DROUGHT CHRONOLOGY DATING IN THE LAKE CHAD BASIN (NIGERIA COMMAND)

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Abstract

That the notorious Sahelian drought (1968-1973) of Sahelo-Sudan Sub-Sahara was not unique has been established as a chronological sequence of past droughts in the Lake Chad basin.[1] Historical drought chronology is traceable to written evidence. Pre-historical evidence of dune landscapes in the Nigerian Lake Chad basin may be located on the ground or in satellite imagery. Nevertheless, the 1980s drought continuum has the characteristic of being unique in the context of its severity and longevity. Some possible forcing agencies are considered as being meterological, while anthropogenetically-induced drought-desiccation is also of concern. Recently it has been indicated that a linkage between sea-surface temperatures and sahelian droughts seems to be of significance.

Keywords: palaeo-climate, former extension of the Lake Chad basin, drought chronology, climatic change, Nigeria.

1 A first version of this paper has been delivered during the Mega-Chad Seminar "Dating and chronology in the lake Chad basin" (Bondy, ORSTOM, 1989).

1. EPISODIC DROUGHTS IN THE SAVANNA ECOSYSTEM

Drought is accepted as endemic to the global Savanna ecosystem, in the context of its seasonal incidence. That the human communities have for centuries adapted their life-style to both seasonal and secular drought incidence throughout the Sahel and Sudan Savanna has been well-established. Within the Lake Chad basin itself, empires have thrived in the drought climate scenario, the Nigeria command sector of the Lake Chad basin included. The now notorious Sahelian drought (1968-1973) with its disastrous impact upon failure of crops and tremendous loss of animal and human population, awakened the global scientific community to this predicament. The immediate response was Africa Drought Symposium in London 1973 (DALBY et al. 1977) which deliberated upon the causes of this severe climatic disaster. It was concluded that even during the present century secular drought episodes had been witnessed in the Sahelo-Sudan Savanna ecosystem. Consequential to the Sahelian drought, evidence had been gathered of increased on-going desertification processes. For the second time the global scientific community was summoned to yet another meeting, the United Nations Conference on Desertification (UNCOD) in Nairobi 1977.

Measures were decided upon for combating desertification as well as provide relief to the affected communities. However, with the return of the rains in 1974 and in the years immediately thereafter and with the acceptance therefore of a seeming "normalcy" in the rainfall regimes in Sahelo-Soudan Savanna, complacent attitudes to the proposed measures replaced the urgency with which the UNCOD was summoned. Then, it was that for the second time the global community was rudely awakened to the most unexpected episodic droughts of the 1980s, very much with us even now in contemporary time. Again, the agricultural communities of the Lake Chad basin witnessed with growing concern, the dwindling of the life-giving waters of the Lake, when in 1984 and as related to the severe environmental drought, the Lake divided itself into two permanent sectors. This phenomenon of a divided Lake was not unique in this century since previous similar episodes were witnessed (THAMBYAHPILLAY 1983a). However, the scenario of the northern lake-lobe completely drying up for this long period of time is unique. Yet again, the global scientific community was summoned by the Lake Chad Basin Commission in 1987, to the International symposium on "The Water Resource of the Lake Chad Basin: Management and Conservation" in N'Djaména (THAMBYAHPILLAY 1987a).

2. LAKE CHAD BASIN: NIGERIA COMMAND

2.1. Geographical environment

The Nigeria command of Lake Chad basin (Fig. 1A) is seen as the western attentation of the larger "basin" and extends nearly 750 km from the shore of the lake.

Edged in by the Nigeria/Niger Republic border in the north and elsewhere in the south by the Jos-Biu Plateau and the Mandara mountain range, a territorial extent of approximately 200,000 km^2 may be recognized. The basin, constituted of the Chad formation, slopes imperceptibly northeastwards to the Lake and is drained by the Komadugu Yobe (north) and the Yedseram-Ngadda river system (south) trending towards the Lake.

2.2. Pre-historic palaeo-climatic chronology

The contemporary landscape bears mute testimony to palaeo-landscapes alternating between the effects of hyper-aridy (dune phase) and super-humidity (pluvial phase). Pre-dating to nearly 50,000 years BP through radiometrically dated evidence, a series of arid and pluvial scenarios may be identified (THAMBYAHPILLAY 1983a). The maximum advance of the middle Wisconsin glaciation dated to approx. 55,000 years BP relates to the earliest identifiable palaeo-climatic chronology of arid phase I. This phase was followed immediately thereafter for nearly 20,000 years by a pluvial phase (45,000-25,000 years BP) related to the Upton Warren Interstadial. Correlated to this pluvial episode is the support for an enlarged lake. While it was to the 10,000-8,000 years BP enlarged lake that the term *Megachad* was first assigned (MOREAU 1963), it seemed appropriate to identify this 45,000-25,000 BP pluvial phase as *Megachad I* (THAMBYAHPILLAY 1983a). The contemporary landscape does not provide evidence of this palaeo-climate. However, the palaeoclimate that followed *Megachad I* dated to c. 25,000-12,5000 years BP and related to the maximum advance of the Wisconsin-Wiechselian glaciation (18,000 years BP) has left copious evidence in the present Nigeria command lake basin. It was this hyper-arid palaeo-climate (*arid phase II*, THAMBYAHPILLAY 1983a) which was appropriately designated the "Erg of Hausaland" (GROVE and WARREN 1958). The fossil dunefields were aligned ENE/WSW longitudinal (sief) dunes and NNW/SSE, transverse dunes. Lake Chad would have dried up and become a dune-landscape. These palaeo-dunes are seen to this day as submerged dune-islands and archipelagos of the lake. These "erg" dunefields have in recent years become "destabilized and mobile" consequent upon cultivation, human settlement and clearance for highways.

Then it was, that arid phase II was followed by a most remarkable pluvial phase which significantly modified the hydrology of the Nigeria command basin, so much that its effects are to be witnessed to this day. This was also the pluvial Sahara phase, when lakes became established and fishing villages and harpoons carbon-dated appropriately. A Megachad of the magnitude of between 350,000 and 400,000 km^2 in extent, dominated the palaeo-landscape extending towards Tibesti mts. (north) and confined in the west and south by its shoreline (Fig. 1B).

This palaeo-lake would have risen to 320 m (compared to the until recently established level of 282 m). *Megachad II* overflowed southward across the Gautiot Falls and eastwards to the Bahr el Ghazal to the Bodela depression. The palaeo-strandline of Megachad II is today traceable via the Bama Ridge (Maiduguri, Borno State) as a 12 m ridge and is seen as interrupted stretches running northwestwards from Maiduguri to the northern border of Nigeria (the strandline has been traced farther away in the Lake Chad basin: Chad and Cameroon Republics).

Next, a short sub-arid/sub-humid phase has been recognized and dated c. 7,000 years BP - correlated with the contemporary Drays glacial advance (THAMBYAHPILLAY 1983a) - a brief interlude, when the Tibesti streams failed to reach the lake.

The pluvial phase that followed immediately thereafter (and dated c. 6,500 years BP) has now been established as having been related to increased precipitation over a vast east-west region, from Senegal/Mauritania to Chad/Sudan. Aptly named *Megachad phase III* (THAMBYAHPILLAY 1983a), the palaeo-lake did not rise to the same level as its predecessor (Megachad II) but produced a lagoon phase. A 7 m sandy ridge named Ngelewa Ridge is traceable west of the lake and up to Arege.

The contemporary climatic scenario designated *arid phase III* is dated to c. 4,500 years BP, when the present-day Sahara desert became established. Hence also it is, that the Nigeria command of Lake Chad basin acquired the contemporary climatic scenario of the Sahel and Sudan regimes, characterised by semi-aridity and seasonally dominated drought regimens.

The origin of the Saharan desiccation to 4,500 years BP relates to the Tassili rock frescoes revealing the change from a hippopotamus (lakes) and rhinoceros (grassland) based scenario yielding to the giraffe and the camel. The Sahara desert thus diminised to its present confines. The contemporary climatic scenario thus would constitute arid phase III with historical evidence of a fluctuational pattern and humid phases.

2.3. Historical climate chronology

It is in the context of the prevailing debate over whether the contemporary scenarios of severe and prolonged droughts during this century relate to a fundamental climatic change or simply a fluctuational phenomenon that it becomes necessary to assess the evidence from historical sources. Some attempts have been made to gather the evidence (NICOLSON 1980a, THAMBYAPILLAY 1984b).

In the *Borno Chronicles (*URVEY 1949) may be noted references to socio-economic and political facets of life in the Nigeria command of the lake basin viz. good harvests, prosperity, famine-less periods, years of good rule undisturbed by agitation and similar events. In some instances, the evidence to climatic scenarios is clear. A major famine, for example, the mention of a famine lasting seven years (1681-1687) and extending beyond the basin to Borno, Tibesti, Kanem, Senegambia, Upper Volta, Mauritania, Dahomey (Benin) has been attributed to the association with the biblical reference to alternating seven year periods of famine and prosperity. A drought-famine scenario in the Sudan has been reported from 1680-1692 (NICOLSON 1980a). A long-term fluctuational picture emerges when the entire period of 1500-1790s is considered, while the famine-less period from 1726-1738 is attributed to the good reign of Hadz Handun (THAMBYAPILLAY 1984b). The *Bornu Chronicles* makes mention of wetter conditions being replaced by aridity with severe droughts at the turn of the 1790s, extending over the Kano-Bornu-Kanem environment.

Climatic events during the 19th century relate to a persistent drought in the first half of century (1828-1839), being also related to low Lake Chad levels (DENHAM 1835, in NICOLSON 1980b). At the turn of the 20th century, all over West Africa an arid phase followed the wet phase mentioned by BARTH in 1857 and NACHTIGALL in 1889 in Bornu (THAMBYAPILLAY 1984a). The years 1913-1915, 1924-1926 and 1942-1944 were short-lived drought periods in the Nigeria command of the basin (THAMBYAPILLAY 1982).

2.4. The drought continuum: Sahelo-Sudan

The debates that ranged over the drought theme during the mid-late 1970s and early 1980s over the issue of the droughts being fluctuational and recurrent events or whether a permanent desiccation had set in (BUNTING et al. 1976, KELLY 1980, NICOLSON 1980, GLANTZ 1976) became resolved following the disastrous 1984 drought year (World Met. Org. 1985, 1986). The most recent documents accept the *fait accompli* of the drought continuum of the 1980s of being coextensive with the Sahelian drought of the late 1960s and early 1970s (DURYAN 1989, NICOLSON 1989). To these two may be added the recognizance of the drought continuum (THAMBYAPILLAY 1982, 1984, LAMB 1982, TICKELL 1986).

It would seem naturally appropriate to attempt an analysis of the climate system of Sahelo-Sudan Nigeria in its regional/zonal context and undertake the specific study of the Nigeria command of the Lake Chad basin so as to relate the theme to that of dating and chronology of the greater Lake Chad basin.

3. SPATIO-TEMPORAL ANALYSIS

3.1. Temporal analysis

3.1.1. The techniques

(i) Mean deviation (curve)

Most studies seem to have adopted mean deviations in their analysis to demonstrate the significance of variability as the inbuilt characteristic of tropical rainfall. The mean deviation curve so constructed indicates the single-value variant from the mean. However, often, instead of revealing any trend or cyclic periodicities, these tend to become suppressed by the highly incidental deviations because of the "noise" feature.

Table 1: Inter-Annual variability in Maiduguri and Kano

Maiduguri mean = 650 mm (1915-1988)

Year	*Rainfall (mm)*	*Deviation (mm)*	*Deviation (%)*
1963	689	+ 39	+ 05
1964	461	- 189	- 29
1967	865	+ 215	+ 33
1968	629	- 21	- 03
1979	721	+ 71	+ 11
1980	622	- 28	- 04

Kano mean = 833 mm (1906-1984)

Year	*Rainfall (mm)*	*Deviation (mm)*	*Deviation (%)*
1909	1234	+ 401	+ 48
1910	681	- 152	- 18
1911	1011	+ 178	+ 21
1949	589	- 244	- 29
1950	924	+ 91	+ 11
1951	798	- 35	- 04
1952	1034	+ 201	+ 24
1953	730	- 103	- 12
1954	1103	+ 270	+ 32

(ii) Moving averages (curve)

To invalidate the incidental deviations of the mean deviation (curve) moving averages are introduced to bring about a more harmonious picture as well as to bring out any inherent trends, cycles or periodicities of the climatic parameter. However, in the process of remedying the shortcomings of the mean deviation (curve) and presenting "phases" viz. wet and dry, the moving averages (curve) does not specifically "locate" the actual dates of phase changes. Every single year location is only a "floating" year, because the single year is an averaged input. Thus, for example, in a 10-year moving average curve (also termed "running means" or "overlapping means" every specific year would be the 5th/6th year.

(iii) Residual mass (curve)

A technique highly successful with hydrologists, the residual mass represents the cumulative deviations. The resultant curve locates the specific dates of actual phase changes, viz. from wet to dry and back to wet or warm-cold-warm sequences.

Effective uses of the three techniques have been demonstrated for tropical rainfall analysis (KRAUS 1955, THAMBYAPILLAY 1958, 1960, 1980, 1987a, YAHYA 1989)

3.1.2. Analysis

Rainfall data from two meteorological stations, one pluvial station and seven "supporting" rainfall stations have been adopted for the analysis.

Kano (KN) with 78 years data (1906-1984) and Maiduguri (MD) with 74 years data (1915-1988) are the two prime stations, while Nguru, the third station has 52 years data (1936-1987). The 1980s rainfall data from the following rainfall stations have been used (Fig. 1 A and 7):

(a) Sahel zone
1. Damasak
2. Kukawa
3. Monguno

(b) Sudan zone
1. Damaturu
2. Gashua
3. Newmarte
4. Potiskum

A. Maiduguri (11°51'N 13°5'E)

The Maiduguri mean deviation curve, while demonstratic of incidental deviations, also reveals "recoveries" in the 1940s, the 1970s and since 1982. However, the 10-year moving average curve (Fig. 2) reveals that while a true "recovery" of rainfall took effect since the drought years of the late 1940s, it does not support a "recovery" since the Sahelian drought years of the 1970s. It is also to be observed that since 1982, the recovery rainfalls are all below the mean.

(Fig. 2)

Table 2: Annual rainfall (1979-1987)

	Maiduguri (mean : 650mm)			Kano (mean 833mm)		
year	*rainfall (mm)*	*deviation (mm)*	*deviation (%)*	*rainfall (mm)*	*deviation (mm)*	*deviation (%)*
1979	711	+ 61	+ 09	723	- 110	- 13
1980	621	- 29	- 04	912	+ 79	+ 09
1981	461	- 189	- 29	575	- 258	- 31
1982	234	- 416	- 64	588	- 245	- 29
1983	283	- 367	- 56	499	- 334	- 40
1984	328	- 322	- 50	479	- 354	- 42
1985	416	- 234	- 36			
1986	503	- 147	- 23			
1987	366	- 284	- 44			

The figures (Appendix A) show clearly a drought phase in the 1930s-1940s and a wet phase in the 1950s-1960s. However, the dry phase of the 1970s does not support a return to a wet phase in the mid-1980s. Again it is to be noted that Maiduguri received its lowest rainfall (234 mm) this century in 1982, with 1983 (283 mm) and 1984 (328 mm) showing the second and third lowest values.

If the 10-year moving averages graph has demonstrated a continuing trend of negatively anomalous rainfall in the 1980s, the second graph of residual mass curve (Fig. 4) is even more supportive. The moving averages curve does not however reveal the actual dates of phase changes from wet to dry and from dry to wet because the annual values on the graph are in effect "floating" values. Thus, while the lowest point in the moving average graph relating to the 1940s-1950s dry phase is seen to be 1946, this year represents truly a "floating" year, viz. mid-year of the 10 year series 1942-1951, hence the adoption of a second technique viz. the residual mass curve (Fig. 4).

The graph reveals that the phase change from a dry to a wet phase commenced in 1951 though the graph is within negative zone (below the mean). The actual dry phase change did not take effect it appears until 1963 and essentially demonstrates a plunge in the 1980s.

B. Kano (12°03'N 08°32'E)

Kano located at the extreme western end of the Chad basin reveals again in its moving averages and the residual mass curves (Fig. 3 and 4) that a long-term decreasing trend is clearly indicative. The lowest rainfall values are seen to be related to the drought years (1913, 1973, 1984) as follows:

1913	479 mm	
1973	416 mm	mean rainfall = 833 mm
1984	479 mm	

The 1913-1915 drought phase had recovered as per over 1000 mm rainfalls in 1916, 1918 and 1920. It is significant that the 1971-1973 drought years do not seem to have "recovered", since in the years 1974, 1975 and 1976 rainfall values are below the mean of 833 mm (Appendix A). The 1980s are reflected in low rainfalls beginning in 1989 with 575 mm, followed by 588 mm in 1982, 499 mm in 1983 and 479 mm in 1984.

C. Nguru (12°53'N 10°28'E)

Nguru, located midway between Kano and Maiduguri (Fig. 1A), within the "basin", reveals in its rainfall the usual inter-annual variability characteristics which is seen in the mean deviation graph (Fig. 2). However, the lowest rainfalls recorded are again in the 1980s, viz. 237 mm in 1983, with 1984 coming close with 326 mm. The previous low rainfalls were associated with the 1971-1973 Sahelian drought viz. 465 mm in 1971 followed by 248 mm in 1972 and finally the very low 259 mm in 1973 while the recovery is marked by an extraordinarily high rainfall of 602 mm in 1974. The 1985 recovery rainfall of 404 mm is yet below the mean.

The superimposed 10-year moving averages curve and the residual mass curve (Fig. 2 and 4) also lend valid support to the theme of a continuing drought in the 1980s.

The "recovery" rainfalls relating to the 1971-1973 drought phase is noteworthy in comparison to those following in the 1982-1984 drought years not indicating similar phenomena.

Table 3: Comparative drought rainfall years 1971-1973 and 1982-1984 (adapted from THAMBYAPILLAY 1987a)

	Maiduguri (mean : 650 mm)			Kano (mean : 833 mm)		
year	*rainfall (mm)*	*deviation (mm)*	*deviation (%)*	*rainfall (mm)*	*deviation (mm)*	*deviation (%)*
1971	503	- 147	- 23	706	- 127	- 15
1972	440	- 210	- 32	669	- 214	- 20
1973	437	- 213	- 33	416	- 417	- 51
1974	613	- 37	- 06	661	- 172	- 21
1975	665	+ 15	+ 02	713	- 120	- 14
1982	234	- 416	- 64	588	- 245	- 29
1983	283	- 367	- 56	499	- 334	- 41
1984	328	- 322	- 48	479	- 354	- 43
1985	416	- 234	- 36			
1986	503	- 147	- 23			
1987	366	- 284	- 44			

It does seem to suggest then, that from a temporal standpoint the 1971-1973 drought years and the 1968-1973 drought phase did "recover" during the years following, viz. 1974/1975 with 613 mm and 665 mm respectively. The same may not be seen in the case of the contemporary 1980s drought years of 1982-1984. On the other hand, in effect what is seen is that since the 1984 drought year the seeming "recovery" does not seem to have become established during the year 1985, 1986 and 1987, the rainfall of 416 mm, 503 mm and 366 mm respectively being very much below the mean, viz. shortfalls of 36 % and 23 % respectively in the three years.

D. Chad basin stations: Precipitation (1979-1987)

Data for other basin stations reveal the very low rainfall years of the 1980s. Since many of these stations do not have sufficiently long period data for indicating the negative departures from the means, low rainfall values are supportive of the revelations based on long period data of Maiduguri, Kano and Nguru.

Table 4: Lake Chad basin: Nigeria command stations
The 1980s rainfall decline (mm) (Fig. 1A and 7)

(a) SAHEL ZONE

Station	Coord.	Elev (m)	1979	1980	1981	1982	1983	1984	1985	1986	1987
Damasak	13°07'N	12°31'E	616	190	163	149	119	N/A	N/A	N/A	N/A
Kukawa	12°56'N	13°33'E	399	288	223	169	225	129	N/A	N/A	N/A
Monguno	12°41'N	13°37'E	526	300	303	194	94	77	N/A	N/A	N/A
Nguru	12°53'N	10°28'E	587	340	429	409	237	321	404	480	N/A

(b) SUDAN ZONE

Station	Coord.	Elev (m)	1979	1980	1981	1982	1983	1984	1985	1986	1987
Gashua	12°52'N	11°03'E	465	421	404	438	200	181	300	N/A	N/A
Maiduguri	11°51'N	13°05'E	711	622	500	234	283	328	416	503	366
Potiskum	11°42'N	11°02'E	822	758	606	560	454	450	519	N/A	N/A
Damaturu	11°45'N	11°57'E	733	415	590	505	287	442	307	N/A	N/A
Newmarte	12°21'N	13°44'E	529	655	487	292	289	216	N/A	N/A	N/A
Kano	12°03'N	08°32'E	723	912	575	588	499	479	494	N/A	N/A

(adapted from THAMBYAPILLAY 1984b and Archive Federal Meteorological services Lagos)

It would appear then that a case may be made for the prevalence of a continuing drought since the 1968-1973 Sahelian drought with a long-term trend of decreasing rainfall since the mid 1960s.

3.2. The spatial analysis

On the basis of having provided evidence of climatic desiccation as relating to precipitation shortfalls on a temporal basis within the Chad basin, it becomes appropriate to ascertain the spatial impact. To this end, a series of maps were constructed for the years 1951 to 1988 on the basis of adequate coverage of rainfall data. The composite map for 1979-1983 (Fig. 6) and the Chad basin Nigeria command isohyetal maps for the peak-drought years of 1973 and 1983 (Fig. 7) reveal that:

(a) The Sahel zone of less than 300 mm annual precipitation has progressed year by year southwards (with isohyet shifts).
(b) The isohyets of the 1980s drought years have migrated to more southerly latitudes than the corresponding isohyets of the 1973 peak drought year.
(c) The isohyets of the year 1983 have migrated more southerly than those of any previous years of the present century.
(d) Ongoing desertification processes have become identified in more southerly locations, probably consequential to increasingly prolonged drought years.

It may be more appropriate to make some reference to the first noted drought of this century, viz. 1912-1914 drought years, so as to have some comparative perspective of evidence of "climatic change" if any.

Apart from Kano, which has precipitation data as from 1906, no other station within the "basin" has corresponding data. Maiduguri's earliest record is for 1915 (viz. 644 mm being close to the mean of 650 mm) when in effect, the 1912-1914 drought years had begun to "recover". However, spatial evidence for the 1912-1914 drought years are available in published form (GROVE 1973).

GROVE has claimed that isohyets had migrated southwards as much as between 150 km and 300 km. It must be conceded that the then available data would have been of limited time-series and the assessment may be taken to have been generalized. The extracted isohyets for the year 1913 (88.6) indicate that while the 300 mm isohyet had migrated southwards in the basin, that year's rainfall for Maiduguri was above 300 mm, viz. 355 mm; the corresponding amounts were 234 mm in 1982, 283 mm in 1983 and 328 mm in 1984. The 500 mm isohyet, on the other hand, seems to have moved southwards of Kano, viz. 479 mm in 1913 while the long period mean is as much as 833 mm (GROVE ibid.).

A. The 1968-1973 drought years

During the peak of the 1971-1973 drought years, i.e. in 1973, the 300 mm isohyet is seen to be depressed between 100 and 125 km southwards of the normal position. The Sahel zone hence had expanded to include Nguru, Gashua, but the 300 mm isohyet was far north of Maiduguri (437 mm). But the very next year 1974 there is seen a tremendous "recovery" as is to be noted from the following table (mm):

	1971	1972	1973	1974	mean
Nguru (12°53'N)	463	290	259	629	569
Gashua (12°52'N)	397	272	270	411	479
Maiduguri (11°51'N)	505	440	437	614	650
Potiskum (11°42'N)	627	686	451	894	790

B. The 1980s drought years

It is unmistakeably clear that by the peak year of 1983, the Sahelian zone had "expanded" southwards most remarkably with the 300 mm isohyet having migrated between 250 and 300 km to lie southwards of Nguru, Gashua, Maiduguri, Damaturu and Ngala (Fig. 6). The more northern stations, on the other hand, recorded very low rainfalls in 1983 and 1984, viz. Damasak 119 mm, Monguno 94 mm and 77 mm (in 1984), Baga recorded only a mere 56 mm in 1984, Gubio with 123 mm in 1983 and Ngala recording 226 mm and 194 mm in 1983 and 1984, respectively. This map (Fig. 7) also has the 1973 isohyet of 300 superimposed on it to demonstrate the greater severity of the 1980s drought in the "basin".

It is also to be noted that the "recovery" year rainfalls in all stations are very low and did not reflect the corresponding feature during the 1970s drought.

Table 5: Comparative rainfall 1982-1987

Thus:	1982	1983	1984 mm	1985	1986	1987
Nguru	411	266	326	404	480	250
Gashua	438	200	181	300	N/A	N/A
Maiduguri	234	283	328	416	503	366
Potiskum	560	454	450	N/A	N/A	N/A
Kukawa	169	225	129	N/A	N/A	N/A
Monguno	194	94	77	N/A	N/A	N/A
Ngala	371	226	195	N/A	N/A	N/A
Newmarte	292	289	216	N/A	N/A	N/A

Thus the evidence may be summarized:

- the 1980s droughts were indeed more severe than those of the 1970s;
- the 300 mm isohyet demarcating the Sahelian zone had been depressed southwards of the normal position to between 200 km and 300 km (with more isohyets following suit). This is in noteworthy comparaison with the lesser 150-200 km during the 1970s drought;
- the 1970s droughts, with the peak year being 1973, had "recovered" the very next year of 1974 with precipitation nearer the mean values. In 1984, the year following the peak year of the 1980s drought, there was not only no evidence of recovery, but in effect, further drought persistence. Even by 1986, the "recovery" precipitation values are found to be far less than the mean.

4. RATIONALE OF DROUGHT CONTINUUM

Now that an attempt has been made in this paper to demonstrate from both the temporal and spatial standpoint, that a "drought continuum" seems to be operative in the Chad basin and in general in the Sahelian zone, it becomes necessary to provide a *rationale* for this drought continuum. In considerations made in this paper, the reference is to meteorological drought only, since other forms, namely hydrological drought, agricultural drought, ecological drought are recognizable. Again, the consideration will be to regional drought linked to global drought, since in the ultimate it is in the global atmospheric circulation that the causative factor of meteorological drought must be sought.

Droughts have been noted in various parts of the globe temporally and spatially - nevertheless, while droughts elsewhere have disappeared, it is now accepted that the Sahelian drought has persisted for nearly twenty years, commencing with the 1970s droughts initiated in 1968. While some have supported the persistence theme and demonstrated coherence in the Saharan, Sahelian and Sudanian rainfall series (NICOLSON 1980, 1981, 1989), others supportive of a drought continuum include LAMB 1982, THAMBYAPILLAY 1982, 1983a, 1983b, 1984, 1985, 1987a, 1987b, FARMER and WIGLEY 1985 and DENNETT 1985.

4.1. The regional context

In the context of the regional climatology of West Africa which in turn is reflected in the climate of Nigeria and the Chad basin, the first resource is to seek a rational for the drought continuum in the mechanics of our regional climate. It is meteorologically accepted that the rainbringer to the Chad basin and Nigeria is the ITD, which is the West African connotation of the *global inter-tropical convergence zone* (ITCZ). It is not always realized that the ITD constitutes the advancing front of the monsoonal system - which persists within the trades globally - from SE Asia through South Asia/Indian Ocean and into West Africa. It is the seasonal movement of the ITCZ that brings in its wake the monsoonal rains. Thus, it would appear logical to seek the first cause in the monsoonal system and the why and wherefore for the "failure" of the ITD to reach the expected latitudinal positions in a year or in a sequence of years. What forcing parameter is responsible for the "failure of the monsoonal rains" - a significant theme of the Indian Ocean monsoonal mechanics? The Indian monsoon has failed time and time again to cause tremendous hardship to the teeming populations of Southern and SE Asia. During the Sahelian droughts and during the current 1980s droughts, there were "failures" of the Indian monsoon. During the meeting of the Indian Ocean Studies International Conference in Perth (Australia) a paper was presented providing for a correlation of the mechanics of the West African and Indian monsoonal systems (THAMBYAPILLAY 1984a). A recent viewpoint (KIDSON 1987) is that the failure of the ITD to reach its accustomed northern latitudes may be linked to the breakdown of the 850 mb trough at 8'N and the disappearance of the easterly jet at 200 mb. The role of the easterly jet in controlling the advancement of the Indian monsoon to its accustomed 25°N latitude had been proven and is being used to forecast arrival of the Indian monsoon in june of every year (THAMBYAPILLAY 1958). Though the Indian monsoon has some surface-based circulation as related to the pressure systems in Asia (summer and winter), upper atmospheric controls play vital roles with respect of the "burst" or onset of the monsoon. The jet located south of the Himalayas has to move north of the mountain range to permit the monsoonal front to advance to 25°N latitude, seemingly as it were to occupy the "vacancy" left by the jet that had moved north of the Himalayas. "Failures" in the monsoon are noted during the years the jet persists in its southerly position. It is also noted that the Indian monsoon has connections with the Indonesian-Australian pressure system which has been designated the Southern Oscillation. In recent times there are references to the link betwen the Southern Oscillation and El Niño, which latter seems to have weather teleconnections. The ENSO and SSTs (sea surface temperature) are candidates for weather teleconnections (KERSHAW 1988). It has been suggested that African droughts may have an ENSO link.

Despite the need to seek the upper atmospheric link, there is some evidence in support of the suppression of the ITD from advancing northward by a southerly displacement of the anticyclonic subtropical high. Though this is not proven in every case, an overall relationship seems probable. It has been demonstrated that "little dry season" in southern Nigeria is absent the years the ITD had not moved far north. On the other hand, the year the ITD has a prolonged "stay" in the north with attendant heavy rainfall, the "little dry season" also was prolonged (MOTHA et al. 1980).

In seeking the answer in changes in atmospheric circulation systems, the carbon-dioxide theme has now come into greater focus. However, during the considerations of the Sahelian drought (London Symposium in 1973), the suggestion was made that the Sahelian drought may be part of a 200-year drought cycle (LAMB 1977). It is now accepted that droughts in Africa have increased in severity in succession but also that they seem to persist for longer periods. It is also the current acceptance in meteorological cycles that a true "climatic change" has been effected (WIGLEY and FARMER 1985) and studies should be directed under this theme.

4.2. Sea-surface temperature (SST) anomalies and monsoon drought

In recent years much interest has been evoked on the theme "linkage" between sea-surface temperature anomalies and droughts in the monsoonal system - both African and Indian. Adopting a regression technique, the initial forecast was issued relating anomalies of world-wide SSTs and Atlantic SST in spring to the Sahel rainfall in the following summer. In 1986, such a forecast was issued, viz. a low Sahel rainfall and which achieved 68 percent accuracy (FOLLAND et al.

1986). Subsequent forecasts were issued with success (PARKER et al. 1988, OWEN and WARD 1989). Similar evidence has been forthcoming recently, wherein the SSTs of the Arabian Sea have been linked to forecasting the onset of the Indian Ocean monsoon (KERSHAW 1988). It would seem imperative to pursue a linkage between the West African monsoonal system and the Indian Ocean monsoonal system (THAMBYAPILLAY 1984a), especially so in view of the vital role of the Sahel rainfall on food production for the growing population. The system of early warning forecasts now being tried out in West Africa may be enhanced by the establishment of such a linkage. A more recent study (ADEYOYIN 1989) related world-wide SST anomalies to characteristics of Nigerian rainfall.

POSTSCRIPT

The original submission of this paper was to the ORSTOM seminar "Dating and Chronology in the Lake Chad basin" (Bondy/France 1989) and hence the climatic scenario was dated to only 1984, viz. data then available. It was demonstrated that a *drought continuum* signal was evident as an extension of the notorious Sahel drought (1968-1973), since apart from the seeming rainfall "recovery" up to 1979, a more severe drought chronology commenced by the 1980s. This was the second time that the scientific community was awakened to an unexpected episodic Sahelian drought.

In the present resubmission of the paper, the availability of rainfall data into the 1990s has become significant to "demonstrate" that the drought episode witnessed in the Lake Chad basin (Nigeria command) since the early 1980s (up to 1984) has continued unabated into the contemporary early 1990s. It has already been demonstrated to the International Conference "Physical causes of drought and desertification", Melbourne/Australia, 1991) that since the 1964 "event" of a significant rainfall climate change in the Sahelian zone (THAMBYAPILLAY 1991) the drought has continued into the 1990s and that "desertification" in the Lake Chad basin's Nigeria command was essentially a meteorologically-induced land degradation. Satellite imagery interpretation supported by field evidence (on the ground) in the Nigerian Sahelo-Sudan ("Nigerian Sahelia") demonstrated anthropogenic desertification to be essentially local and at most highly regionalised and even specifically related to the "borehole locale" as per livestock trampling extension zones.

The graphs re-adapted (Fig. 2, 3, 4 and 5) for presentation of the current paper using rainfall data updated to the end of the 1992 rainy season (Sept.-Oct.) provide supportive evidence for a *drought continuum* that commenced in the mid-1960s (1964).

The composite rainfall graph (Fig. 5) integrating the data of the three meteorological stations within the Lake Chad basin (Nigeria command) - Kano (West), Nguru (Centre) and Maiduguri (East) (Fig. 1A) - demonstrate traceable the commencement of the drought continuum to 1964 - the first significant rainfall shortfall ending the 14 years positive rainfall phase that commenced in 1950, ending in 1964.

Table 6: Comparative rainfall data : Lake Chad basin (Nigeria command)

	Kano (833mm)		Nguru (569mm)		Maiduguri (650mm)	
year	*deviation* (mm)	*deviation (%)*	*deviation* (mm)	*deviation* (%)	*deviation* (mm)	*deviation* (%)
1985	-199	-24	-165	-29	-234	-36
1986	-140	-17	-789	-16	-147	-23
1987	-327	-35	-319	-56	-284	-40
1988	+220	+26	-246	-43	-22	-03
1989	-133	-16	-230	-40	-43	-07
1990	N/A	N/A	-151	-27	-223	-34
1991	N/A	N/A	-347	-51	-163	-25
1992	N/A	N/A	N/A	N/A	-75	-12

The evidence that has been presented is clearly indicative of a climatic change in the rainfall scenario in the Nigerian Sahelia and as earlier mentioned is tracebale to have begun in 1964.

It has been pointed out (WIGLEY and FARMER 1985) that the Sahel is witness to evidence of climatic change. During the Drought and Desertification Seminar in Australia, the composite evidence for six stations in the Nigerian Sahelo-Sudan zone (including the Lake Chad basin command) was provided (THAMBYAPILLAY 1991) in support of land degradation conditioned by remarkable shortfalls in rainfalls since the mid-1960s.

It is concluded here that within the Nigeria command of the Lake Chad basin, rainfall shortfalls have been realised over a quarter century (1964-1992) and the socio-economic impact of this drought continuum is being investigated.

Appendix A. Annual precipitation : Maiduguri (11°51'N 13°05'E)
1915 - 1985 Mean = 650 mm d = deviation

Year	mm	d (mm)	d (%)	Year	mm	d (mm)	d (%)
1915	644	+06	+01	1954	767	+117	+18
1916	839	189	+29	1955	951	+301	+46
1917	557	-93	-14	1956	637	-13	-02
1918	880	+230	+35	1957	732	+82	+13
1919	430	-220	-34	1958	750	+100	+15
1920	790	+140	+21	1959	866	+216	+33
				1960	732	+82	+13
1921	733	+83	+14				
1922	450	-200	-31	1961	722	+72	+11
1923	657	+7	+01	1962	678	+28	+04
1924	971	+321	+50	1963	689	+39	+06
1925	636	-14	-02	1964	452	-198	-30
1926	396	-254	-39	1965	578	-72	-11
1927	701	+61	+09	1966	623	-27	-04
1928	593	-57	-09	1967	865	+215	+33
1929	711	+61	+09	1968	629	-21	-03
1930	738	+88	+14	1969	583	-67	-10
				1970	740	+90	+14
1931	813	+163	+25				
1932	465	-185	-25	1971	503	-147	-22
1933	652	+02	+0,3	1972	477	-173	-22
1934	800	+150	+23	1973	437	-213	-33
1935	538	-112	-17	1974	613	-37	-06
1936	806	+156	+24	1975	665	+15	+03
1937	609	-41	-06	1976	709	+59	+09
1938	758	+108	+17	1977	658	+08	+01
1939	566	-84	-13	1978	740	+90	+14
1940	379	-271	-42	1979	711	+61	+09
				1980	621	-29	-05
1941	515	-135	-21				
1942	486	-154	-24	1981	461	-189	-29
1943	562	-88	-14	1982	234	-416	-64
1944	513	-137	-21	1983	283	-367	-56
1945	714	+64	+10	1984	328	-322	-50
1946	770	+120	+18	1985	416	-234	-36
1947	652	+02	+0,3	1986	503	-147	-23
1948	543	-107	-11	1987	366	-284	-44
1949	447	-203	-31	1988	628	-22	-04
1950	690	+40	+06	1989	607	-43	-06
				1990	427	-223	-34
1951	571	-79	-12				
1952	680	+30	+05	1991	487	-163	-25
1953	738	+88	+14	1992	585	-65	-10

(Adapted from THAMBYAPILLAY 1987a, 1991 and updated to 1992)

Appendix B. Annual Precipitation : Kano (12°03'N 08°32'E)
1906-1984 : Mean = 833 mm   d = deviation

Year	mm	d (mm)	d (%)	Year	mm	d (mm)	d (%)
1906	551	-282	-34	1946	1053	+222	+03
1907	651	-182	-22	1947	798	-35	-04
1908	846	+13	+02	1948	721	-112	-13
1909	1234	+401	+48	1949	569	-244	-29
1910	681	-152	-18	1950	924	+102	+12
1911	1011	+178	+21	1951	798	-35	-04
1912	742	-91	-11	1952	1034	+201	+24
1913	479	-354	-38	1953	730	-103	-12
1914	685	-148	-18	1954	1103	+270	+30
1915	819	-14	-02	1955	1067	+234	+27
1916	988	+155	+19	1956	758	-75	-09
1917	869	+36	+04	1957	932	+99	+12
1918	1035	+202	+24	1958	826	-07	-01
1919	824	-09	-01	1959	1021	+188	+22
1920	1896	+263	+32	1960	757	-76	-09
1921	867	+34	+04	1961	780	-53	-06
1922	912	+79	+10	1962	1139	+306	+37
1923	305	-28	-03	1963	704	-129	-15
1924	867	+14	+02	1964	551	-82	-10
1925	700	-133	-16	1965	904	+71	+08
1926	705	-132	-16	1966	778	-55	-07
1927	769	-64	-08	1967	789	-44	-05
1928	883	-50	-07	1968	609	-224	-27
1929	855	+22	+03	1969	909	+76	+09
1930	996	+163	+20	1970	922	+89	+11
1931	1163	+330	+40	1971	706	-127	-15
1932	1003	+170	+20	1972	669	-164	-20
1933	738	-95	-11	1973	416	-417	-50
1934	795	-38	-05	1974	661	-172	-21
1935	938	-105	-13	1975	713	-120	-14
1936	979	+146	+18	1976	543	-290	-35
1937	736	-97	-12	1977	786	-47	-06
1938	1115	+282	+34	1978	931	+98	+12
1939	845	+12	+01	1979	723	-110	-13
1940	811	-22	-03	1980	912	+79	+09
1941	837	+04	+0,5	1981	575	-258	-31
1942	622	-211	-30	1982	588	-245	-29
1943	794	-39	-05	1983	499	-334	-40
1944	486	-347	-43	1984	479	-354	-42
1945	970	+137	+42	1985	634	-199	-24

1986	693	-140	-17
1987	506	-327	-35
1988	1053	+220	+26
1989	700	-133	-16

(Adapted from THAMBYAPILLAY 1987a, 1991 and updated to 1992)

Appendix C. Annual Precipitation : Nguru (12°53'N 10°28'E)
1934-1984 : Mean = 569 mm d = deviation

Year	mm	d (mm)	d (%)	Year	mm	d (mm)	d (%)
1934	612	+43	+08	1964	536	-33	-06
1935	589	+20	+04	1965	564	-05	-01
1936	496	-73	-13	1966	461	-108	-21
1937	529	-40	-07	1967	517	-52	-09
1938	675	+106	+19	1968	540	-29	-06
1939	501	-68	-12	1969	391	-178	-31
1940	570	+01	+0,002	1970	533	-33	-06
1941	478	-91	-16	1971	461	-108	-19
1942	432	-137	-24	1972	248	-321	-56
1943	643	+74	+13	1973	259	-310	-54
1944	413	-156	-27	1974	602	+33	+06
1945	630	+61	+11	1975	558	-11	-02
1946	868	+299	+53	1976	509	-60	-11
1947	536	-33	-06	1977	454	-115	-20
1948	347	-222	-39	1978	497	-72	-13
1949	328	-241	-42	1979	587	+18	+03
1950	716	+147	+26	1980	340	-229	-40
1951	619	+50	+09	1981	429	-140	-25
1952	558	-11	-02	1982	409	-160	-28
1953	643	+74	+13	1983	237	-332	-58
1954	719	+150	+26	1984	326	-243	-43
1955	559	-10	-02	1985	404	-165	-29
1956	582	+13	+02	1986	480	-89	-16
1957	597	+28	+05	1987	250	-319	-56
1958	630	+61	+11	1988	323	-246	-43
1959	515	-54	-09	1989	339	-230	-40
1960	516	-53	-09	1990	418	-151	-27
1961	609	+40	+07	1991	322	-347	-61
1962	441	-128	-22	1992			
1963	647	+78	+14				

(Adapted from THAMBYAPILLAY 1987a, 1991 and updated to 1992)

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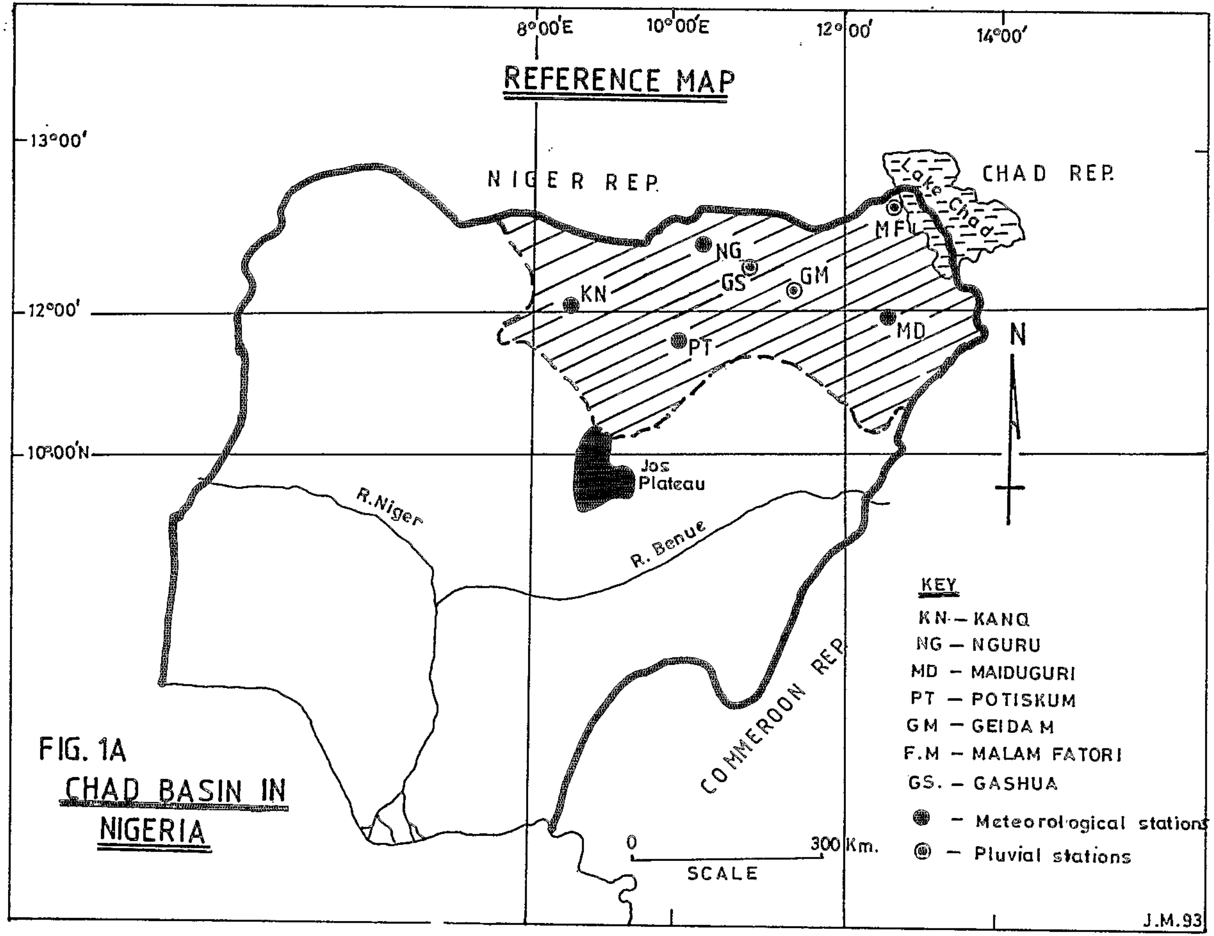
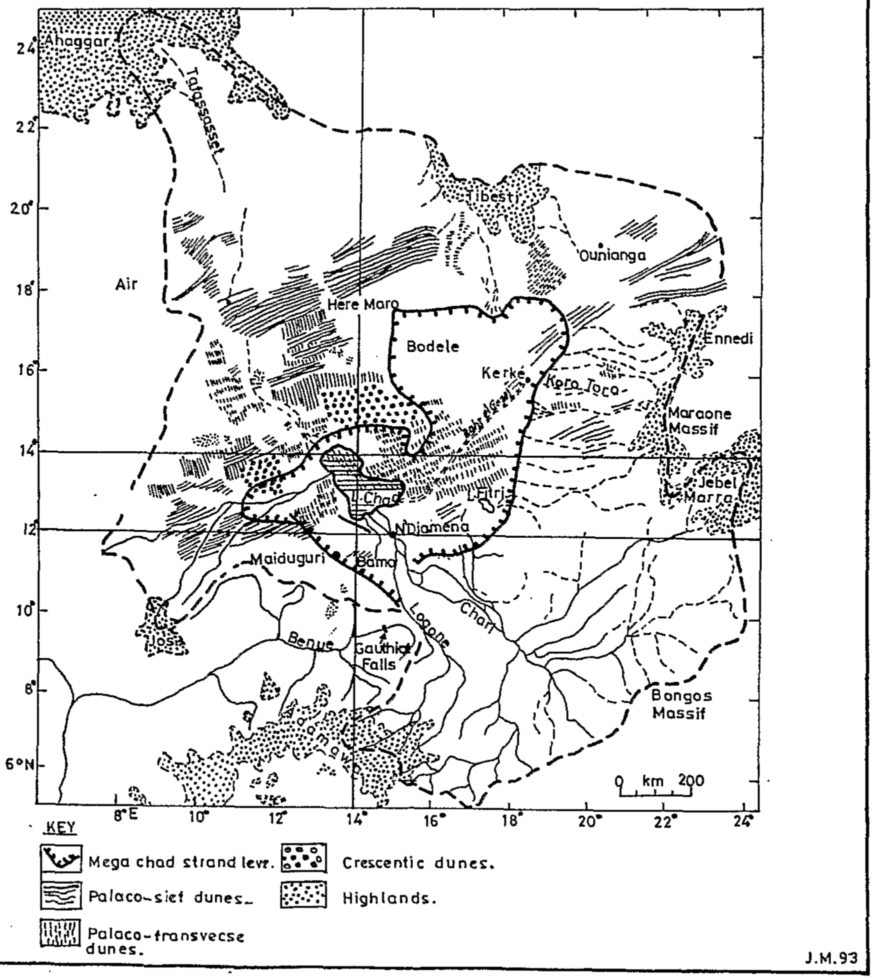
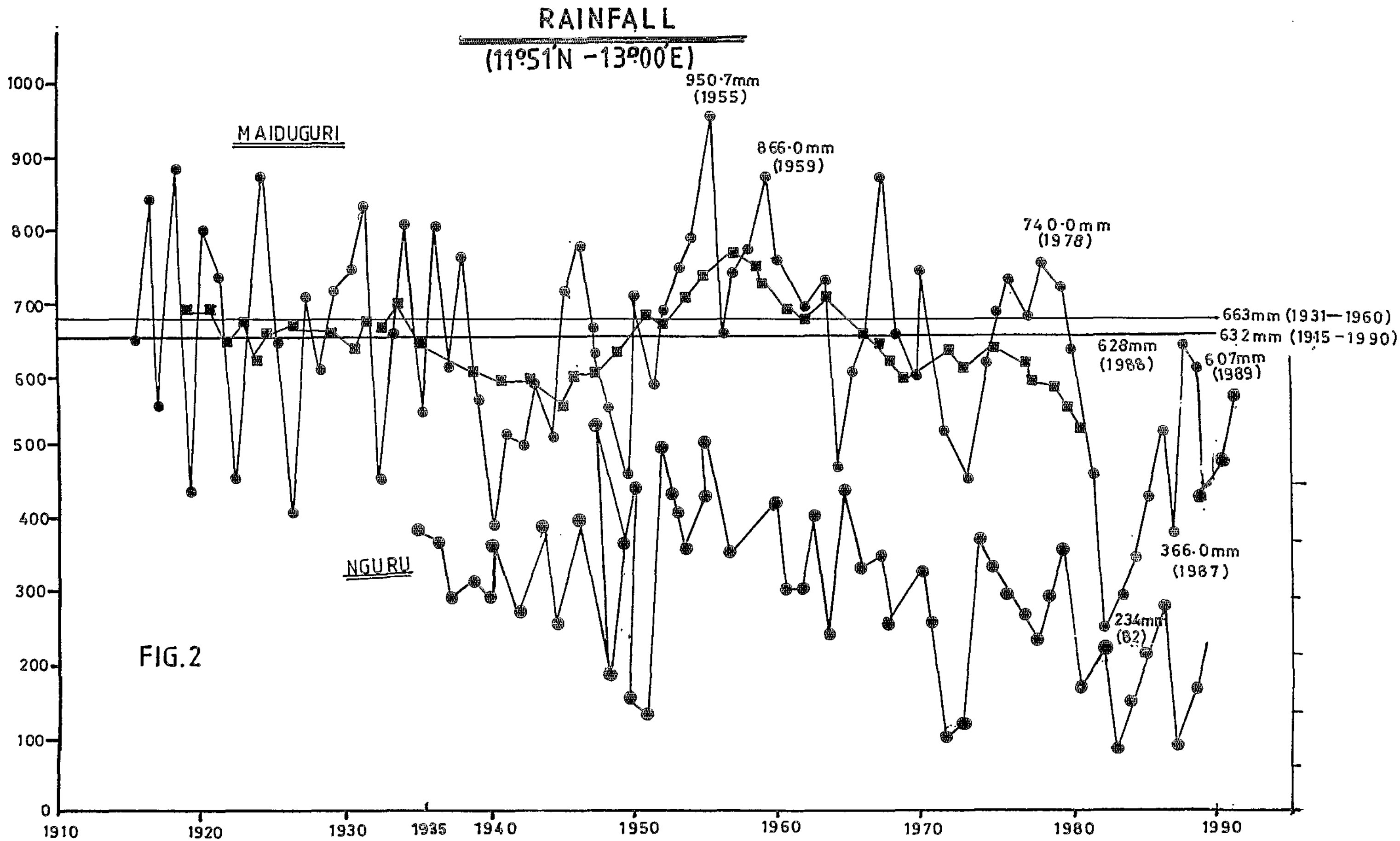


FIG. 1A
CHAD BASIN IN NIGERIA

FIG.1B LAKE CHAD BASIN — PALAEOGEOGRAPY





RAINFALL
(11°51'N -13°00'E)
950·7mm
(1955)
866·0mm
(1959)
740·0mm
(1978)
MAIDUGURI
NGURU
663mm (1931—1960)
632mm (1915-1990)
628mm
(1988)
607mm
(1989)
366·0mm
(1987)
234mm
(82)
1000
900
800
700
600
500
400
300
200
100
0
1910
1920
1930
1935
1940
1950
1960
1970
1980
1990

FIG. 2

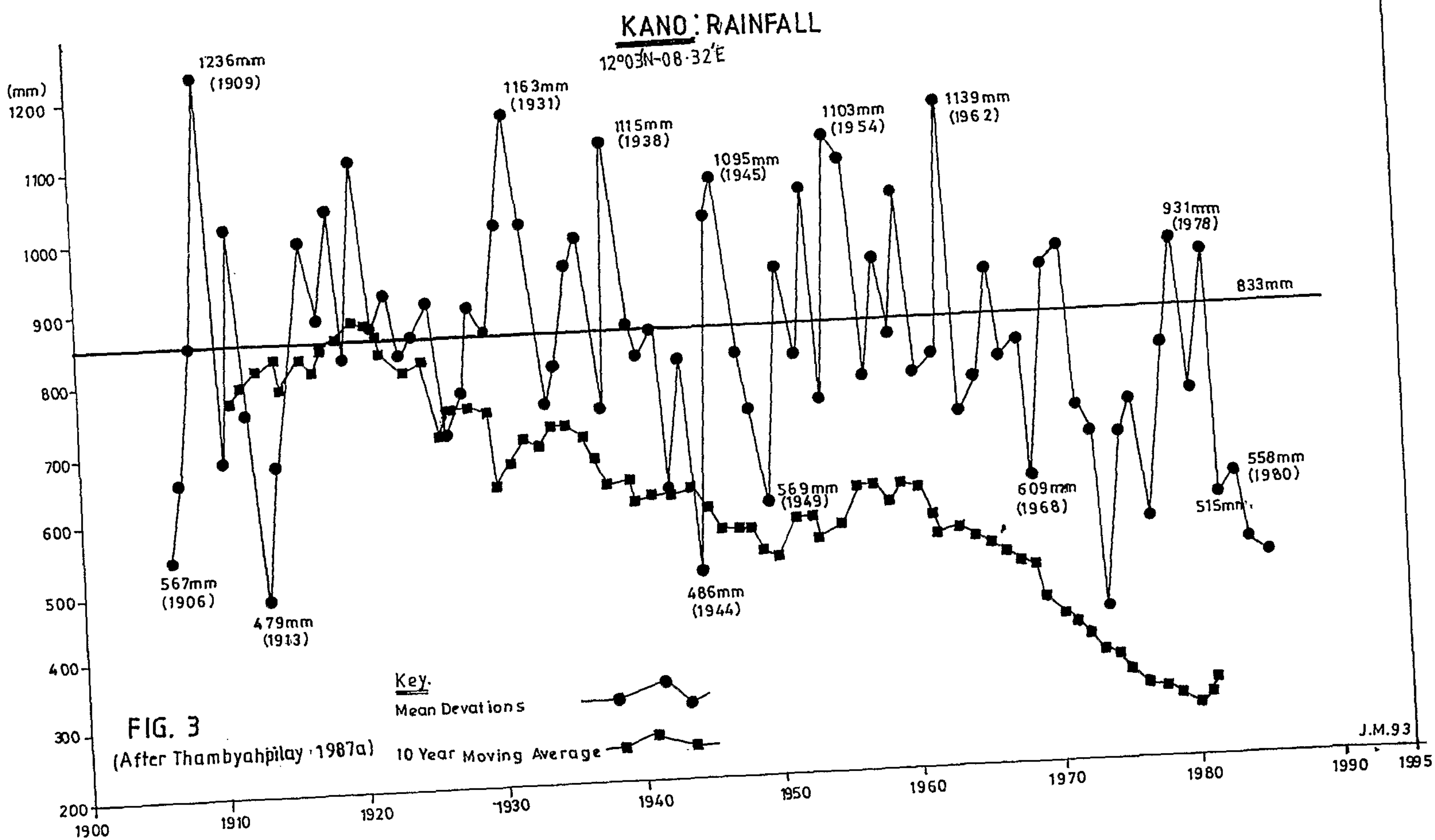


FIG. 3
(After Thambyahpilay 1987a)

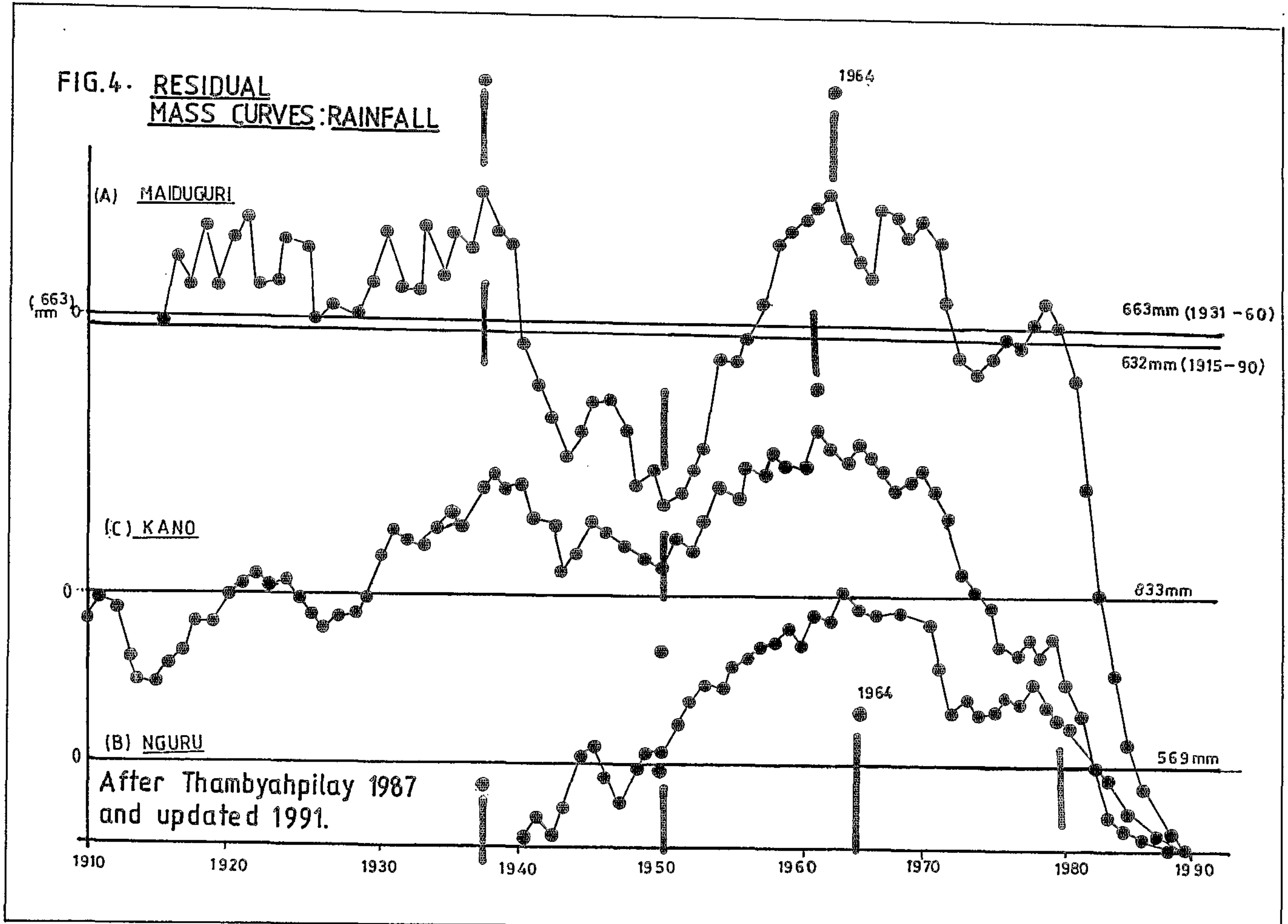


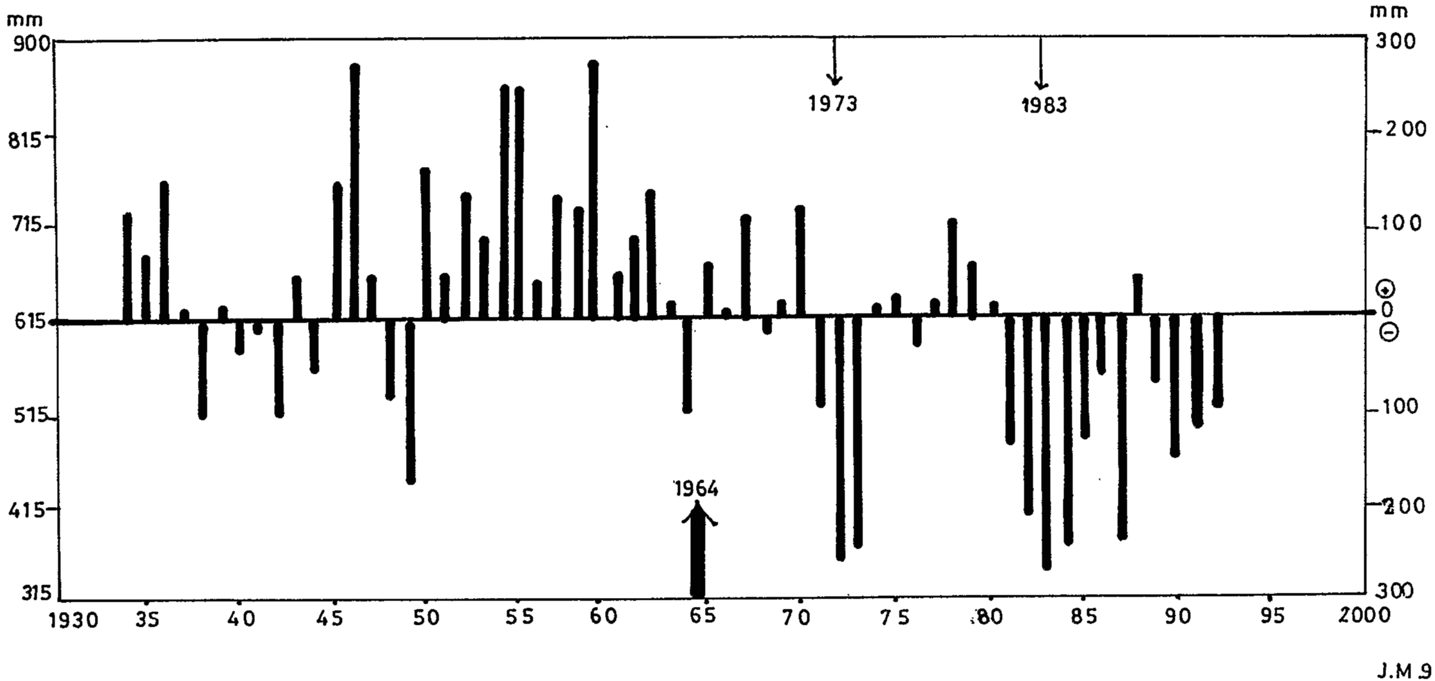
FIG.4. RESIDUAL MASS CURVES: RAINFALL

FIG.5 COMPOSITE RAINFALL GRAPH (Three stations)

CHAD BASIN : NIGERIA COMMAND MEAN = 615mm (1934–90)

(a) KANO WEST 12°03'N & 08°32'E (3) MAIDUGURI 11°51'N & 13°05'E

(b) NGURU CENTRAL 12°53'N & 10°28'E



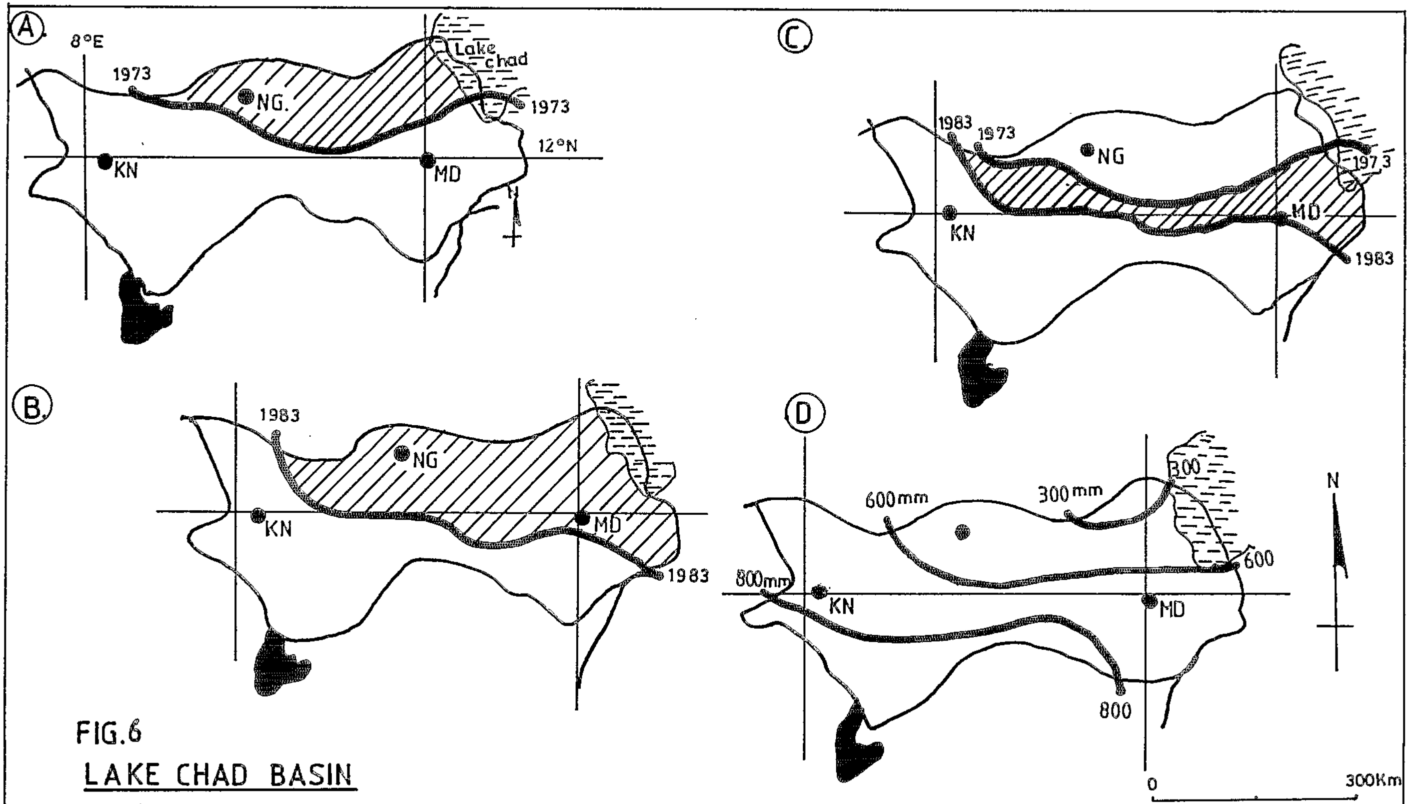


FIG.6
LAKE CHAD BASIN
NIGERIA COMMAND
300mm Isohycts
(After Thambyaphily 1989.)

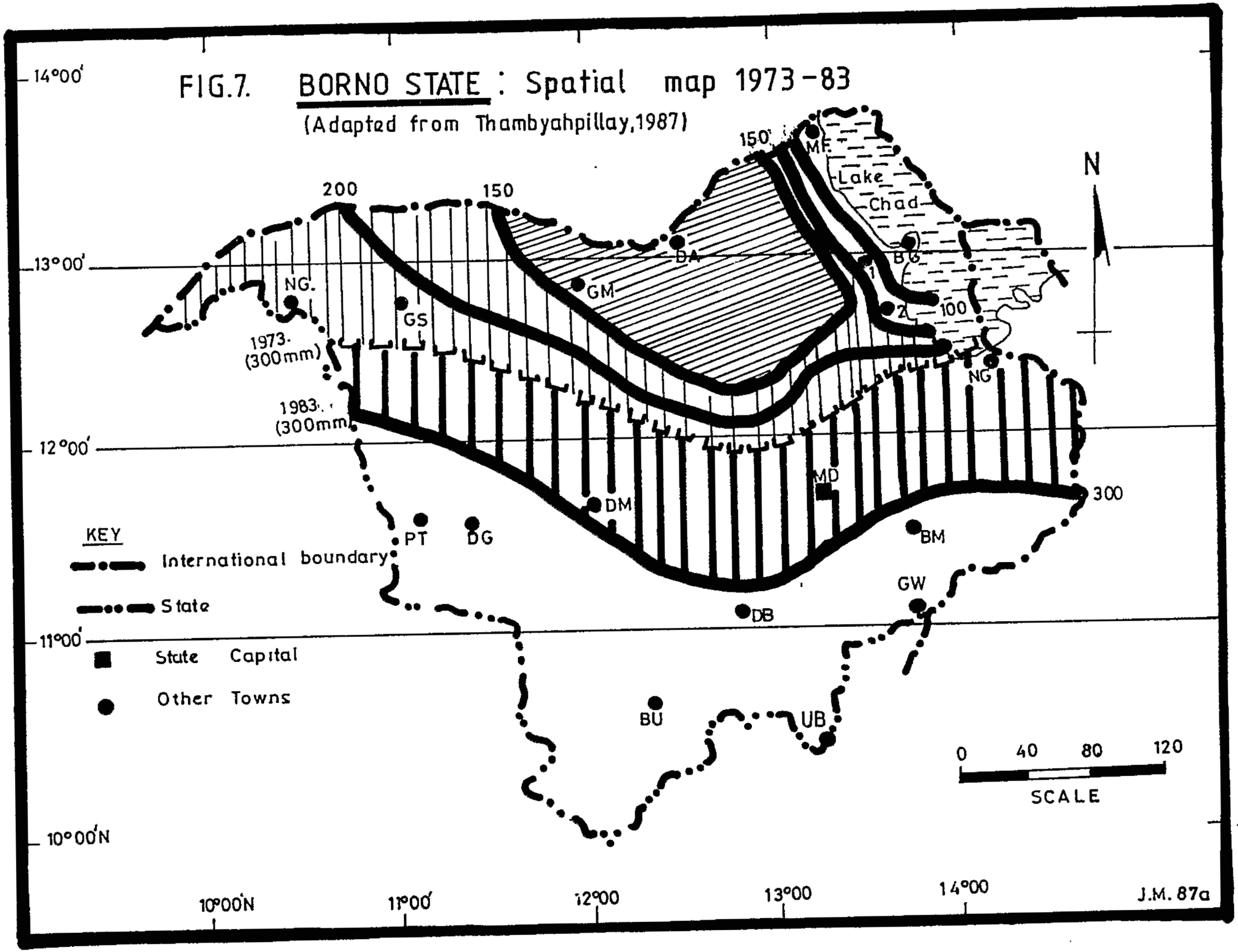


FIG.7. BORNO STATE : Spatial map 1973-83
(Adapted from Thambyahpillay, 1987)