private a warehouse or factory office
6 Institution		D Educational* a school*
5 Commerce	V	C Stores* a grocery* b hardware*
4 Residence		A Single-family* a bungalow*
1 Paved or unplanted spaces	V, I	D Vacant lot*

Thus the scale of 1:6,000, in spite of its amenability to the mapping of wild and rural types, does not readily allow reading beyond the fourth order in the urban panel, and the third in the industrial. It would then remain, of course, to further enlarge the scale proportionately to the desired refinement which is needed.

The information contained on this map allows a useful interpretation of the present state and of the dynamics of the land mosaic. It shows a rural (B) environment where the processes of transformation of resources are not very active (predominance of block 1). On the other hand, cultivated land is hemmed in on all sides by residential (panel D) and industrial (C) development. The latter is represented by activities belonging to the upper echelons of human escalation (blocks 5 and 4). The concentration of wild areas (A) in the vicinity of urban and industrial occupations implies a regression of the rural spaces. The fact that a substantial part of wild land is in the prairie stage $\frac{\text{A 4 A}}{\text{II}}$ allows the inference that the inversion of man's interference is of relatively recent date.

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