Working Paper 25

PROFILE OF RAINFALL CHANGE AND VARIABILITY IN THE KANO-MARADI REGION, 1960-2000

Michael Mortimore

2000

Drylands Research
Crewkerne, Somerset, UK
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Preface

Drylands Research Working Papers present, in preliminary form, research results of studies carried out in association with collaborating researchers and institutions.

This Working Paper is part of a study which aims to relate long-term environmental change, population growth and technological change, and to identify the policies and institutions which are conducive to sustainable development. The study builds upon an earlier project carried out by the Overseas Development Institute (ODI) in Machakos District, Kenya, whose preliminary results were published in a series of ODI Working Papers in 1990-91. This led to a book (Mary Tiffen, Michael Mortimore and Francis Gichuki, More people, less erosion: environmental recovery in Kenya, John Wiley, 1994), which was a synthesis and interpretation of the physical and social development path in Machakos. The book generated a set of hypotheses and policy recommendations which required testing in other African dryland environments. Using compatible methodologies, four linked studies have been carried out in:

<table>
<thead>
<tr>
<th>Country</th>
<th>District/Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td>Makueni District</td>
</tr>
<tr>
<td>Senegal</td>
<td>Diourbel Region</td>
</tr>
<tr>
<td>Niger</td>
<td>Maradi Department</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Kano Region</td>
</tr>
</tbody>
</table>

(in association with ODI)

For each of these study areas, there is a series of working papers and a synthesis, which have been reviewed at country workshops. An overall synthesis was discussed at an international workshop at London on 17 January, 2001.

Due to the limited number of working papers on Nigeria, they are included in a combined Niger-Nigeria Series. The Nigeria study is limited to one in-country study on food marketing in the Kano Region (leader Dr J. Ayodele Ariyo). The remaining studies explore other aspects of long-term change in natural resource management, livelihoods and policy, and are based on published and unpublished material. The Research Leader for these studies is Michael Mortimore. He, Mary Tiffen or J. Ayodele Ariyo may be contacted at the following addresses.

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Preface map
Abstract
Rainfall data from five stations (Kano, Magaria, Maradi, Nguru and Zinder) are analysed for the period 1931-1999, to show long-term trends, seasonal changes, and the incidence and severity of droughts. The first of these analyses shows that long-term trends were spatially persistent and that the record is dominated by a long downward trend from the 1950s to the 1970s, two severe troughs in the early 1970s and early 1980s separated by a short recovery, and followed by divergent trends (rising in Kano and persistently low in Zinder) during the 1990s. The long-term trends provide no reliable basis for predicting future rainfall. The second analysis shows that inter-annual variability and long-term decline differ from month to month, with the steepest decline in August and the greatest variability in May and June. The third analysis shows that all the five stations are equally affected, though not to the same degree every year, by drought (defined in terms of standard precipitation indexes based on deviation from mean annual rainfall). The success of rural households in adapting to the challenge of climate change can be evaluated against these measures.

Résumé
Les données pluviométriques de cinq stations (Kano, Magaria, Maradi, Nguru et Zinder) ont été analysées pour la période 1931-1999, afin de montrer l’évolution à long terme, les changements saisonniers, et la fréquence et la sévérité des sécheresses. La première de ces analyses indique que l’évolution à long terme est persistante sur le plan spatial. Les données montrent qu’elle est marquée par une tendance régulière à la baisse des années 1950 aux années 1970, deux périodes de sécheresses sévères au début des années 1970 et 1980 séparées par une courte période de reprise, et suivies par des tendances divergentes (hausse à Kano et faiblesse persistante à Zinder) durant les années 1990. L’évolution à long terme de la pluviométrie ne fournit pas d’indications suffisamment sûres pour pouvoir faire des prédictions quant à l’avenir. La seconde analyse indique que la variabilité inter-saisonnière et le déclin à long terme varient selon les mois, avec la plus forte baisse en août et la plus grande variabilité pendant les mois de mai et de juin. La troisième analyse montre que les cinq stations sont affectées par la sécheresse (définie par des indices de précipitation standard obtenus en calculant la différence avec la moyenne pluviométrique annuelle) bien qu’elles ne le soient pas toutes au même degré. La manière dont les ménages paysans ont réussi à s’adapter au défi présenté par ces changements climatiques peut être évalué en tenant compte de ces mesures.
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Data used in this study were provided by the Climate Change Unit, University of East Anglia.

About the author
Michael Mortimore is a geographer who taught and researched at Ahmadu Bello University, Zaria, Nigeria between 1962 and 1979, and was Professor of Geography at Bayero University, Kano from 1979 to 1986. Subsequently he carried out research studies as a Senior Research Associate in the Department of Geography, Cambridge University, the Overseas Development Institute and as an Honorary Fellow of the Centre of West African Studies, University of Birmingham. His research and publications have focused on environmental management by smallholders in the drylands of Africa. In 1998 he and Mary Tiffen set up the Drylands Research Partnership.

Acronyms and abbreviations

ITC: Inter Tropical Convergence
PI: Precipitation Index
1 INTRODUCTION

Change and variability in the rainfall are supremely important determinants of livelihoods in the Kano-Maradi region. They determine primary production from year to year. They define the possibilities for investment, both in enhancing productivity and in conserving natural resources. In so far as they constrain primary production, they strengthen peoples’ need to diversify their incomes. The rainfall has therefore been a constantly recurring theme during the four decades of this study.

The objective of this profile is to identify those aspects of rainfall which have had an impact on human activities. This analysis is based on the records of annual rainfall from the stations listed in Table 1 (see Preface map for locations).

Table 1: Rainfall stations and periods

<table>
<thead>
<tr>
<th>Niger</th>
<th>Period</th>
<th>Nigeria</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magaria</td>
<td>1938-1999</td>
<td>Katsina</td>
<td>1931-1987</td>
</tr>
<tr>
<td>Maradi</td>
<td>1932-2000</td>
<td>Kano Aero*</td>
<td>1931-1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kano Farm*</td>
<td>1916-1999</td>
</tr>
</tbody>
</table>

*Kano Aero series commenced in 1905. However, data for recent years after 1994 are not presently available.

2 SAHELIAN RAINFALL IN LONG-TERM PERSPECTIVE

The densely-populated farmlands and heavily grazed pastures of the Sahelo-Sudanian Zone of West Africa have experienced fluctuations in rainfall on all time-scales - from decadal (based on ten-day analytical periods) to monthly, seasonal, annual, and longer term. The longer term fluctuations are caused by the oscillations of the climatic borders of the Sahara Desert, of which there is abundant geological, archaeological and recent historical evidence (e.g., Grove and Pullan, 1964; Nicholson, 1978, Tucker et al., 1991). Contemporary changes in rainfall should be evaluated, therefore, not as aberrations from a natural equilibrium, but as normal occurrences in a disequilibrial regime. A necessary condition for sustainable livelihoods in such a region is for people to adapt continuously in their farming, livestock-keeping, or other income-earning activities (Behnke et al., 1994; Mortimore, 1998).

The Great Sahel Drought, whose culmination shocked the region and the world in 1972-74, created a perspective among outside observers which was at variance with these facts of life. It was seen then not only as a drought and a crisis in food production but also as a failure of farming and stock-keeping systems, of resource conservation and of economic coping strategies (Mortimore and Adams, 2000). The reactions of the international community precipitated several Sahelian countries, including Niger (but not Nigeria) into a state of chronic dependency on food aid.
Subsequently, drought was described as ‘persistent’ in the Sahel region (Lamb, 1982), and in 1983-4 some stations, including those in northern Nigeria, recorded even lower rainfall than in the early 1970s (Mortimore, 1989). However in some years rainfall was satisfactory for crop and livestock production, so the meaning of ‘persistence’ became, essentially, an increased probability of drought. Indeed, the long-term decline of average rainfall is better described as ‘desiccation’ than as ‘drought’ in order to distinguish its effects from those of annual or shorter term deficiencies in the rainfall. Such deficiencies, for practical purposes, are defined in terms of the needs of the natural ecosystems and of the crop and livestock production systems.

No matter what statistical averaging period is used, the downward trend manifests itself in long-term rainfall series (Agnew and Chappell, 1999). However, a straight-line downward-sloping trend, all too easily imposed on such data, provides no basis for forward projections, and may give a misleading description of the changes that occurred. The data may be as well described by a step-wise or ‘jump transition’ model, in which a significant shift occurred in the late 1960s. This event was ‘an abrupt change in precipitation in the form of a more or less well defined jump in the mean, preceded by an otherwise stationary pattern of events’ (Demaree and Nicolis, 1990: 221). This change resulted in a reduction of up to 30 percent in the average rainfall of tropical northern Africa between the periods 1931-60 and 1961-90 (Hulme, 1992), a change which was observed locally in an area immediately east of the Kano-Maradi region (Hess et al., 1994).

Desiccation is the product of an increased frequency of drought, and given a sharply seasonal rainfall regime in which one growing season is separated from the next, this is what matters for farmers and livestock keepers. No mechanism linking the rainfall in one season with that in the next has been demonstrated. Linkages between land use or vegetation changes, as proposed in Charney’s surface reflectivity model (1975), and Walker and Rowntree’s soil moisture model (1977), did not receive immediate empirical confirmation (Nicholson, 1988). The rainfall in each season, therefore, is a random probability for practical purposes (though modelling of the effects of land cover and soil or surface condition on rainfall continues: Zheng and Eltahir, 1998). A random probability approach certainly accords with folk understanding in Sahelian societies.

Variability is a normal characteristic of Sahelian rainfall. The Sahel is intermediate between the desert and the subhumid zones of Africa, with average departures from the annual mean rainfall (1901-1973) of 20-40 percent (Janowiak, 1988). The key source of variation - and of drought - is the seasonal rainfall. This has a characteristically sharp peak in July or August. Rainfall in August shows a low-frequency fluctuation, which is superimposed on the general downward trend, so that August rainfall is significantly correlated with seasonal rainfall (Nicholson and Palao, 1993). Rainfall in June-July, however, fluctuates with a high frequency, that is, it is less related to seasonal rainfall or to the general trend.

It has also been shown that the number of storm events, rather than the amount of rain that they each deliver, accounts for much of the variation (D’Amato and Lebel, 1998; Agnew and Chappell, 1999). This carries the connotation that the migrations of the Inter-Tropical Convergence (ITC) - the mechanism that brings rain to the Sahel - are not the primary cause of drought. Rather, drought is the result of dynamic conditions in the weather system. Consequently, in drought years, convectional rainfall fails to develop
normally, and storms often produce dust rather than rain. A study of the relationship between the position of the ITC and rainfall (during the period 1983-88), which used satellite indicators of cloud formations, showed that other than in one year (1988), there was no systematic difference between dry and wet years in the location of the ITC. Rather, differences were readily apparent in the intensity and spatial extent of convection, justifying the conclusion that ‘....the ITCZ appears to be displaced northward in some, but not all, wet years in the Sahel, but that no anomalous southward displacement is evident in dry years. Drought in the Sahel is then apparently more clearly linked to reduced convective activity’ (Ba et al., 1995: 428; Nicholson, 1981).

Defining and evaluating Sahelian rainfall anomalies, among which drought is foremost, is affected by the selection of an averaging period as a ‘normal’ baseline with which to compare the rainfall in a particular year, month or decade. The long-term fluctuations affect averages (Hulme, 1992; Jones and Hulme, 1996). Thus if the 30-year period 1931-60 is taken as ‘normal’, the subsequent years of strong negative anomalies truly suggest a crisis for land-users. When the Sahel Drought first struck in the early 1970s, the rainfall of those 30 years was large in the ‘collective memory’ of farmers and livestock keepers. Younger people could not remember a comparable drought. On the other hand, to use the 30-year period 1961-90 (currently used by the World Meteorological Organisation) produces a distorted picture of the previous period, and the 1950s in particular, as ‘exceptionally’ wet. In the analysis which follows we use a data series based on the 60 years, 1931-1999.

Meteorological definitions of drought, to which there is no practicable alternative, nevertheless present certain difficulties as the ecological or agronomic impact of a rainfall anomaly is affected by the seasonal distribution of rainfall, in combination with soil conditions, natural vegetation, and other factors which can be affected by management. In this profile we are concerned with the significance of climate change for such interactions. The impact of desiccation on human affairs can be graphically portrayed in maps showing the migration of rainfall isohyets, in this region southwards, as latitude is significantly correlated with rainfall (Mortimore, 1989; Sivakumar, 1992; ICRISAT, 1993; Ozer and Erpicum, 1995; Badiane, 2000, Bouzou, 2000). This simple picture is complicated by an increased variability and seasonality (Hulme, 1992), which add to the risk faced by the production systems. The question of adaptation to these risks is taken up again below.

3 **ANALYSING THE CHANGES**

3.1 **Desiccation**

Figure 1 shows long-term annual rainfall series for Kano Farm (Lat. 12° N; mean annual rainfall, 796 mm) and Zinder Aero (Lat. 14°N; mean annual rainfall, 469 mm), from 1916 to 1999. The annual series show strong similarities, with low rainfall at both places in 1917, 1919, 1926, 1937, 1943, 1949, 1972-73, 1983-84, and 1987. The two series have a correlation coefficient of 0.66. The running means show similar slopes throughout, and especially from 1928 to 1949, and from 1954 to 1973 (both periods of approximately twenty years). After 1974, the next twenty years saw a short-lived rise
Figure 2: Seasonal rainfall (5-yr means), Katsina, Magaria, Maradi, Nguru, 1933-1999
from 1974 to 1979-80, followed by a fall to very low rainfall in 1982-86 (Kano) and 1983-86 (Zinder), and then an improvement at Kano but two very dry years in 1996 and 1997 at Zinder. The similarity between these series illustrates the strong spatial persistence of rainfall patterns (which extend across latitudes) noted by Nicholson and Palao (1993), not only in the long-term downward tendency but also in the shorter 20-year phases or low frequency fluctuations.

These long-term patterns condition the expectations of ‘normal’ rainfall and define the adaptive challenge that faces farmers and livestock keepers in the Kano-Maradi region. No other series of this length are available. To accommodate shorter series (Table 1), but to include two successive 30-year periods, we now focus on the period beginning in 1931.

For this period, three of the other four stations (Magaria, Maradi, Nguru) confirm the general pattern (Figure 2). The data series for Katsina is incomplete. The graphs show rainfall during the growing season only (May-September). Rainfall before this season is useless, being usually followed by drought; and amounts received in October are usually negligible, though an unexpected shower can assist late maturing crops.

3.2 Changes in seasonality

Given the similarity of rainfall patterns among the six stations, changes in seasonality are shown with 5-yr running means for an average of all six stations, arranged by month (Figure 3). Trend lines are added. Strong differences in slope suggest significant variation between months in the rate at which rainfall has declined during the period, with May and September declining most steeply and July the least. This is consistent with a shortening of the average rainy season. However, these trends disguise large differences in variability, judged by a visual inspection of the running means. Rather surprisingly, variability about the trend diminishes steadily from the beginning (May) to the end (September) of the season. In practical terms, this means that the beginning of the growing season is increasingly unpredictable, but a shortening at the end is increasingly likely. It may further be observed that each month has its own pattern of low-frequency fluctuation, though a close inspection reveals most of the key features of the annual and seasonal curves in the monthly ones. The differences are due to the small number of stations used.
Figure 4c: Variability of annual rainfall (SPI), Kano Farm, 1931-1999
3.3 Drought

The measurement of drought depends on the selection of averaging period (Agnew and Chappell, 1999), and to avoid the distortions implicit in using either of the two 30-year periods (1931-60 and 1961-90), we employ the long-term average seasonal rainfall (May-September) for each station to compute a Precipitation Index (PI) according to the formula

\[ \text{PI} = \frac{(X - \bar{X})}{\text{SD}} \]

where
- \( X \) = seasonal rainfall for the year and station,
- \( \bar{X} \) = average seasonal rainfall (of the period specified for the station), and
- SD = the seasonal standard deviation for the station (Downing et al., 1988; Mutiso et al., 1990 - in a parallel study of Machakos District; Agnew, 2000).

Figure 4 shows the results of this analysis for the three stations for which we have complete records: Zinder Aero and Maradi (seasonal rainfall) and Kano Farm (annual). As this construction represents each year or season separately, in terms of departures from expectation (the long-term mean) rather than absolute amount of rainfall, it reflects the circumstances of farmers and livestock keepers more realistically than a running mean. A transition from frequent positive anomalies to negative in the early 1960s is clearly shown at all the stations. The exceptional high rainfall in 1998 confirms a rising trend during the later years of the sequence. But a straight trend line does not describe the pattern as well as a sinuous curve with a 30-40 year wavelength. If this pattern is continued into the future, it carries positive implications for both governments and land users.

Drought probability classes for the Sahel have been proposed by Agnew and Chappell (1999), using a normalised precipitation index based on standard deviations from mean rainfall. This allows rainfall anomalies to be computed for each station in relations to its own ‘normal’ rainfall, in a form which permits comparison with other stations irrespective of the amount of average rainfall. Using this method, the intensities of drought experienced at our six rainfall stations are shown in Table 2. Some of them were, to a varying degree, local but the major regional droughts of 1949, 1972-73, 1983-84 and 1987 are very clearly shown. From 1931 until 1942, drought was rare, and an even longer period of relative freedom from drought occurred between 1950 and 1970. But in the following 26 years there were three major regional droughts, two of them lasting for two years or longer (1972-73 and 1983-84). An important observation is the significantly greater severity of the drought of 1983-84 compared with that of 1972-73. This was most conspicuous at Maradi, where three extreme droughts occurred in consecutive years (1982-84). Indeed, drought had become such a frequent occurrence by the 1980s that the extreme event of 1987, which affected all six stations, attracted little attention outside the region.

The frequency of moderate, severe and extreme droughts at the six stations is shown in Table 3. During the 60 years, a moderate or worse drought occurred on average every 4.8 years and a severe or extreme drought every 8.1 years. However, as their distribution in time shows, the frequency of droughts increased after the early 1970s, so
such averages have little practical value. Remarkably, this table shows that the frequency of drought (moderate or worse, severe or worse), characterised by this method, does not vary significantly. It is for practical purposes equally common and equally severe at all six station, irrespective of latitude or average seasonal rainfall. This corrects a common illusion that drought becomes more frequent as rainfall diminishes towards the desert.

Table 2: Intensity of droughts at six stations, 1931-1990 (seasonal rainfall) (major regional droughts shown in bold)

<table>
<thead>
<tr>
<th>Year</th>
<th>Zinder Aero</th>
<th>Magaria</th>
<th>Maradi</th>
<th>Nguru</th>
<th>Katsina</th>
<th>Kano Aero</th>
</tr>
</thead>
<tbody>
<tr>
<td>1942</td>
<td>Mod</td>
<td>Mod</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1944</td>
<td></td>
<td>Sev</td>
<td>Ext</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1948</td>
<td>Mod</td>
<td></td>
<td>Ext</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1949</td>
<td>Sev</td>
<td>Sev</td>
<td>Sev</td>
<td></td>
<td>Sev</td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>Mod</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>Sev</td>
<td></td>
<td>Sev</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sev</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>Mod</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1971</td>
<td>Mod</td>
<td>Mod</td>
<td>Mod</td>
<td></td>
<td>Mod</td>
<td></td>
</tr>
<tr>
<td>1972</td>
<td>Sev</td>
<td>Mod</td>
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<td>Sev</td>
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<tr>
<td>1975</td>
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<td>Sev</td>
<td></td>
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<td>1976</td>
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<tr>
<td>1977</td>
<td>Sev</td>
<td></td>
<td></td>
<td></td>
<td>Mod</td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mod</td>
</tr>
<tr>
<td>1981</td>
<td>Sev</td>
<td>Mod</td>
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<td>Mod</td>
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</tr>
<tr>
<td>1982</td>
<td>Sev</td>
<td></td>
<td>Ext</td>
<td>Mod</td>
<td>Mod</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>Sev</td>
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<td>Ext</td>
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<td>1984</td>
<td>Sev</td>
<td>Sevt</td>
<td>Ext</td>
<td>Mod</td>
<td>Ext</td>
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<td>1985</td>
<td>Mod</td>
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<td>Ext</td>
<td>Mod</td>
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<td>1986</td>
<td>Mod</td>
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<tr>
<td>1987</td>
<td>Ext</td>
<td>Ext</td>
<td>Sev</td>
<td>Sev</td>
<td>Ext</td>
<td>Sev</td>
</tr>
<tr>
<td>1988</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1989</td>
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<td></td>
<td></td>
<td></td>
<td>Mod</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Sev</td>
<td>Sev</td>
<td>Mod</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Extreme drought: PI= < -1.65
Severe drought: PI = < -1.28
Moderate drought: PI = <-0.84
- no data

Is the period of low rainfall and frequent drought observed since the 1960s soon to be reversed? Upturns in the running means in the late 1990s (at Kano) are influenced by the exceptionally high rainfall of 1998. There has also been a diminution there in the frequency of droughts. But while offering some hope of a return to higher levels, such an upturn cannot be shown to have any statistical significance.
Table 3: Frequency of droughts at six stations, 1931-90 (seasonal rainfall)

<table>
<thead>
<tr>
<th>Station</th>
<th>Lat. (°N)</th>
<th>Mean (mm)</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
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<td>13.45’</td>
<td>473</td>
<td>6</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Magaria</td>
<td>13</td>
<td>511</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Maradi</td>
<td>13.25’</td>
<td>553</td>
<td>3</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Nguru**</td>
<td>13</td>
<td>472</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Katsina***</td>
<td>13</td>
<td>667</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Kano Aero</td>
<td>12</td>
<td>773</td>
<td>5</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

**1942-92    **1931-1987

4 ADAPTATION

It is commonplace for observers of rainfall decline in the Sahel to underline, not only the risk to production, but the possibility of environmental degradation or desertification (Sivakumar, 1992; Agnew, 1995; Le Houérou, 1996). In such scenarios, climate is never the sole agent, but the effects of climate change are thought to be amplified by maladaptive behaviour on the part of human populations (overgrazing, over-cutting and deforestation, over-cultivation and the abandonment of fallowing, over-exploitation of subsurface water resources). There is also a number of studies of the possible reverse effects of changes, brought about by management of the vegetation, soil or surface conditions, on rainfall itself (for a recent review, see Zheng and Eltahir, 1998).

It is not within the scope of this profile to explore the nature of adaptive change in the economic, technical and social or institutional systems of the Kano-Maradi region (see other Working Papers in this series). However, the inevitability of degradation is challenged by the positive achievements of human populations in sustaining their livelihoods under conditions of severe climatic deterioration. Among these, the following may be mentioned:

- Between 1960 and 2000, both Niger as a whole and Maradi Department in particular have maintained or increased food grain production, notwithstanding the exhaustion (or ‘saturation’) of the cultivable land available (Hamadou, 2000). This has been achieved without a major fall in millet yields per hectare. In the Kano region, farmers switched from groundnuts to grain production in response to price incentives (Ariyo et al., 2000).

- Technical changes have been brought about in agriculture on a wide scale, including the intensified use of bas-fonds or fadama depressions, the substitution of short-cycle for long-cycle millet and cowpea varieties, the exploitation of sorghum varieties adapted to grow on residual moisture, and the adoption of new commercial crops such as tiger nut (Maradì), guna melon (NE Kano), and Hibiscus. Ploughing technology has been extended.

- Livestock populations have been reconstructed after each drought episode and a long-term rising trend in animal populations (in standard Tropical Livestock Units)
has been maintained in tandem with rising human populations and increasing pressure on land. Integrated management of crops and livestock has increased, and there is a growing fattening industry which responds to a rising demand for meat.

- An increasing proportion of arable land has been brought under permanent cultivation (Mahamane, 2000; Turner, 1997), with organic fertilisation replacing the use of subsidised inorganic fertilisers since the 1980s. There is evidence that fertility can be sustainable under such management, provided that animal manure is available in sufficient quantities (Harris, 2000; Mahaman, 2000).

- Stable and well-managed tree populations on farms, long recognised in the Kano Close-settled Zone and other densely populated areas of Nigeria, are now increasingly common in areas with lower but rising densities where arable land is rapidly replacing natural woodland (Awaiss, 2000).

- Not only because of the risk to agricultural activities, but also in response to a need for employment, monetary incomes, funds for consumption and investment capital, household incomes have been diversified further, through migration in search for opportunities (Tiffen, 2000).

These trends, which are selectively mentioned here, show that while a majority of rural households are poor in both the Maradi and the Kano regions, climate change has not undermined the basis of economic life. Positive trends in soil fertility and tree management, in a context of intensifying drought stress, are remarkable in such circumstances.

REFERENCES


