Journal of Environmental Technology 1(2) 2002 1 - 14

Defining Climatic Zones for Architectural Design in Nigeria: A Systematic Delineation

Dr. Olu Ola Ogunsote and Dr. (Mrs.) Bogda Prucnal-Ogunsote

Department of Architecture, Federal University of Technology, Akure

Abstract

This paper reviews existing definitions of climatic design zones in Nigeria including definitions based on natural vegetation, the definitions by the National Universities Commission and Nick Hollo, the Koppen system, the Atkinson system, the Martin Evans method, a method based solely on the Mahoney tables and the Hosni method based on the concepts of adaptation and set theory. A method for the systematic delineation of climatic zones for architectural design is proposed. The method is basically manual but a computer program, CLIZONE was designed in order to reduce some of its limitations. The proposed system produced nine different responses for the Nigerian reference stations used. These responses are used as the basis for proposing six design zones: the Coastal Zone, the Forest Zone, the Transitional Zone, the Savannah Zone, the Highland Zone and the Semi-Desert Zone. It is concluded that the data available are not sufficient for the accurate determination of the boundaries of these zones and the relativity of all definitions is reiterated. In this respect the open, adaptive and yet stable nature of the proposed system is emphasised.

The Need for Design with Climate

The need to design with climate has always been a major consideration in architecture. Vitruvius, in his *Ten Books on Architecture* drew attention to the importance of climate in architecture and town planning. Fitch (1971) pointed out the extravagant reliance by architects on recent environmental technologies and advocates, in consonance with the Building and Road Research Institute, Kumasi, "methods of building which will enable the building structure itself effect the desired environmental control" (Essien, 1968).

The search for such methods has been undertaken by several countries, as documented by Essien (1968), Fitch (1971), Lacy (1972 and 1977) and Hooper (1975). Contributions have also been made by the United Nations Department for Economic and Social Affairs (1971) and the United Nations Centre for Human Settlements – HABITAT (1984). The importance of finding such methods for Nigeria was stressed by Madedor (1980) when he expressed the need to provide "guidelines for design for the various climatic zones in the country".

The Need for a Systems Approach

Christopher Alexander (1964), in his *Notes on the Synthesis of Form*, pointed out that the many variables involved in contemporary architectural decision-making simply outrun the capacities of even the finest minds. Under such circumstances, according to Fitch (1971), "the electronic computer has inevitably become an important tool". This argument is buttressed by the fact that the very nature of the analyses involved in energy-conscious design encourages the use of computers (Ogunsote, 1991a). A systems approach may therefore help solve the problems faced by architects in developing countries who have tended to ignore methods of design with climate for various reasons, not least of which are:

- The dynamic nature of the design process.
- The considerable time and effort required, for which the architects receive no obvious extra remuneration.
- The lack of flexibility, the degree of complexity and the arguable ambiguity of some of the existing methods (Reynolds, 1980).
- Ignorance and lack of training and equipment.

Aims and Objectives of the Paper

This paper aims to:

- review the existing definitions of climatic zones in Nigeria as well as some methods of definition of climatic zones for architectural design applicable to Nigeria;
- analyse the applicability of the various methods to the systematic definition of climatic zones for architectural design in Nigeria;
- propose a method for the systematic delineation of climatic zones for architectural design in Nigeria;
- propose the climatic zones for architectural design in Nigeria using the proposed method.

Definitions of Climatic Zones

Climatic zones are defined for a better understand-ing of the workings of the global climatic system (Markus and Morris 1980). It is necessary in this respect to differentiate between climatic zones for agricultural purposes and climatic zones for architectural design. The former are usually closely related to vegetation and are not directly linked to human comfort needs. The definition of the latter stems from the fact that *climatic conditions and hence the requirements for thermal comfort are the basis for the selection of building form and building elements* such as size of windows, insulation value of roofs and walls and orientation. It is therefore possible, in the words of Evans (1980), "to determine the approximate boundaries where

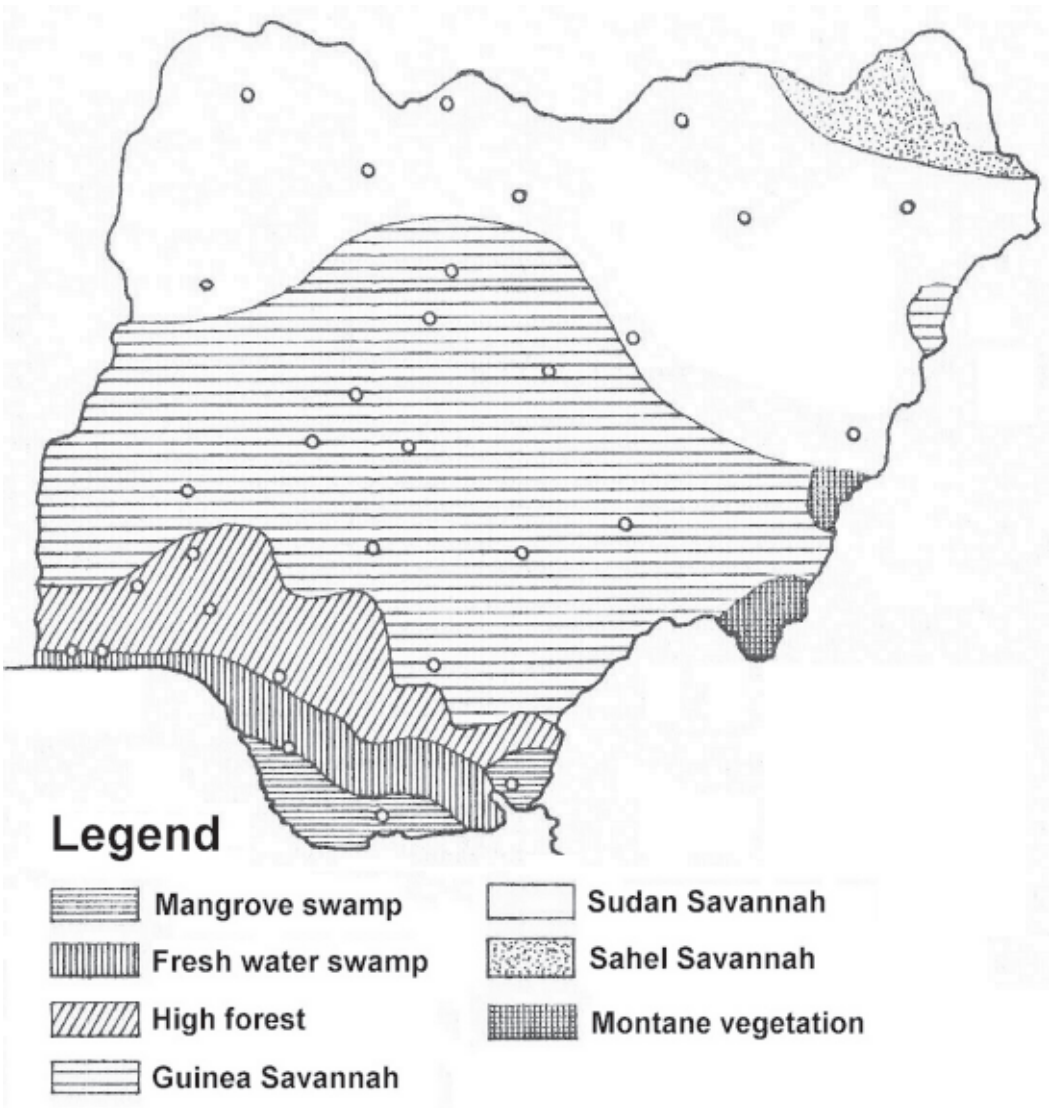

Figure 1: Vegetational types in Nigeria. Source: Iloeje, N. P. (1965). A New Geography of Nigeria.

a change in the climate and a change in thermal comfort requirements should be reflected in changed building form or changed building elements". These boundaries will effectively define the climatic zones for architectural design.

Zones Based on Natural Vegetation

Vegetation is rarely used on its own for classifying climatic design zones but most climatic classifica-tion systems relate to it (Evans, 1980). The logic of this is impeccable, since living vegetation reflects every nuance of climatic conditions throughout the year.

The Times Atlas of the world describes the characteristics of the main vegetation zones.[1] There are seventeen different zones and several sub-zones in the world. The system of classification is generalized and there is considerable variation within each zone or sub-zone caused by differences in topography, altitude, wind patterns and ocean currents.

There are certain difficulties experienced when defining climatic zones based on vegetation. One is the difficulty of defining boundaries, since there is usually considerable mixing of flora. Furthermore, the destruction of natural vegetation leads to a change in climatic conditions.

While the climatic zones for architectural design cannot be established solely on the basis of vegetation, a knowledge of the distribution of flora can be useful for comparative purposes. The vegeta-tional types in Nigeria are presented in Figure 1.

The Koppen System

The Koppen system of climate classification is generally accepted for the global evaluation of climatic zones. This system was first proposed in 1900, but it has been modified by several authors since, notable among which is Trewartha (1943).[2] The classification recognises seven major zones and several sub-zones (Ogunsote, 1990a). A major shortcoming of the system can be traced to its dependence on rainfall and temperature and as such, like classifications based solely on vegeta-tional cover, it does not necessarily relate to building design for thermal comfort (Evans, 1980). In fact, according to Olgyay (1963), the "classifications are not directly applicable to housing". This is linked to the absence of humidity, an important thermal comfort factor, in the classification.

The Atkinson System

This system is commonly used for the classification of hot climates in relation to building needs and it is discussed in detail by Koenigsberger *et al* (1974). It is the basis for the proposal by the United Nations (1971), of house and plan

Table 1: Summary of the characteristics of the Atkinson system of climate classification.

		Warm Humid	Warm-humid Island	Hot Dry Desert		Hot Dry Maritime Desert		Composite			Tropical Upland
				Hot	Cool			HD	WH	CD	
Air Temperature	Min.	21 - 27	18 - 24	24 - 30	10 - 18	23 - 30	10 - 18	21 - 27	24 - 27	4 - 10	10 - 13
	Max.	27 - 32	29 - 32	43 - 49	27 - 32	< 38	21 - 26	32 - 43	27 - 32	< 27	24 - 30
Humidity (%)		55 - 100	55 - 100	10 - 55		50 - 90		20 - 25 (dry) 55 - 95 (wet)			45 - 99
Precipation (mm)		2000 - 5000	1250 - 1800	50 - 155		Very low		500 - 1300			>1000
Sky Conditions		Fairly cloudy	Clear	Clear		Clear		Clear-overcast			Clear
Solar Radiation		Painful glare	Strong, direct	Direct, strong		Strong		Strong, direct			Strong, direct
Winds		Low velocity, freq. calms	Trade winds 6 - 7m/s	Local, hot, dusty		Local, coastal winds		Hot, dusty			Easterlies
Vegetation		Very luxuriant	Luxuriant	Sparse		Sparse		Sparse			Green
Special Conditions		Mosquitoes Rusting Rotting Thunderstorms	Cyclones Hurricanes	Dust and sand storms		Dust and sand storms		Dust and sand storms			Heavy dew fog, hail thunderstorms

Source: Koenigsberger et al (1974). Manual of Tropical Housing and Building.

Table 2: Climatic variation between the two climatic zones identified by the National University Commission.

Zone	Season	Air Temperature		Humidity %	Annual Rainfall (mm)	Wind (Km)
		Day °C	Night °C			
Northern	Hot Dry (Nov/Dec to April/May)	32 - 43	15 - 27	20 - 55		1 - 10
	Warm Humid (May/June to Sept)	27 - 32	24 - 27	55 - 95	500 - 1300	1 - 10
	Cool Dry (Sept/Oct to Nov)	18 - 27	4 - 15	20 - 55		1 - 10
Southern	Warm Humid (All year)	27 - 32	21 - 27	55 - 95	2000 - 5000	Calm to 10

Source: National Universities Commission (1977). Standard Guide for Universities.

Table 3: Summary of the analysis of the validity and logic of the NUC classification of climatic zones for architectural design in Nigeria.

Reference station	% concurrence		Method 1		Method 2		Final Zone
	North	South	North	South	North	South	
Abuja	38	37	●	○	●	○	□?
Bauchi	73	26	□	○	○	○	○
Benin-City	30	94	●	●	●	●	●
Bida	73	41	□	○	○	□	?
Calabar	26	97	●	●	●	●	●
Enugu	30	55	●	□	●	□	?
Gusau	72	26	□	○	○	○	○
Ibadan	68	56	□	□	○	□	□
Ibi	73	40	□	○	○	□	○?
Ikeja	27	62	●	□	●	●	●
Ilorin	62	47	□	○	○	□	?
Jos	31	30	●	○	●	○	?
Kaduna	72	33	□	○	○	○	○
Kano	70	27	□	○	○	○	○
Kastina	67	23	□	○	○	○	○
Lagos	24	66	●	□	●	●	●
Lokoja	62	54	□	□	○	□	□
Maiduguri	70	24	□	○	○	○	○
Markurdi	34	47	●	○	●	□	?
Minna	46	36	●	○	□	○	?
Nguru	65	20	□	○	○	○	○
Ondo	30	48	●	○	●	□	?
Oshogbo	63	50	□	□	○	□	□
Port Harcourt	29	93	●	●	●	●	●
Potiskum	70	28	□	○	○	○	○
Sokoto	73	27	□	○	○	○	○
Warri	27	91	●	●	●	●	●
Yelwa	76	36	○	○	○	○	○
Yola	80	31	○	○	○	○	○
Zaria	74	30	□	○	○	○	○

Legend: ○ Northern zone (composite). ● Southern zone (warm-humid climate).
□ Transitional zone. ? Not clear.

types for the various climates. This classification exhibits a bias towards certain climatic types and it is not applicable to cold climates (Evans, 1980). The characteristics of the Atkinson system of climate classification are presented in Table 1 after Koenigsberger et al (1974).

National Universities Commission Method

The National Universities Commission (1977) recognises two climatic zones in Nigeria, the Northern zone and the Southern zone (Table 2), though a transitional zone is also mentioned. A closer look at this method however revealed that the NUC based the division of the country into climatic design zones on the Atkinson system of climate classification. The southern zone actually corresponds to the warm humid climate and the northern zone to the composite or monsoon climate. The differences can be found in the specification of the various seasons and slight adjustments in the temperature and humidity limits.

The authors tried to use the proposed method for a systematic classification and wrote a computer program, NUC, in FORTRAN to do the necessary calculations. The methodology, analyses and results are discussed by Ogunsote (1990a). The following general observations were made from the analyses, a summary of which is presented in Table 3:

- There was not even one single case of a 100% concurrence with the zoning criteria.
- The rainfall limits seem rather arbitrary and contributed much to the low degree of concurrence with the zoning criteria.
- Even when a high degree of latitude was permitted, it was not possible to definitely determine the zones in which about 30% of the reference stations lie.

From the foregoing it can be argued that the NUC definition was not based on an in-depth analysis. Furthermore, the logical shortcomings of the method indicate that it may be unsuitable for the delineation of climatic zones for architectural design in Nigeria.

The Martin Evans Method

This method was proposed after an analysis of different existing methods, including the Koppen system, the Atkinson system and the Mahoney table method (Evans, 1980). He defined seven zones in terms of differences in the air temperatures, the humidity, the rainfall, the sky conditions, the wind and other conditions. He further related these climates to similar climates and sub-climates and identified the corresponding Koppen classifications for easy cross-referencing.

In proposing the seven climatic types, Evans recognised the need to define zones in terms of thermal comfort for building design but he pointed out the relativity of standards and the importance of relating to social and economic contexts especially as regards traditional or

Table 4: The climatic types indicated by program MOTOLA on the basis of the differences in design recommendations.

Reference stations	Climatic types												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Abuja									●				
Bauchi						●							
Benin-City	●												
Bida								●					
Calabar	●												
Enugu			●										
Gusau													●
Ibadan		●											
Ibi							●						
Ikeja	●												
Ilorin				●									
Jos										●			
Kaduna									●				
Kano						●							
Kastina												●	
Lagos	●												
Lokoja				●									
Maiduguri							●						
Markurdi					●								
Minna								●					
Nguru											●		
Ondo	●												
Oshogbo		●											
Port Harcourt	●												
Potiskum						●							
Sokoto							●						
Warri	●												
Yelwa						●							
Yola							●						
Zaria									●				

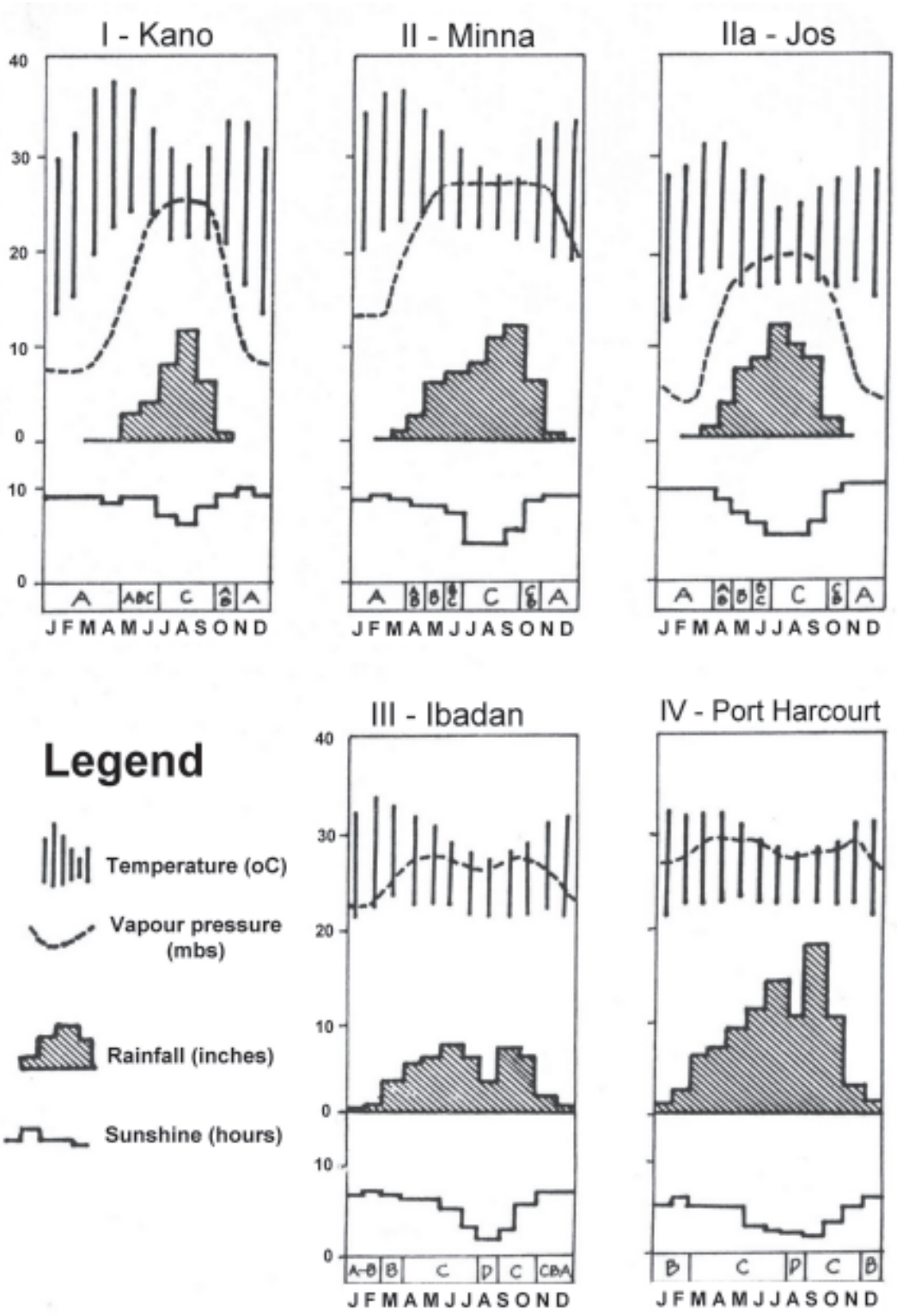

Figure 2: Characteristics of the climatic regions in Nigeria according to Nick Hollo / B. J. Garnier.

conventional forms of construction. The method, though based on the Atkinson system proposes more realistic limiting values of rainfall, temperature and humidity. The descriptive nature of the method however makes it difficult to systematically and uniquely identity zones with the aid of only very basic climatic data. This does not however negate the usefulness of the method in understanding the subtleties of the different climatic design zones.

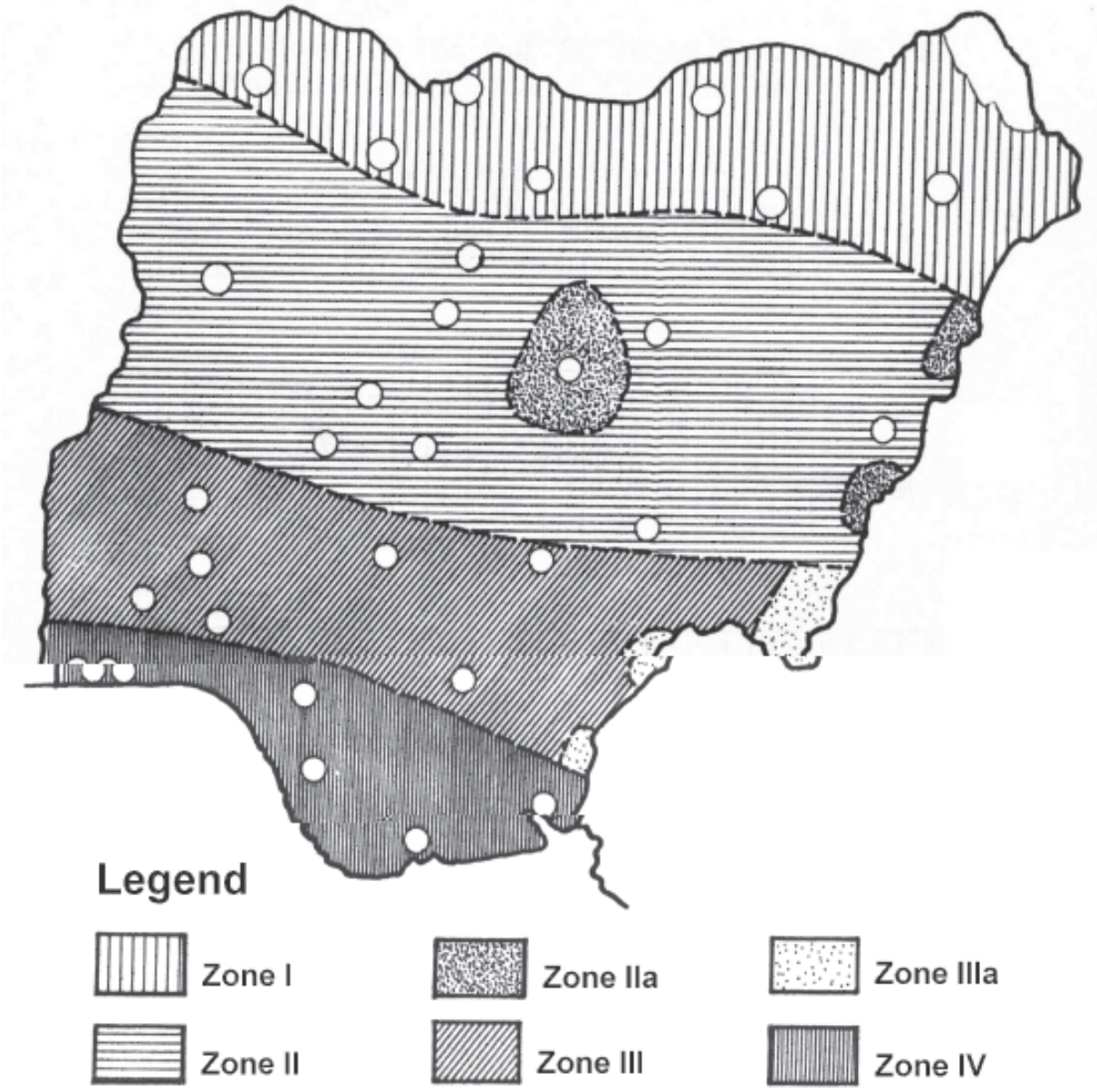

Figure 3: The climatic regions for bioclimatic design in Nigeria according to Nick Hollo.

The Mahoney Tables Method

A detailed system of classification was developed by Koenigsberger, Mahoney and Evans and was presented by the United Nations (1971) and Koenigsberger *et al* (1974). The main advantage of this system is that climatic zones are defined in terms of building needs such as orientation, spacing, air movement, openings and construction of walls and roofs. The method makes use of seven tables. The authors wrote a computer program, MOTOLA, to simulate the Mahoney tables (Prucnal-Ogunsote *et al*, 1985). A more user-friendly version of the program, Klimax, was written in 1989 for the National Primary Education Commission (Ogunsote, 2001). This program gave a set of recommendations which indicated 13 different climatic zones. (Table 4). At this stage shortcomings of the Mahoney tables were detected and it became obvious that they should be revised to incorporate the effect of the wind and to remove logical errors (Celik, 1973).

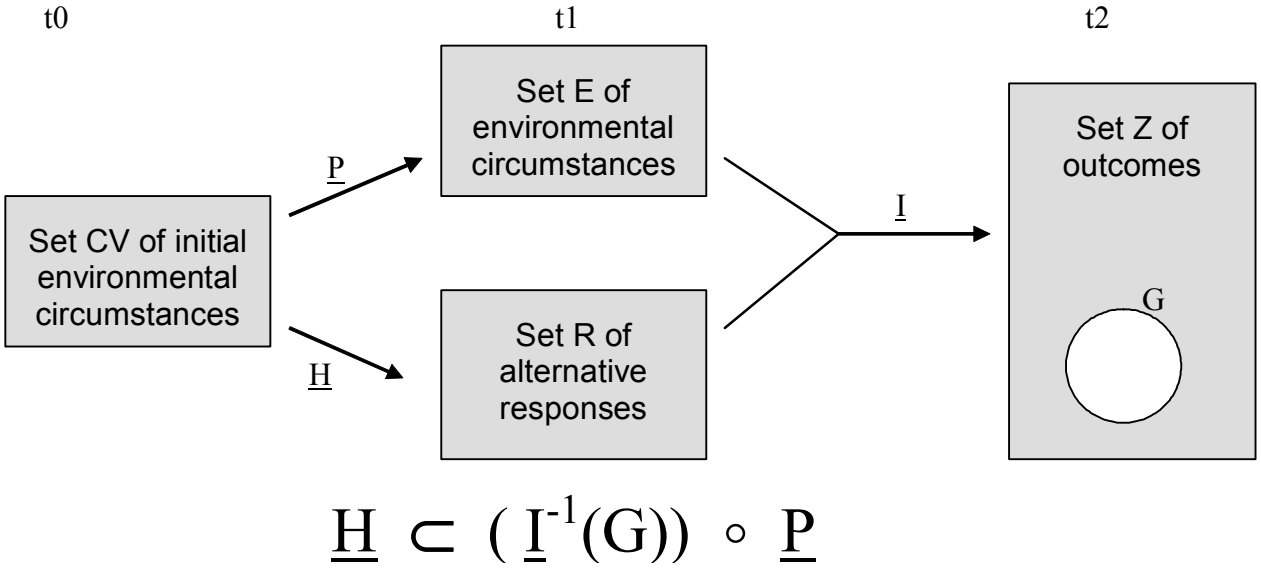

Figure 4: The essentials of directive correlation after Ashby. Source: Ashby, W. R. (1967). The set theory of mechanism and homeostasis.

The Nick Hollo Classification

Nick Hollo defined four zones in Nigeria after Garnier (1967) but he expanded on this definition by identifying sub-regions within these major zones (Figures 2 and 3). The method is appealing and depends heavily on descriptions and imagery.[3] However, when an attempt was made to apply the method to locations identified only by the most basic climatic data, its general and unspecific nature became evident.

The Hosni Method

This method is based on the concept of adaptation and set theory. According to Sommerhof (1968), adaptive systems are defined as systems possessing "the ability to react to their environment in a way that is favourable, in some sense, to the continued operation of the system". Ashby (1967) defined a behaviour as being adaptive if it maintains the essential variables within limits. Sommerhof (1950 and 1968), saw the notion of adaptation when applied to systems as referring to the "*appropriate-ness* which organic activities show in relation to the needs of the organism, and to the *effectiveness* with which organisms meet the demands made upon them by their environment". Appropriate response links four spatio-temporally distinct elements:

- events which act as stimuli (S_{t0})
- the response (R_{t1})
- the environmental circumstances (E_{t1})
- the goal (G_{t2}).

Sommerhof used this model to define effective response, appropriate response and adaptation (Sommerhof, 1968). Adaptation is defined as "a form of non-accidental appropriateness" and adaptive behaviour as possessing the "typical character of involving an objectively biased and non-accidental occurrence of appropriateness and success". Every adaptation is therefore an instance of directive correlation as shown in Figure 4 (Ashby, 1967).

Hosni (1978) used this definition to propose a method of defining the relation from the set of climates of selected locations in Egypt to the set of possible alternative architectural responses such that given "any element in the first set, one and only one element in the second set results". After considering the procedures of Olgyay (1963), Givoni (1969) and Mahoney, he decided upon the Mahoney method and wrote a FORTRAN program, SPECOO, to do the necessary calcula-tions.

The Proposed Method

The general inconsistency of the zones obtained when using different methods of climate classifica-tion is obvious and disconcerting. Schiller however pointed out that the essence

Table 5: The set E' of environmental circumstances.

	Remedial Actions Number of months of the year					
Locations	H1	H2	H3	A1	A2	A3
Abuja	6	0	5	6	3	0
Bauchi	3	0	2	9	2	0
Benin-City	12	0	6	0	0	0
Bida	6	0	3	6	3	0
Calabar	12	0	7	7	0	0
Enugu	8	0	4	4	0	0
Gusau	3	0	2	9	1	0
Ibadan	10	0	0	2	0	0
Ibi	6	0	1	6	2	0
Ikeja	12	0	3	0	0	0
Ilorin	7	0	1	5	0	0
Jos	1	4	4	7	0	0
Kaduna	5	0	3	7	1	0
Kano	3	0	2	9	2	0
Kastina	2	0	1	10	4	0
Lagos	12	0	3	0	0	0
Lokoja	7	0	1	5	0	0
Maiduguri	3	0	1	9	3	0
Markurdi	7	0	2	5	0	0
Minna	5	0	3	7	5	0
Nguru	1	0	1	11	4	0
Ondo	12	0	3	0	0	0
Oshogbo	10	0	0	2	0	0
Port Harcourt	12	0	6	0	0	0
Potiskum	3	0	2	9	3	0
Sokoto	3	0	1	9	5	0
Warri	12	0	7	0	0	0
Yelwa	6	0	2	6	2	0
Yola	5	0	1	7	2	0
Zaria	4	0	3	8	2	0

Table 7: The relation from the set of climates to the set of possible alternative architectural responses.

Reference stations	Set of possible alternative architectural responses								
	r(1)	r(2)	r(3)	r(4)	r(5)	r(6)	r(7)	r(8)	r(9)
Abuja						●			
Bauchi					●				
Benin-City	●								
Bida						●			
Calabar	●								
Enugu				●					
Gusau					●				
Ibadan		●							
Ibi					●				
Ikeja	●								
Ilorin			●						
Jos							●		
Kaduna						●			
Kano					●				
Kastina									●
Lagos	●								
Lokoja			●						
Maiduguri					●				
Markurdi			●						
Minna						●			
Nguru								●	
Ondo	●								
Oshogbo		●							
Port Harcourt	●								
Potiskum					●				
Sokoto					●				
Warri	●								
Yelwa					●				
Yola					●				
Zaria						●			

which every definition tries to state is simply the point which it is for the time being important to elucidate. "It follows that the essences and definitions of things are necessa-rily plural, variable, relative, and never absolute".[4] Evans (1980), also pointed out the complexity of the relation between climate and building design which is further compounded by the fact that cost, technology and social custom will affect almost all design decisions. The need to define zones and regions despite these difficulties is however generally accepted (Chapman, 1977; Learmonth *et al*, 1971).

The proposed system was developed along lines similar to those followed by Hosni (1978) and it uses the Sommerhof definition of adaptation to establish the relation from the set of climates to the set of possible alternative architectural responses such that given any element in the first set, one and only one element in the second set results.

A revised version of the Mahoney tables was used for the definition. When this revised version was compared with the logic of the Hosni computer program SPECOO, it was found that the revised elements were very similar, though

Table 6: The set E of environmental circumstances.

	Remedial actions (number of months of the year)					
	H1	H2	H3	A1	A2	A3
e(1)	11 - 12	0 - 1	3 - 12	0 - 1	0	0
e(2)	10	0 - 1	0	2	0	0
e(3)	3 - 9	0 - 1	1-2	3 - 5	0	0
e(4)	3 - 9	0 - 1	3 - 12	3 - 5	0	0
e(5)	3 - 9	0 - 1	3 - 12	3 - 5	0	0
e(6)	3 - 9	0 - 1	3 - 12	6 - 10	1 - 12	0
e(7)	1	2 - 12	3 - 12	6 - 10	0	0
e(8)	1	0 - 1	1-2	11 - 12	1 - 12	0
e(9)	2	0 - 1	1-2	6 - 10	1 - 12	0

not identical. The climatic data used are the same as those required for the Mahoney tables, except for the wind data, which were omitted. The climatic data for the reference stations gave the set of initial environmental circumstances, CV. The Mahoney tables 1 to 4 were used to determine the humid and arid indicator totals with the aid of the table for the determination of the comfort limits as well as the table for the determination of the humid and arid indicators. The humid and arid indicator totals obtained gave the set E' of environmental circumstances (Table 5).

Table 8: Table of possible alternative architectural responses.

			Alternative responses								
			r(1)	r(2)	r(3)	r(4)	r(5)	r(6)	r(7)	r(8)	r(9)
Layout	A1	Buildings oriented on East-West axis.	●	●	●	●	●	●			●
	A2	Compact courtyard planning.							●	●	
Spacing	B1	Open spacing for breeze penetration.	●								
	B2	Open spacing, protect from hot and cold winds.		●	●	●	●	●			
	B3	Compact planning.							●	●	●
Air movement	C1	Rooms single banked, permanent provison for air movement.	●	●	●	●	●	●			
	C2	Double-banked rooms with temporary provision for air movement.							●	●	●
	C3	No air movement required.									
Size of Openings	D1	Large, 40 - 80% of North and South walls.	●								
	D2	Medium, 25 - 40 % of wall area.		●	●	●					
	D3	Composite, 20 - 35% of wall area.					●	●	●		●
	D4	Small, 15 - 25 of wall area.								●	
Positions of Openings	E1	Openings in North and South walls at body height on windward side.	●	●	●	●	●	●			
	E2	Openings in North and South walls at body height on windward side and on internal walls.							●	●	●
	E3	Has no climate-related value.									
Protection of openings	F1	No special protection necessary.									
	F2	Exclude direct sunlight.		●	●		●			●	
	F3	Protect from rain and direct sunlight.	●			●		●	●		●
	F4	Provide protection from rain.									
Walls and floors	G1	Light: low heat capacity.	●	●							
	G2	Heavy: over 8 hours time lag.			●	●	●	●	●	●	●
Roofs	H1	Light: reflective surface and cavity	●	●							
	H2	Light and well insulated.			●	●					
	H3	Heavy: over 8 hours time lag.					●	●	●	●	●
Outdoor sleeping	I1	No space for outdoor sleeping required.	●	●	●	●			●		●
	I2	Space for outdoor sleeping required.					●	●		●	
Rains protection	J1	Adequate drainage for rain water.			●		●			●	
	J2	Protection from heavy rain needed.	●			●		●			●
	J3	No protection from heavy rain needed.		●					●		

The revised Mahoney table 5 which replaces the former Mahoney tables 5 and 6, was used to analyze the set E' of environmental circumstances. This gave the set E of environmental circumstances (Table 6), such that each and every member of the set E' of environmental circumstances corresponds to one and only one member of the set E of environmental circumstances. Next, the relation P from CV, the set of initial environmental circumstances to E, the set of environmental circumstances was defined. Finally, the relation H from CV, the set of initial environmental circumstances, to the set of possible alternative architectural responses was determined (Table 7).

This is basically the proposed system with the computerization option left out. Thus when basic climatic data is given for any location in Nigeria the proposed system can be used to determine the climatic design

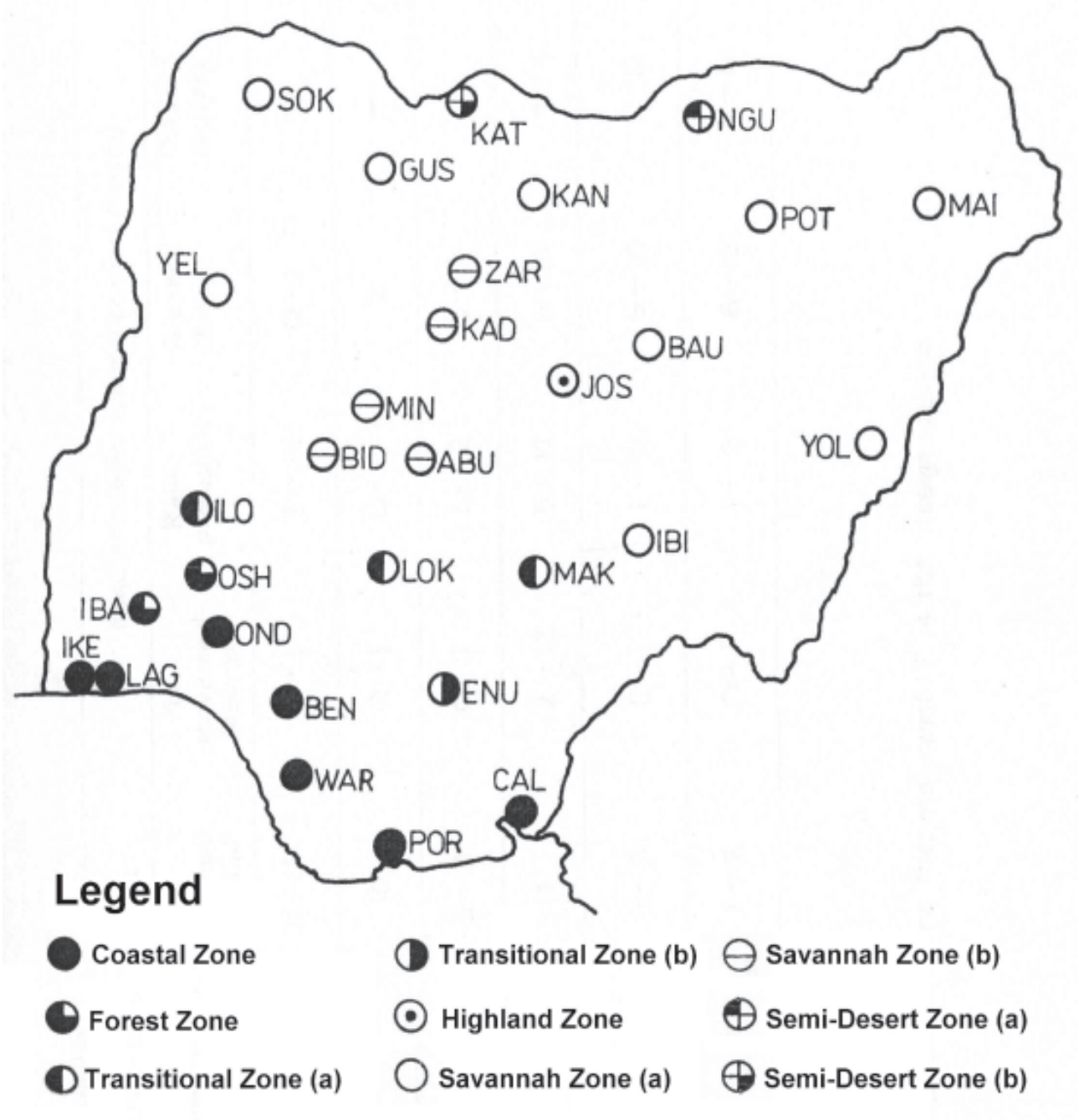

Figure 5: The proposed climatic zones for architectural design in Nigeria.

zone in which the location lies by taking the following steps:

- Use the Mahoney tables 1 to 4 to manually determine the humid and arid indicator totals.
- Use these indicator totals and the set of environmental circumstances (Table 6) to determine the corresponding member of this set.
- Determine the adapted response with the aid of Table 8.
- If required, obtain the design recommendations manually from the revised Mahoney table 5 using the humid and arid indicator totals.

The indicated response will uniquely identify a climatic zone containing only locations giving the same response. A computerisation of this method, CLIZONE, effectively reduced the limitations:

- of climatic data (Ogunsote, 1990b; 1991b);
- imposed by the method used to determine the relationship between climatic conditions and building requirements;
- of the number of possible responses;
- imposed by the tendency to enforce rigid geographical boundaries of design zones.

The proposed method of systematic delineation of climatic zones for architectural design in Nigeria thus has the following form from a practical viewpoint.

- Inform CLIZONE of the station you want to analyze, stated as the name of the location and the period over which the data were recorded. If the data are not available, enter them using one of the subroutines named CLIDATA (Ogunsote, 1991b).
- CLIZONE does all the necessary computations and comparisons and interactively presents, among others, the indicator totals, the response and the design recommendations. A printed report of the analysis is automatically produced.

The Proposed Climatic Zones

The computer program, CLIZONE, was written in FORTRAN by the authors for the determination of the response adapted to given environmental circumstances. The program was implemented on the CDC Cyber 72 under the NOS operating system at the Iya Abubakar Computer Centre, Ahmadu Bello University, Zaria, Nigeria. The climatic data used - long-term averages of usually over 20 years - were presented by Prucnal-Ogunsote *et al* (1985). The responses obtained are presented in Tables 7 and 8. The nine responses obtained were used to propose six zones (Figure 5):

Coastal Zone:		response 1
Forest Zone:		response 2
Transitional zone	subzone a:	response 3
	subzone b:	response 4
Savannah Zone	subzone a:	response 5
	subzone b:	response 6
Highland Zone:		response 7
Semi-Desert Zone	subzone a	response 8
	subzone b:	response 9

The Semi-Desert Zone was established mainly for convenience since only two stations fall within the zone and the design recommendations for each are different. In the Transitional and Savannah Zones, the far-reaching similarities between responses 3 and 4 as well as 5 and 6 respectively were used as the basis for definition (Ogunsote, 1993).

Conclusion

The definition of climatic zones for architectural design in Nigeria is misleadingly apparent. Divisions of the country into southern and northern regions are obviously simplistic and lacking in scientific conviction. More elaborate methods are capable of forging scientific relations between the climate and building design but this environmental determinism is achieved through ever-increasing complexity. In the final analysis, it is realised that it is impossible to absolutely delineate climatic design zones, since all definitions are necessarily plural and relative. The proposed system is open and adaptive, yet stable. The locations lying in the different climatic design zones have been identified (Figure 5) but the limited data available do not allow for the establishment of boundaries.

Notes

1. See Table 5.1 in Evans (1980) showing Plate 5 of the Times Atlas of the World, Comprehensive Edition, London 1968.
2. Trewartha “offered modifications of these divisions based on isotherms of the coldest months” and established zero degree Celsius as the limit below which

special building requirements may become necessary.

3. All the information presented on the Nick Hollo method of climate classification was obtained from the handouts he prepared for students while he was a lecturer in the Department of Architecture, Ahmadu Bello University, Zaria, in the late 1970's. Mr. Nick Hollo had remarkable talents of graphic expression and much of the information in the handouts was contained more in the form of presentation than the content.
4. This quotation, after F. C. Schiller, was obtained from Ackoff, R. L. (1962). *Scientific Method*. John Wiley and Sons, New York. p 147.

References

Ackoff, R. L. (1962). *Scientific Method*. John Wiley and Sons, New York.

Alexander, C. (1964). *Notes On the Synthesis of Form***.** Harvard.

Ashby, W. R. (1967). "The Set Theory of Mechanism and Homeostasis". **In:** *Automation Theory and Learning Systems*. Ed. D. J. Stewart. Thompson Book Company, Washington.

Celik, A. P. (1973). Discussion on the Applicability of the Mahoney Tables for Bioclimatic Building Design to Turkey. Building Research Institute, STRCT. Ankara.

Chapman, G. P. (1977). *Human and Environmental Systems - A Geographer's Appraisal*. Academic Press, London.

Essien F. (1968). "Climatic Data for Thermal Environmental Design in Ghana". **In:** *Research Note No. 21, Building and Road Research Institute*, Kumasi, Ghana.

Evans, M. (1980). *Housing, Climate and Comfort*. The Architectural Press, London.

Fitch. J. M. (1971). *American Building - The Environmental Forces That Shape It*. New York.

Garnier, B.J. (1967). *Weather Conditions In Nigeria*. Mcgills University Press. Montreal.

Givoni, B. (1969). *Man, Climate and Architecture*. Elsevier, London.

Hooper, C. (1975). *Design For Climate: Guidelines For The Design of Low Cost Houses For The Climates of Kenya*. Housing Research and Development Unit, University of Nairobi, Nairobi, Kenya.

Hosni, S. H. B. (1978). *Studies In Egyptian Architecture. Volume One. Climate and Architecture: A National Evaluation*. Department of Architecture, Faculty of Engineering, Alexandria University, Egypt.

Lacey, R. E. (1972). *Survey of Meteorological Information for Architecture and Building*. Current Paper 5/72. Building Research Station, Watford, United Kingdom.

Lacey, R. E. (1977). *Climate and Building In Britain. A Review of Meteorological Information Suitable for Use In The Planning, Design, Construction and Operation of Buildings*. Building Research Establishment Report, Her Majesty's Stationery Office, London.

Learmonth, A., Sarre, P. and Edge, G. (1971). *Evolution or Revolution in Geography?* The Open University Press, Buckinghamshire.

Madedor, A.O. (1980). "Building Research in Nigeria: The Past and the Future". A paper presented at the Third International Conference on Housing. Theme: Fifty Years of Housing Development in Africa: Lessons for the Future. Held in Kaduna, 17-24 August.

Markus, T. A. and Morris, E. N. (1980). *Buildings, Climate and Energy*. Pitman Publishing Limited, London.

National Universities Commission (1977). *Standards Guide for Universities*. National Universities Commission, Lagos.

Ogunsote, O. O. (1990a). "Architectural Design With Nigerian Climatic Conditions In View: A Systems Approach". Doctoral Dissertation, Department of Architecture, Ahmadu Bello University, Zaria.

Ogunsote, O. O. (1990b). "Data Storage and Retrieval for Urban and Building Climatology In Africa". **In**: *African Urban Quarterly* special issue on Urban and Building Climatology, Vol. 5, No. 1, pp 9-13, World Meteorological Organisation (WMO), Nairobi, Kenya.

Ogunsote, O. O. (1991a). "Computer Assessment of Architectural Design" **In:** *Habitat International*, Vol. 15, No. 4, Pergamon Press, London.

Ogunsote, O. O. (1991b). Notes on Computerised Storage of Climatological Data for

the Architect. **In:** *Climate and Human Settlements - Integrating Climate into Urban Planning and Building Design in Africa***.** United Nations Environment Programme (UNEP), Nairobi, Kenya.

Ogunsote, O. O. (1993). *An Introduction to Building Climatology - A Basic Course for Architecture Students*. Ahmadu Bello University Press, Zaria.

Ogunsote, O. O. (2001). "Klimax: A Computer Program for Climatic Site Analysis". Paper presented at the Valedictory Conference of the Association of Architectural Educators in Nigeria (AARCHES), Federal University of Technology, Akure.

Olgyay, V. (1963). *Design With Climate - Bioclimatic Approach To Architectural Regionalism*. Princeton University Press, Princeton, New Jersey.

Prucnal-Ogunsote, B. and Ogunsote, O. O. (1985). Program MOTOLA: A Computerisation of the Mahoney Tables for the Determination of Architectural and Planning Design Recommendations Based on Climatic Data. Research Report of the Department of Architecture, Ahmadu Bello University, Zaria.

Reynolds, R. A. (1980). *Computer Methods For Architects*. The Butterworths Group.

Sommerhof, G. (1950). *Analytical Biology*. Oxford University Press, London.

Sommerhof, G. (1968). "Purpose, Adaptation and Directive Correlation". **In**: *Modern Systems Research for the Behavioural Scientist*. Ed. Walter Buckley. Aldine Publishing Company, Chicago.

Trewartha, G. T. (1943). *An Introduction to Weather and Climate*. McGraw-Hill Book Company, New York.

United Nations (1971). *Design of Low -Cost Housing and Community Facilities. Volume I, Climate and House Design*. Department of Economic and Social Affairs, New York.

United Nations Centre For Human Settlements - HABITAT (1984). *Energy Conservation In The Construction And Main-tenance of Buildings. Volume One: Use of Solar Energy and Solar Cooling In The Design of Buildings In Developing Countries*. UNCHS--HABITAT. Nairobi, Kenya.

Vitruvius, M.P. (1960). *The Ten Books On Architecture*. New York.