Cahiers de géographie du Québec

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Volume 11, Number 22, 1967

URI: https://id.erudit.org/iderudit/020681ar
DOI: https://doi.org/10.7202/020681ar

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Publisher(s)

Département de géographie de l'Université Laval

ISSN

0007-9766 (print)
1708-8968 (digital)

Explore this journal

Cite this article

Harris, S. A. (1967). Areal Distribution of the Various Combinations of Quaternary Climates. *Cahiers de géographie du Québec*, *11*(22), 55–62. https://doi.org/10.7202/020681ar

Article abstract

On reconnaît maintenant que les paléoclimats ont laissé leur trace dans le sol, sur la végétation et les paysages de diverses régions du monde. De nombreuses méthodes d'analyse, discutées et discutables, permettent de découvrir quels étaient les climats du Tertiaire et du Quaternaire, leur forme, leur influence et leur extension et ainsi de connaître l'évolution et les changements des paysages.

AREAL DISTRIBUTION OF THE VARIOUS COMBINATIONS OF QUATERNARY CLIMATES

by

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Palæoclimates have recently been recognized as a major influence in controlling the type of landscape, soil and vegetation found in diverse areas of the world. Their methods of recognition have been discussed and their effects are well known. Most of these phenomena have been produced in Tertiary and Quaternary times. In this paper, the apparent extent of various simple combinations of climatic variations during Quaternary times are outlined and some of their implications in physical geography are discussed.

Basic climatic units

The basic climatic units used in this study must be those which can be recognized and differentiated in past deposits. Glacial materials are the product of one climatic environment. It is also possible to separate tropical and mesothermal temperature conditions in humid regions using the flora. Studies show that arid periods may be recognized in palæosols, while these can also often be split into warm and cold regions.

Thus five simple climatic units can be distinguished, viz. : ice caps, temperate humid, temperate arid, tropical arid and tropical humid climates. The present-day distribution of these units can readily be determined ; they are presented in Figure 1. The areas of aridity are mapped according to the arid homoclimates of Meigs (1). These are the areas with a deficit in average annual precipitation in relation to potential evapotranspiration according to the Thornthwaite system. Mean monthly temperature during the coldest month of less than 48°F. (about 5°C.) are used to separate the areas of cold arid conditions from the hot arid climates. The humid areas can be conveniently divided into temperate and tropical climates on a basis of a mean monthly temperature below or above 64.4°F. (18°C.) in the coldest month.

Climatic variation during the quaternary period

By examining part of the voluminous literature accumulated by archæologists, pedologists, palynologists, geomorphologists and geologists, it is possible to map the combinations of these five climatic zones which have occurred over most of the world in Pleistocene times. This has been carried out in Figure 2, and Table I shows the approximate percentage of land areas of the earth in the ten climatic zones mapped. The available data are not equally good for all areas of the world ; South America and Southeast Asia are the areas for which by far the least information is available.

It is not, of course, claimed that an exact boundary can be determined for mesothermal and tropical regions for the various moments of time during the Pleistocene, though botanists now claim remarkable precision in the cases of Europe and North America. However, at the scale of mapping, there appears to be sufficient information to demonstrate clearly the small size of the areas which may have been under one climatic zone for the whole Quaternary period.

Table* 1 *Approximate percentages and areas of the earth in the ten climatic zones mapped

		Approximate Land Area of the Earth	
	Climatic Group	%	*Actual (million sq. miles).*
1	Ice Caps	10	5.7
1-2		16	9.1
1-3		1.5	0.9
2	Temperate Humid	18	10.2
2-3		6.5	3.7
3	Temperate Arid	0.5	0.3
3-4		2	1.1
4	Tropical Arid	0.5	0.3
4-5		40	22.8
5	Tropical Humid	5	2.8
		100	56.9

Whether the present ice caps have always existed there throughout Pleistocene times seems rather doubtful. The area of Tropical Rain Forest was once greatly diminished in Africa, while there is as yet little firm evidence for its persistence at all times in the Amazon Basin. Some pockets or « oases » of Rain Forest must have persisted at suitable sites in order to maintain the lowland tropical floras, but they may have been very small. Evidence from the East Indies suggests a much greater persistence of Rain Forest, probably due to the proximity of all areas to the sea.

The presently available evidence suggests that the only possible areas of continuously cool arid climate lie in the Gobi Desert of China and again in Patagonia. Hot arid climates may have persisted in part of the Kalahari desert, a small patch in Western Egypt and the Atacama desert in Chile. The large areas of continuously moist and humid climate lying in the present-day cyclonic belt show abundant evidence of changes in climate but subdivision is difficult due to lack of evidence. It does however emphasize the great persistence of cyclonic humid winds in the higher latitudes.

The most widespread climatic combination is tropical humid and arid (4-5), which is dominant at low latitudes. The alternating glaciated and temperate humid combination (1-2) covers 16% of the total land area, mainly in the higher latitudes. In addition, there are appreciable areas which have suffered glaciated-temperate arid (1-3), temperate arid-temperate humid (2-3), temperate arid-tropical arid (3-4), and temperate humid-tropical arid (2-4) combinations. A few insignificant areas may have suffered a glaciated-tropical humid climatic

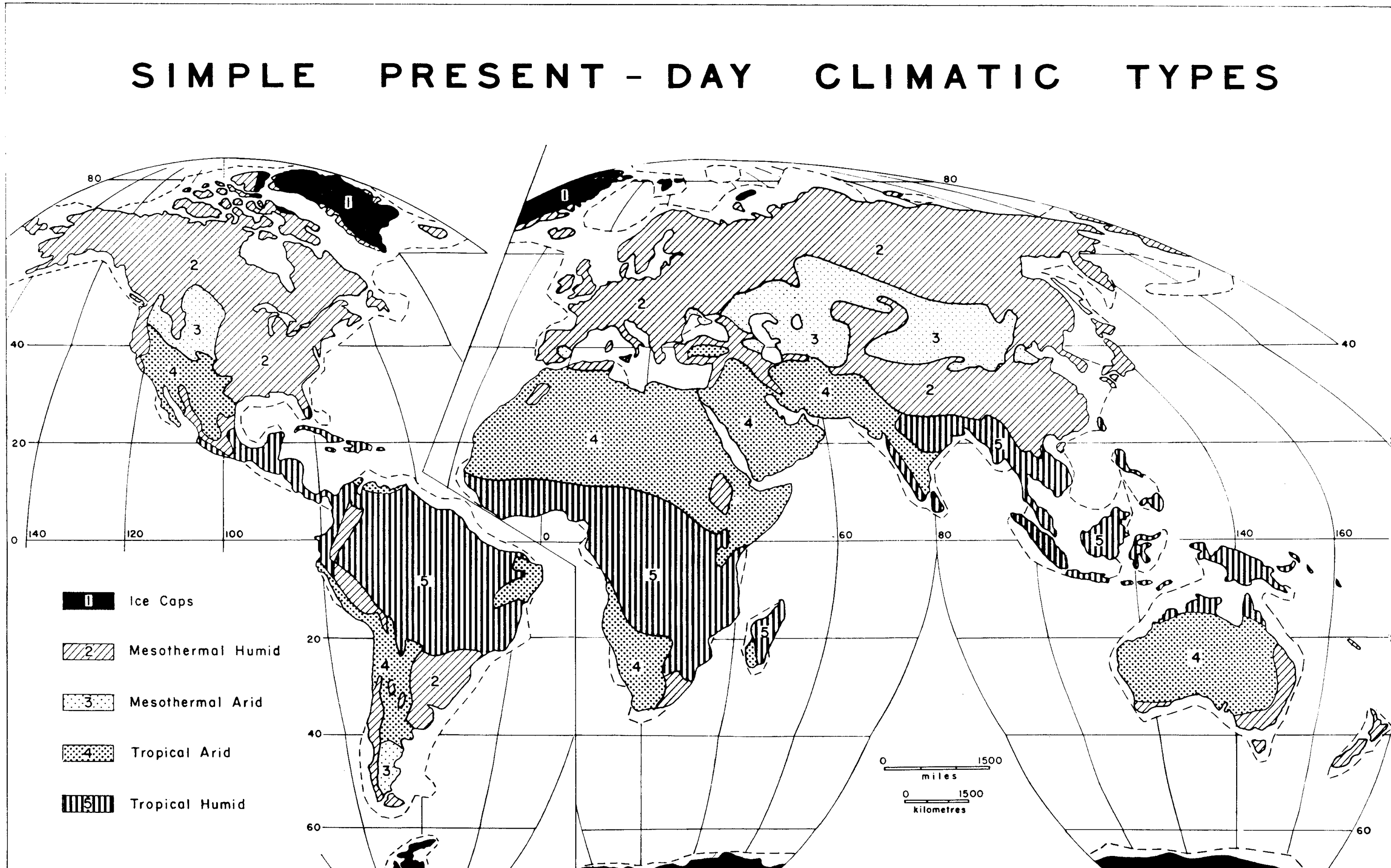
SIMPLE PRESENT - DAY CLIMATIC TYPES
Ice Caps
Mesothermal Humid
Mesothermal Arid
Tropical Arid
Tropical Humid
miles
kilometres

Figure 1

combination but these were included in with the temperate humid-glaciated region in this instance.

Importance of these changes

Climate is perhaps the major controlling factor in the physical environments of land areas. Its effects are seen in all processes occurring in the biosphere and in the outer zones of the lithosphere. Every time there is a change in the climatic environment, this will be reflected in these dependent phenomena. It therefore follows that in order to determine the relationship of climate and the physical environment, it is essential to consider the effect of the changing pattern of climate. It is only by a clear understanding of the zones of various kinds of climatic change that these relationships with other phenomena can be properly approached.

A good example is found in the realm of soil science. The great advance made by Curtis Marbutt in his system of soil classification was to realize and make use of the interrelationship between soils and climate in soil classification (2). It enabled him to produce a classification system which was to last for over a quarter of a century. Its strength lies in its simplicity and the ease with which the units can be compared with distribution maps of other phenomena. The great defects of his system were his inadequate knowledge of world soils and their distribution, and the failure of the system to recognise climatic changes. The first defect is slowly being remedied with the passage of time (3), but all the soil types of the world are still not known. This defect is therefore one common to all classification systems devised so far, including the recent Seventh Approximation (U. S. D. A.) (4), which uses over 500 soil categories to accommodate most of those soils which are presently known.

The main reason for dissatisfaction with Marbutt's system lies however in the presence of the so-called polycyclic or polygenetic soils (5), throughout the world. These are the soils formed during more than one set of soil-forming conditions so that they bear the imprint of at least two soil-forming phases superimposed on one another. Soils of this type occur in most of the world, while monocyclic soils formed under only one set of formative conditions are relatively rare. The Seventh Approximation tries to evade this issue by cataloguing soil properties, both visual and chemical. As stated by Stephens (6), it functions « rather as a key than a classification. » The result is an unwieldy number of soils grouped in a fashion which is supposed to follow and exemplify the main soil forming processes. To determine the latter we need to decide the nature of the processes producing the soils. In other words, the issue is not evaded but merely made as inconspicuous as possible. Unfortunately without a master simplification, the new U. S. D. A. system is of little use to anyone who is not a specialist in soils. The F. A. O., in making world soils maps, appears to be keeping to modifications of Marbutt's system that can be more readily understood (7). Here again, no attempt is made to differentiate between monocyclic and polycyclic soils (8). If such a differentiation were made a

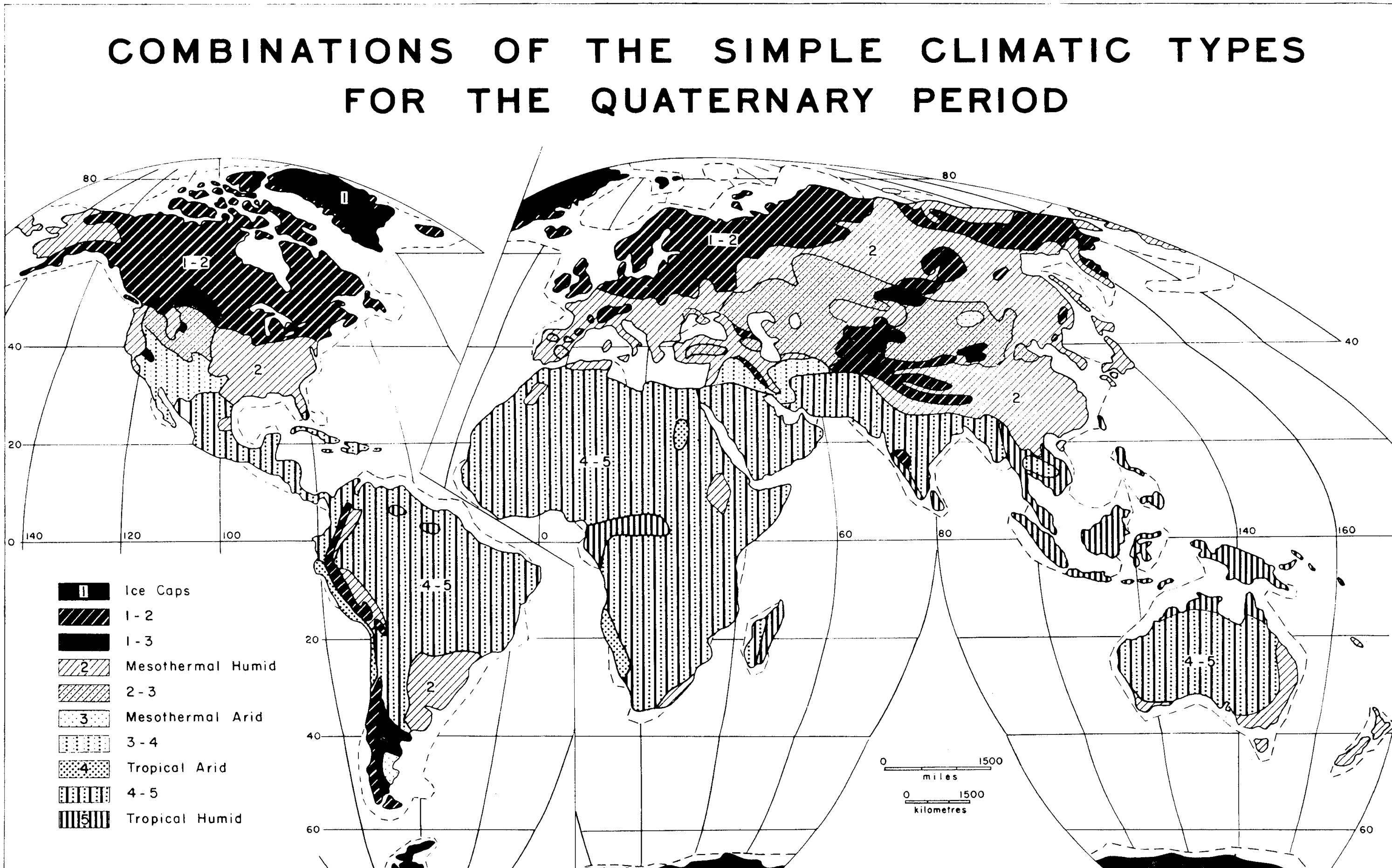
COMBINATIONS OF THE SIMPLE CLIMATIC TYPES FOR THE QUATERNARY PERIOD
Ice Caps
1 - 2
1 - 3
Mesothermal Humid
2 - 3
Mesothermal Arid
3 - 4
Tropical Arid
4 - 5
Tropical Humid
0 1500 miles
0 1500 kilometres

Figure 2

comparatively simple system of grouping of the monocyclic soils could be employed to make teaching and understanding of the nature of soils considerably easier, and from the results of this study, the origin of the infinitely variable polycyclic soils would readily be deduced. It is work of this type that is rapidly bringing a new look to soil science.

Similar problems are encountered in dealing with landforms. It is obvious that we must be prepared to base the nomenclature of landforms on definitions which are independent of present-day climate. Thus terms such as mesa, butte and pediment should be applied to the appropriate landforms in climatic regimes which are currently humid as well as to those which are arid. If we compare such landforms with the palæoclimatic zones, we arrive at the following groupings :

1. Landforms confined to those landscapes which have been under glacial conditions ;
2. Landforms produced in regions where running water has been active ;
3. Landforms due to wind action in periods of dry climates ;
4. Landforms in which the initial surface is dominant ;
5. Landforms due to mass wasting in arid periods ;
6. Landforms due to mass wasting under humid regimes ;
7. Landforms due to mass wasting in periglacial conditions ;
8. Landforms due to karst action.

Landscapes, of course, consist of various combinations of these groups. In a given present-day climate, two sets of landforms may currently be produced by seasonal or longer term climatic fluctuations. Variations in relative proportions of these landforms in different areas caused Budel to introduce his *formkreisen* (9), or morphogenetic regions (10). Provided that landforms are linked to palæoclimates instead of present-day climates, the study and mapping of landforms remains a valuable tool of the geomorphologist.

In the geographical cycle of landscape development, first proposed by Davis (11), any landform was regarded as being a function of structure, process and time. As commonly used, it is a very valuable teaching tool, but it fails in practice largely because of the definition of « process ». In spite of his clear writing style, Davis did not realize, or at any rate emphasize, the difference between present-day climate and the balance between the main terrestrial agents of denudation, viz. : running water, wind, ice, mass wasting and weathering. Instead, he came to use « process » as being synonymous with a present-day climatic regime, though, of course, recognizing the influence of past glaciations. This concept of a cycle is very useful but a modification of the usage of « process » is needed.

Provided we use processes such as wind, water and mass wasting in place of climate, we regain the flexibility needed to apply the cyclic concept. However, we must also accept the ideas of G. K. Gilbert that the processes may change during a cycle (12). Using these modifications, the geographical cycle of Davis can be given a new and much more useful life. Here we should use the system of description of landscape devised by Horberg (13). He split them into three basic groups, viz. : monocyclic landscapes formed under one cycle of erosion, compound landscapes formed under several cycles of erosion, and exhumed or resurrected (i.e. fossil) landscapes. Clearly these can be subdivided by his other two groups, the simple landscapes formed under one geomorphological process, and compound landscapes formed under more than one geomorphological process. This gives us at least six combinations, but it also emphasizes the vagueness of this term «process» as used in the past.

Using this nomenclature, we can achieve much greater precision in describing landscapes without resorting to a mathematical code which is boring to learn and can only be used to describe the gross features of the landscape, if it is not to become unduly long and cumbersome (14).

Conclusion

It is clear from the above discussion that the distribution of combinations of Tertiary and later climates is of considerable importance in resolving certain problems which have arisen in physical geography. An attempt has been made to show the probable distributions and nature of the changes in climate since the end of Tertiary times. It is based on limited knowledge and is obviously open to correction and improvement. It is hoped that it will cause just this, so that we may ultimately obtain a better understanding of the nature of our environment.

Comparing the landforms of the various palæoclimatic zones, there is a marked correlation between the occurrence of certain landforms and the various agents of denudation as would be expected. Likewise soils show a marked correlation with palæoclimates. The soils which are so difficult to classify and cause the complexity of the system in the Seventh Approximation (15), are produced by the various permutations and combinations of the agents of denudation and associated climates. It is therefore suggested that descriptive methods and systems of classification should be employed that emphasize these correlations. These should be the easiest to understand and to teach and should be easy to map.

Acknowledgments

The writer is indebted to Drs. R. M. Adams, C. Harris and C. Howell, of the University of Chicago, for help in collecting data for the map. Drs. K. Butzer and O. Løken critically read the manuscript and made helpful suggestions.

RÉSUMÉ

On reconnaît maintenant que les paléoclimats ont laissé leur trace dans le sol, sur la végétation et les paysages de diverses régions du monde. De nombreuses méthodes d'analyse, discutées et discutables, permettent de découvrir quels étaient les climats du Tertiaire et du Quaternaire, leur forme, leur influence et leur extension et ainsi de connaître l'évolution et les changements des paysages.

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