Chapter 20

IMPLICATIONS FOR AFRICAN AGRICULTURE OF THE GREENHOUSE EFFECT

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ABSTRACT

Africa is the one continent which still relies very heavily on agriculture to feed its fast growing population because industry, though significant in a few patches in the North and in the South, is still in its infancy. African agriculture is still largely traditional although important facets of it are gradually coming under increased scientific management. As it is, agriculture is very sensitive to climate which is marked by fluctuations and incessant variability. Frequent and prolonged droughts and dessication are already a threat to agricultural production. Thus the risk of CO_2 induced global warming as part of the greenhouse effect would naturally be an added burden to be coped with. At present the projections of global warming produced by the various GCMs suggest that much of tropical Africa will remain warm and may be up to 1°C warmer, but that the subtropical parts of the continent could experience a more significant warming of up to 1.5°C. Contrary to the expectations, global warming in Africa may be accompanied by a Northward shift in the rainbelts bringing more rainfall to the hitherto parched desert lands of the Sahara in the North and the Kalahari in the South, making it possible to carry out some form of agriculture in these regions. But not enough is known of the actual likely distribution of rainfall on a seasonal and annual basis and how agriculture in these lands will respond to the changed conditions. Certain crops like wheat and corn associated with the subtropical latitudes may suffer a drop in yield due to increased temperature on the one hand and rice may may disappear due to higher temperatures in the tropics. Elsewhere agriculture is expected to survive and even become stronger especially where mixed cropping is currently practised and where tree crops are predominant. The high altitude farming districts may have their altitudinal zonation wiped out and be forced to find new forms of agriculture. However, methods of adjustment could be adopted to cope with climate change including the use of new seeds, drought resistant crop varieties and the greater use of irrigation where water availability becomes a constraint to agricultural production. In general Africa should be in a position to survive a global warming by introducing such adjustments and, by making agricultural land use more flexible.

INTRODUCTION

The African continent relies heavily on agriculture to support its rapidly growing population. Industry is still relatively insignificant except in South Africa, and restricted parts of the Mediterranean Region such as Egypt and some of the Maghreb states, but the total contribution to the greenhouse effect in Africa as a whole is very small. Forests cover large parts of tropical Africa, but in almost all cases they are under severe pressure leading to large scale felling for timber as well as clearing for agriculture, and this is thought to be adding to the global warming through the massive release of greenhouse gases, chiefly CO_2. As is well-known, large parts of the continent are either arid (as in the Sahara and Kalahari Deserts), semiarid (including all the "Sahelian" lands - with the "Sahel" as a generic term) or subhumid. The continent has a long chequered history of droughts and dessication, which have been marked by severe famines since time immemorial, and these should be considered a good dress rehearsal for the global warming if it ever comes. All the same, it is fair to say that much of Africa will be peripheral to the greenhouse induced global warming because it is already either tropical or subtropical whereas the greatest impacts of such warming will be experienced in the temperate and polar latitudes.

What is known about African agriculture, if indeed it could be generalised, is that it depends heavily on rainfall, hence on the significance of climatic fluctuations as well as the possibility of climate change because these could exacerbate the already severe conditions of drought which have been typical of the Sahelian lands of West Africa and other semiarid and sub-humid regions throughout the continent. In this context the subtropical parts of the continent both in the North as well as in the South are different because these are the regions where crops sensitive to significant temperature variations such as wheat, barley and oats are grown, and which will be affected by large temperature shifts as predicted in global warming models. The highland areas in tropical and subtropical Africa will fall into the same category as the subtropics so that significant temperature shifts could disrupt existing agricultural patterns which are currently strictly zoned according to altitude induced temperature differences.

African agriculture as a whole is arranged according to agroecological zones (FAO, 1982) which are climate sensitive. Any drastic changes as those likely to be brought about by global warming could be extremely disruptive in terms of the crops which could no longer be grown, and other farming systems which could no longer be sustained. Areas of the continent which rely on irrigation, though not very extensive, are significant, and cover the densely populated areas such as the Upper and Lower Nile Valley in the Sudan and Egypt, and large tracts of the Mediterranean lands of Northern Africa (the Maghreb lands including Morocco, Algeria, Tunisia and Libya). Greenhouse induced global warming could bring about important changes in the agricultural potential of such areas, and it is therefore interesting to study the likely nature of climate changes to be expected so that appropriate adjustments can be made. In the event of climate change, conditions suitable for continued agricultural production could change in two directions, either adverse or more conducive, depending on the particular circumstances of a given region or subregion. Changes in precipitation will largely be expressed in terms of changes in soil moisture; similarly changes in temperature will be reflected in seasonal changes in evapotranspiration rates and ultimately in soil moisture and changed conditions for crop growth. Unfortunately most of the projected changes are better understood at the experimental level (i.e. in the laboratory) than at the country level, let alone, at the continental level. Nevertheless, it is instructive to study the projected climatic changes even if they remain theoretical, because with these projections it is possible to learn how African agriculture might respond to the new conditions.

WHAT THE GCMS SAY ABOUT GREENHOUSE WARMING IN AFRICA

In a short article such as this one it is not possible to go into too much detail about the various climate models and what they say or do not say about the expected conditions for Africa. Nevertheless, it is possible to summarize the main arguments put forward, and their relevance to the African scene. To begin with most GCMs are generally vague and even more vague about the tropics. Part of the reason for the vagueness about the tropics, and about the tropical Africa in particular, is due to the paucity of climatological data upon which to base their analyses. Secondly, it is true to say that the greatest sources of CO_2 emission (industrial) are located in the temperate latitudes of the Northern Hemisphere, and that simulations of global warming indicate that it is these same latitudes which will also be the most affected, and that the effects will spread polewards (see Hansen et al. 1981 and 1988; Manabe and Whetherald 1986). Over a 50-100 year period, global mean annual temperatures are expected to rise by from 1.5°C to 5°C, assuming that by that time global CO_2 levels will have doubled (2 x CO_2). Practically all the models agree on the fact that the warming will be more pronounced at higher than lower latitudes, and that the warming will probably be greater in winter than in summer (Parry et al. 1986 and 1990). If one looks at the conclusions of the main GCMs, namely the CCM, GFDL, GISS and OSU, medium USA temperature increases are of the order of 3.0°C, 5.6°C, 3.8°C and 3.5°C respectively for a doubling of CO_2 and accompanying rainfall scenarios are more uncertain than temperature change scenarios and may vary considerably over regions. For example, under some scenarios there is a likely decrease rather than an increase in precipitation with increased temperatures. If additional GCMs are considered for example NCAR (Washington and Meehl 1984) and UKMO, there is an even more categorical statement that expected global mean temperature rises will be around 2°C in the tropics and 5°C in higher latitudes. Inevitably, all the models are more refined when commenting about temperature changes than they are about rainfall and other climatic parameters which are relevant to agriculture such as cloud cover, radiation, soil moisture and air movement. So far few categorical statements are found in the models about what temperature rises will look like in the tropics and what the rainfall distribution will look like in specific regions such as tropical Africa. As a result of this vagueness in the GCMs it may be of some assistance to look at analogue data or historical evidence in areas with poor or broken records such as in Africa.

HISTORICAL EVIDENCE OF CLIMATE CHANGE IN AFRICA

The most comprehensive evidence of climate change in Africa over the last 4,000 years has been put together by Sharon Nicholson (1976, 1978, 1979, 1980 and 1981). It is not possible to summarize all her contributions in a short paper, but her work contains a more detailed record of rainfall variability and general climate variations in various parts of tropical Africa over the period covered. A detailed record is provided of droughts, enhanced or depleted lake levels and river gaugings, which leave no doubt about the dramatic changes that have been experienced. The historical information on famines, droughts, lake and river levels in Africa has been supplemented by dendrochronological evidence from other parts of the continent, and they all confirm the variability as well as long-term climatic fluctuations which are continuing into the present era. Indeed, if the CO_2 induced global warming occurs in large parts of arid and semiarid Africa, one will not be taken by surprise because the droughts, famines and dessication have already provided a dress rehearsal for what may be expected and the new conditions may not necessarily be much worse than the experience of for example the 20 year drought in the Sahel.

Other scholars have equally elucidated the historical evidence of climate change and climatic fluctuations in Africa. Most authors agree on the frequency of prolonged droughts and dessication some of which may have a return period of 30 to 50 years. From the point of view of agricultural performance it is clear from the available evidence, in particular of droughts, that much of tropical Africa has already had to cope with so much rainfall variations that even the projected changes, projected under CO_2 induced global warming will not necessarily be worse. If anything, the arrival of the presumed global warming might bring wetter conditions with it for many currently semiarid areas like the Sahel in West Africa and even for parts of the Sahara and Kalahari deserts which have not experienced wet conditions for centuries.

Kellogg (1977) and Kellogg and Schware (1981), two of the earlier researchers on CO_2 induced global warming, collected some interesting analogue evidence for Africa from more than 100 sources which were used to construct a map showing what the conditions looked like during the Altithermal Period

(4000-6000 BP) in terms of areas which were then "wetter" or "drier" than at present. For tropical Africa, and similar areas like the Rajasthan Desert in India, conditions then were decidedly wetter than they are today (see Fig. 20.1).

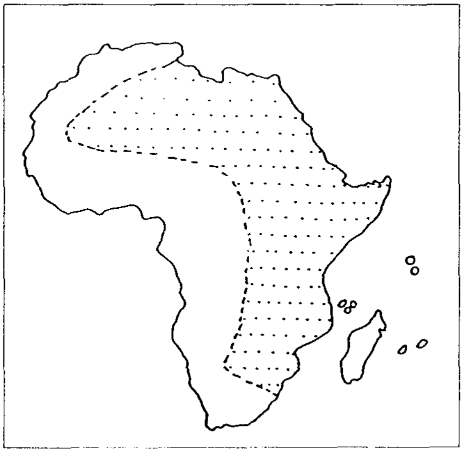

Fig. 20.1 Rainfall distribution in summer during the Altithermal period of 4000 to 6000 BP (after Kellogg and Schware (1981)

If the Altithermal experience could be reproduced for Africa during the CO_2 induced global warming of the next 50-100 years, even large areas currently unable to support agriculture because they are too arid might become very attractive for the first time in several centuries. The map in Fig. 20.1 is best interpreted if compared with Fig. 20.2 which portrays the current mean annual rainfalll on the continent, and the map showing the co-efficient of the variability of annual rainfall for Africa given in Fig. 20.3. The rainfall in many parts of Africa has been marked by violent fluctuations, interannual variability and general lack of dependability. There is nothing to suggest, even with changed climate as is postulated in global warming, that the characteristics of the climate of Africa will be any different. Thus, even if global warming were to bring more rainfall to the hitherto parched lands of the Sahara Desert and its fringes, agricultural planners will still have to cope with both seasonal and interannual variability of rainfall.

In the context of the current climate, researchers in Africa still have very little to go on since the signals from the GCMs seem to be much clearer for areas outside the tropics, more towards the polar latitudes, especially on the Northern Hemisphere. What is known and fairly well established is the fact that the effect of increased CO_2 levels on the atmospheric circulation pattern and hence on the temperature and precipitation distribution, will result in a general northward movement of agroclimatic zones (Bach 1978). If this shift will occur, there is some general agreement that tropical agriculture may suffer the least (Bach 1978), but increased drought risk on the fringes will occur.

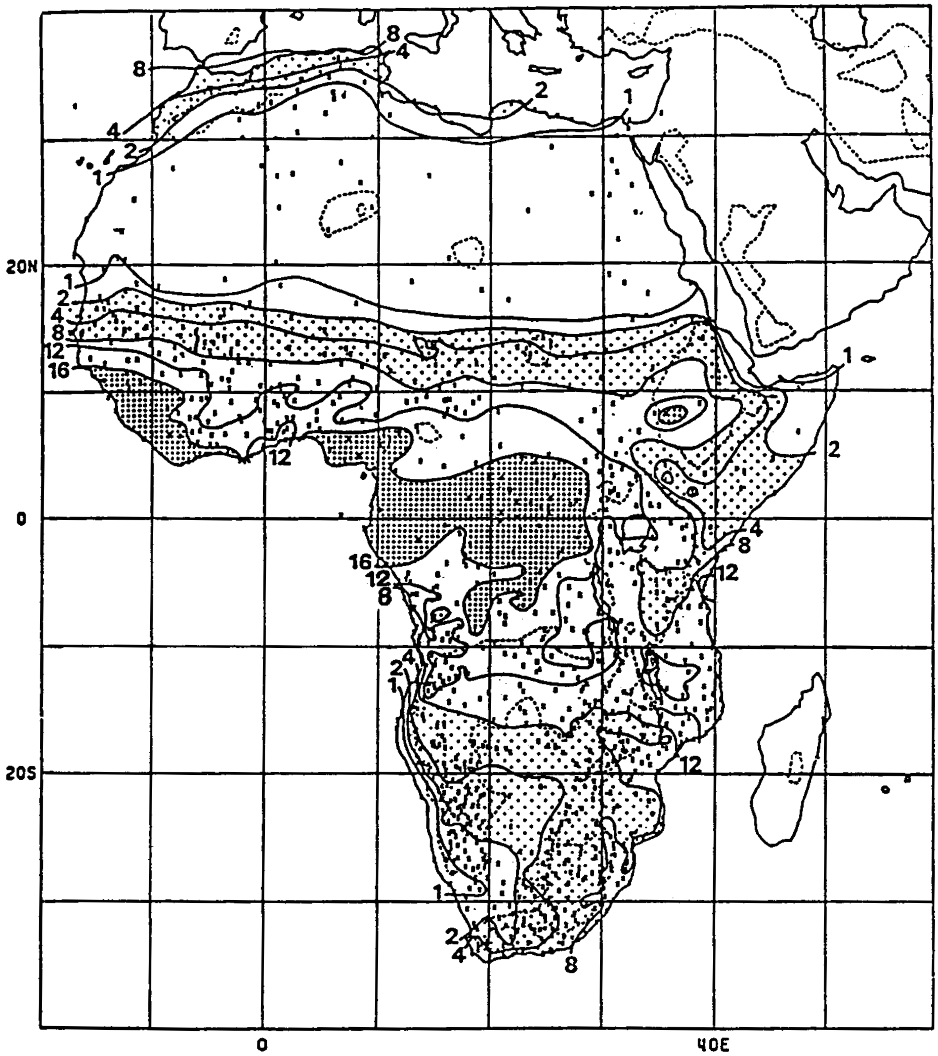

Fig. 20.2 *Annual mean rainfall. Unit: 100 mm. Dark shaded area: > 1600 mm. Light shaded area: 200-800mm. Cross marks: rainfall observation stations. Thin broken line: 1000mm contour (derived from Nicholson African data set, in Makomura (Ed.) 1989)*

CLIMATIC CHANGE AND LAND USE AND AGRICULTURE IN AFRICA

Before tackling the more specific impacts of climate change on the African scene in general, and global warming in particular, it should be instructive to work at the general picture of land use on the continent. The current land use is very much governed by water availability whether this be in the form of rainfall, or in the form of water available for irrigation.

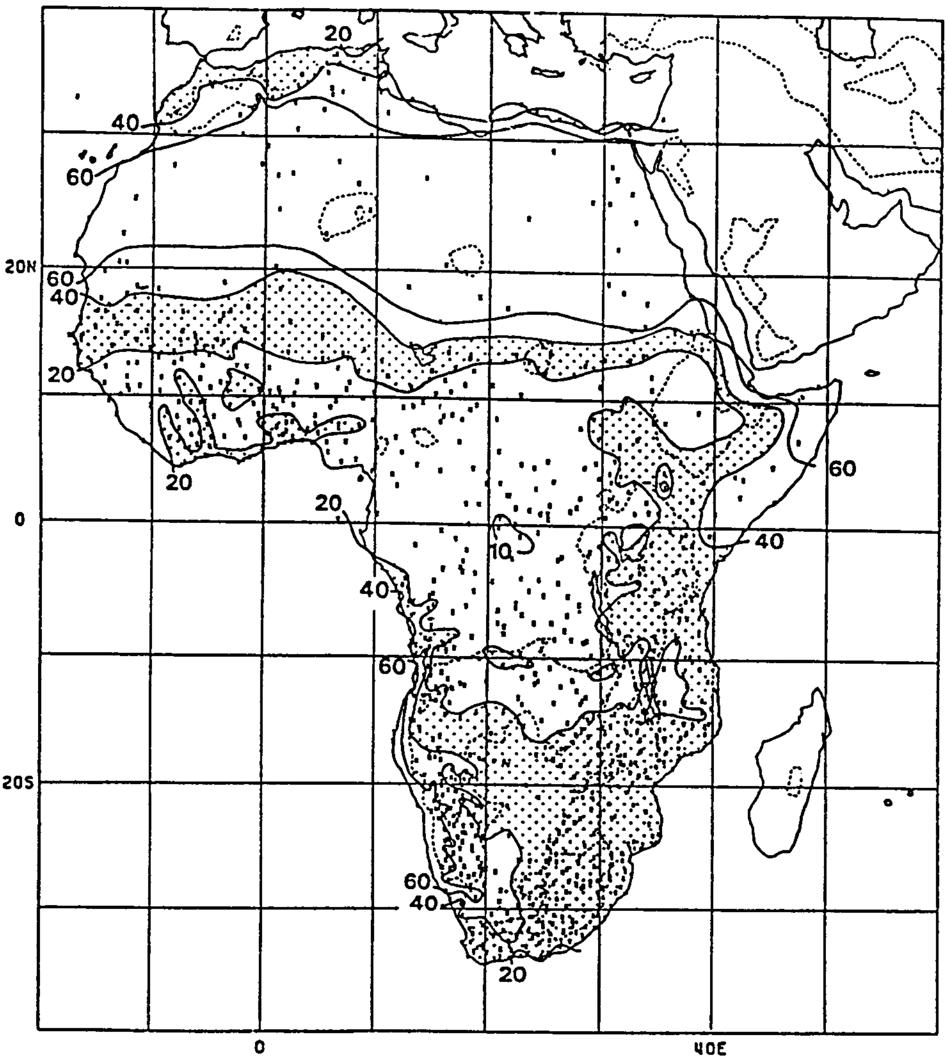

Fig. 20.3 *Coefficient of the variability of annual rainfall (standard deviation of annual totals/annual mean). Unit: %. Shaded area: 20-40%. (derived from the Nicholson African data set, in Kadomura (Ed.) 1989)*

Fig. 20.4 is a generalised map showing the extent of water resources which can support agriculture on the continent, including irrigated areas, areas with adequate rainfall and the semiarid, arid and extremely arid areas where water for crops becomes a problem progressively. In this map one cannot fail to notice the perennial problem areas where inadequacy of rainfall coupled with the lack of irrigation water have resulted in the impossibility of any meaningful form of agriculture. Fig. 20.5 illustrates the expected response to the water situation which has evolved over centuries.

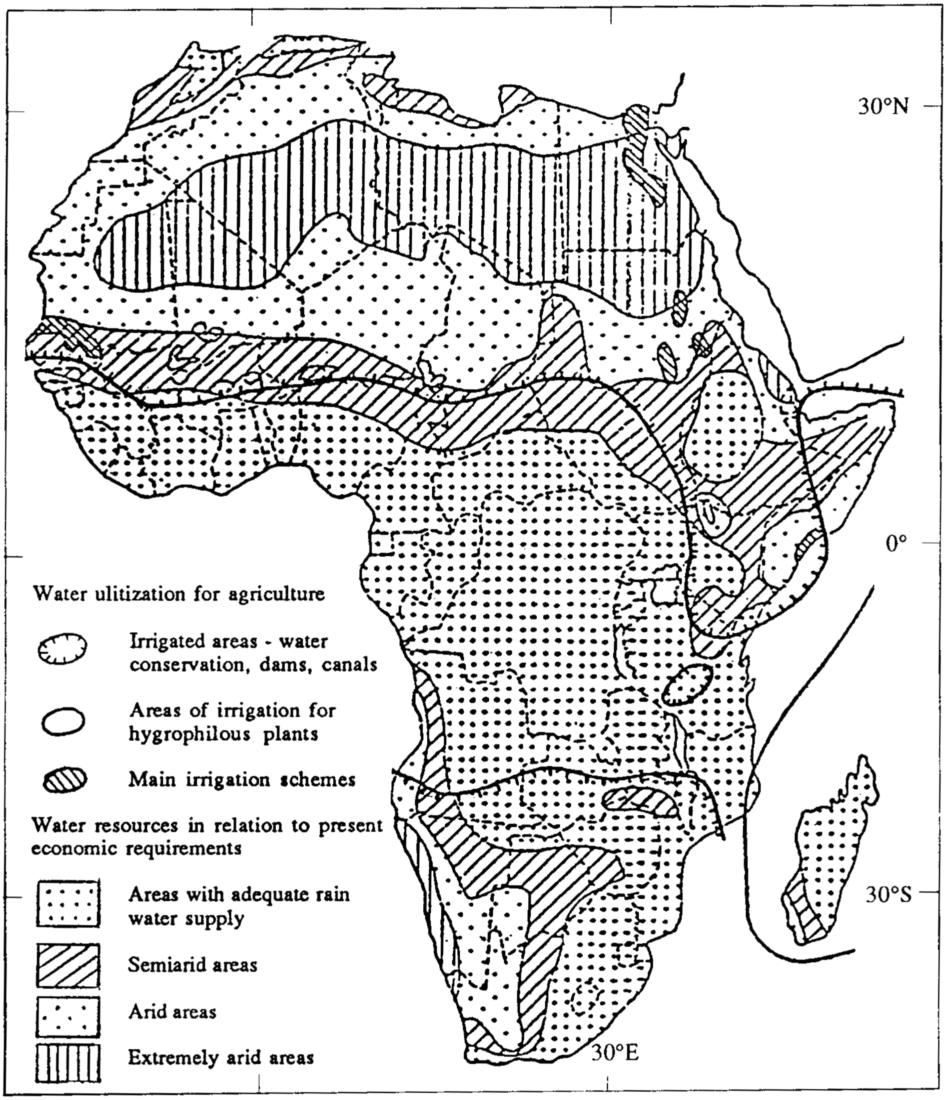

Fig. 20.4 Water availability for agriculture

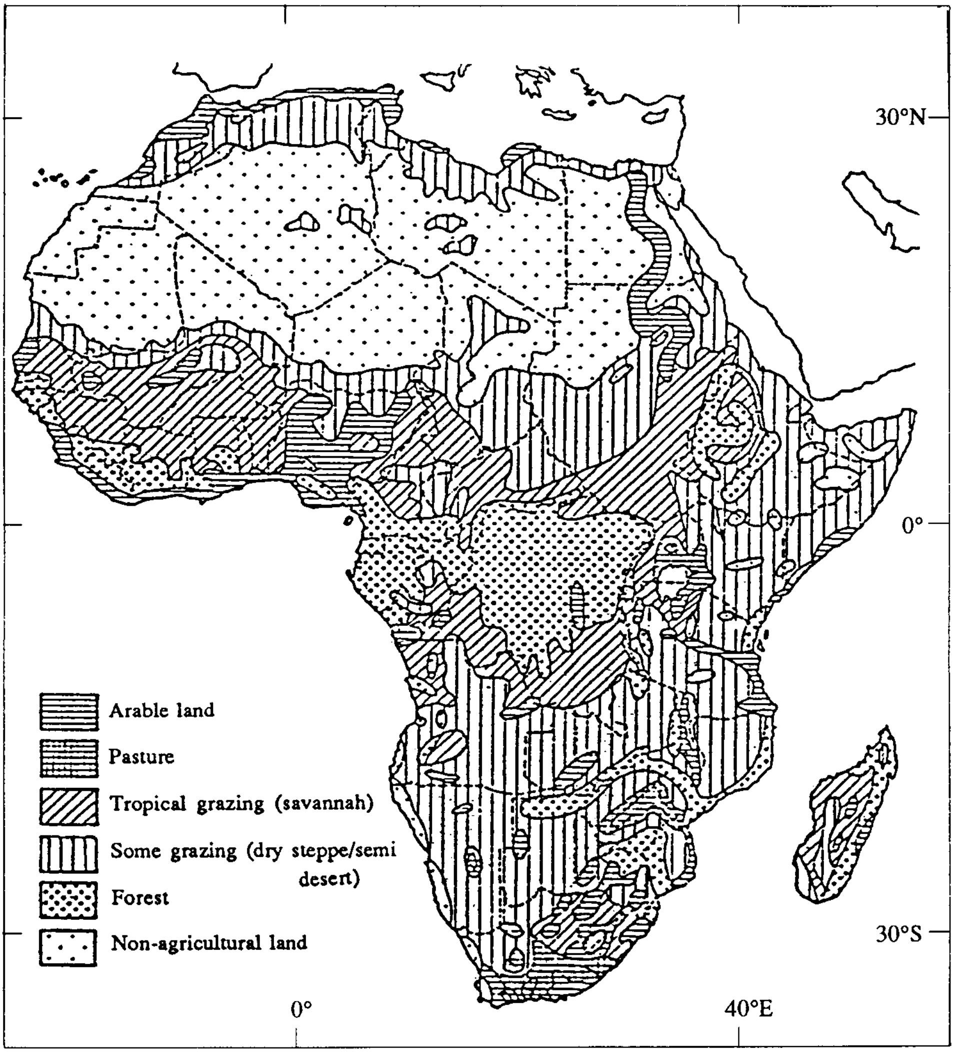

Fig. 20.5 Land use in Africa

This land use map shows areas where arable land is in abundance (largely because water for agriculture is available), pasture lands, tropical grazing (usually associated with the savannahs with adequate rainfall), dry steppe and semidesert grazing (where the shortage of moisture keeps out agriculture), the deserts , and the closed forests.

The foregoing section has briefly sketched the current climatic background to agriculture in Africa. It is also possible to go into detailed agro-climatological zoning of the whole continent, as has been carried out by the United Nations

Food and Agriculture Organization (FAO) and the International Institute of Applied Systems Analysis (IIASA) who prepared an Agro Climatological Map of Africa and followed this with an analysis of the potential population supporting capacities of the various agroecological zones for tropical Africa (FAO/UNFPA/IIASA 1986).

The point that needs emphasising is that currently Africa is relying rather heavily on rainfed agriculture. However, in the projected climate change scenarios, there is likely to be increased availability of rainfall, hence soil moisture even if this is not evenly distributed regionally. It therefore now only remains to comment on the likely impacts on agriculture of the changed conditions which are expected to accompany global warming.

TYPES OF AGRICULTURE IN AFRICA AND THE LIKELY EFFECTS OF GLOBAL WARMING

The likely effects of global warming on African agriculture are expected to be uneven even if one were to assume a generally increased rainfall because the current agriculture is already sensitive to temperature in two particular subregions and subzones, namely:

- The subtropical parts of Africa in the "Mediterranean North" and "Mediterranean South" are currently referred to as areas of Mediterranean agriculture with cereals like wheat, orchards, vineyards and specialized crops which are all sensitive to even minor temperature changes and therefore likely to be impacted by the envisaged temperature increases (1.5°C?) under a global warming.
- High altitude areas within the tropics where currently temperate crops (including cereals like barley and wheat) are grown because of the reduced temperatures brought about by altitude.

For the rest of Africa and especially for tropical Africa current agricultural practices are likely to shield the agriculture from the adverse effects of a changed climate, in particular a warmer climate. Fig. 20.6 which shows the main types of agriculture in Africa brings out certain important features. There is for instance a preponderance of mixed cropping which is thought to be advantageous even in a changed climate because some crops will benefit from temperature increases where others suffer. In general, areas dominated by tropical crops are expected to benefit rather than suffer from increased temperatures. Even more important is the fact that the GCMs do not envisage very large temperature increases (1.5°C) for these tropical areas. It is therefore somewhat hypothetical to try and guess how the agriculture is likely to respond to a changed climate where the possible change is expected to remain within the ranges which have always been experienced, at least in the last 200 years. In the final analysis each crop will have its own unique response to changed or changing climatic conditions and it is here where some instructive information may be sought. Unfortunately, the bulk of the studies on these aspects has been carried out in temperate latitudes, so one can only infer what is likely to transpire in the tropics and subtropics where similar crops are found, as will be summarised briefly in the next section.

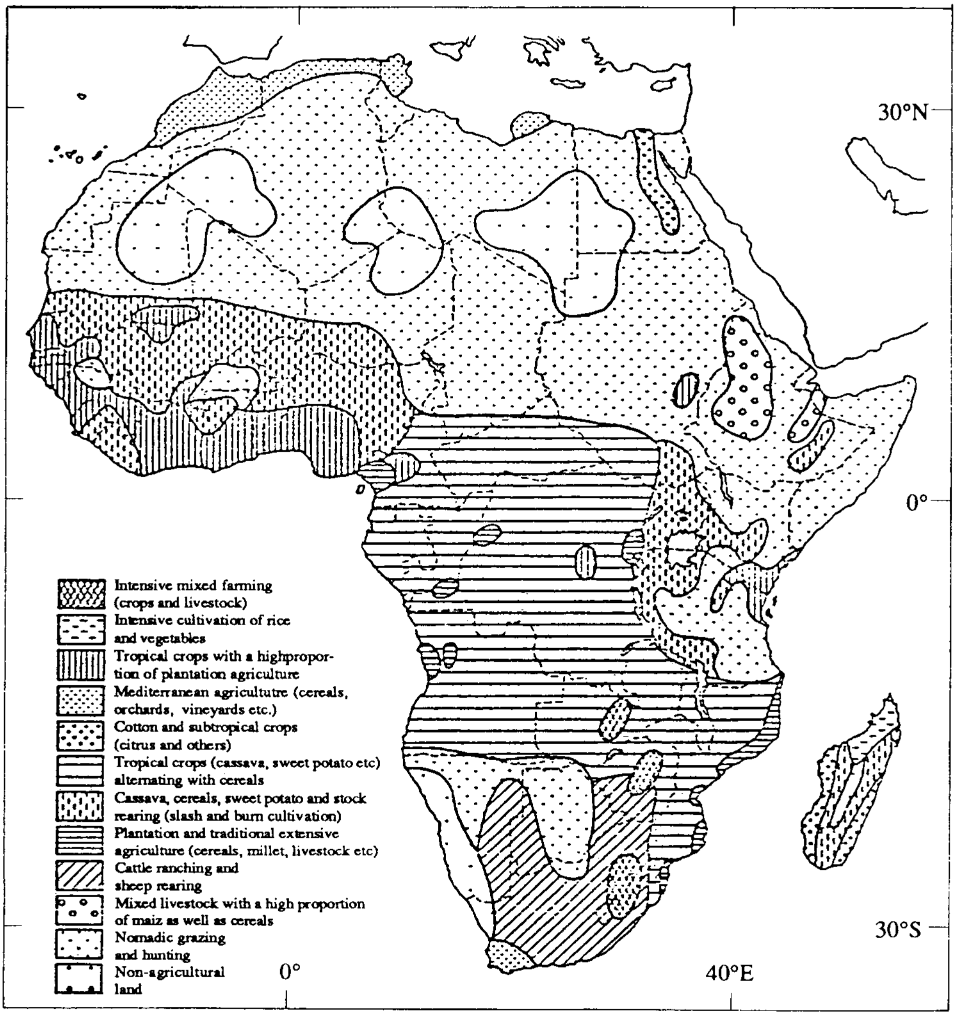

Fig. 20.6 *Types of agriculture in Africa*

CLIMATIC EFFECTS ON SELECTED CROPS RELEVANT TO THE AFRICAN SITUATION

Bach (1978) briefly analysed the effects of rainfall and temperature changes on corn (maize in Africa), and these are summarized in Figs. 20.7 and 20.8. In these illustrations it is shown that corn is very sensitive to both temperature and rainfall changes particularly during those months (July and August) where the combined effects of temperature and rainfall are critical to their growth. The accompanying projected yield changes linked to temperature and precipitation are also summarised in Table 20.1 obtained from Bach (1978). According to this table expected changes would be significant enough to depress corn yields by up to 11%.

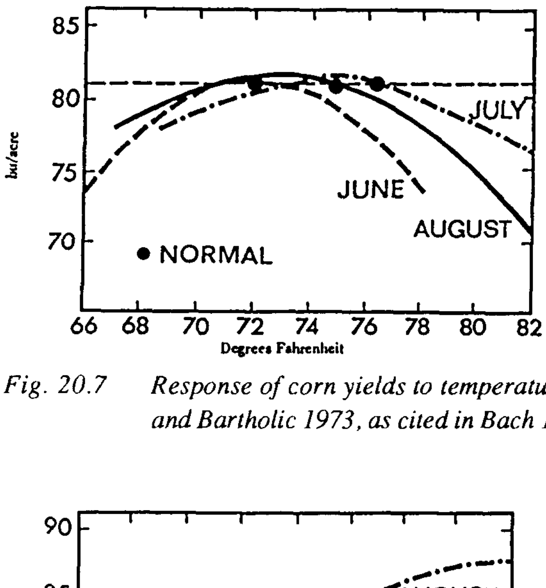

Fig. 20.7 Response of corn yields to temperature in the US corn belt (from Biggs and Bartholic 1973, as cited in Bach 1978)

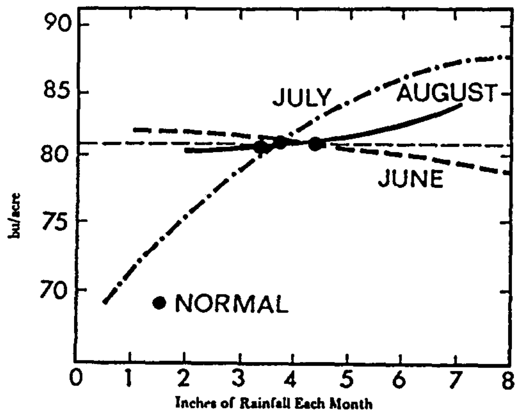

Fig. 20.8 Response of corn yields to rainfall during different stages of growth in the US corn belt (frrom Biggs and Bartholic 1973, as cited in Bach 1978)

Table 20.1. Estimated percent change in corn yield due to changes in temperature and precipitation

Temperature change, °C	Change in precipitation (% of normal *) -20	-10	0	+10	+20
-2	19.8	21.2	22.7	24.2	25.6
-1	8.4	9.8	11.3	12.8	14.2
0	-2.9	-1.5	0	1.5	2.9
+1.0	-14.2	-12.8	-9.8	-8.4	-8.4
+2.0	-25.6	-24.2	-22.7	-21.2	-19.8

Source: Benci et al. (1975) quoted in Bach (1978) p.155
* Normal = 85+16 bu/acre, 1901-1972 average for selected stations in Missouri, Illinois, Indiana, Nebraska, Iowa and Kansas.

Two other crops which are also grown abundant in Africa and for which there are research results from other parts of the world are wheat and rice. Fig. 20.9 and Fig. 20.10, obtained from Yoshida (1978) and Asama (1976) respectively, show the intimate link between temperature changes and rice productivity, and between day/night temperature changes and wheat productivity. There is no doubt whatsoever that changed temperatures such as those exptected under a global warming will be highly significant for continued rice and wheat production with available evidence pointing clearly in the direction of possible drastic declines in the yields of these two key crops.

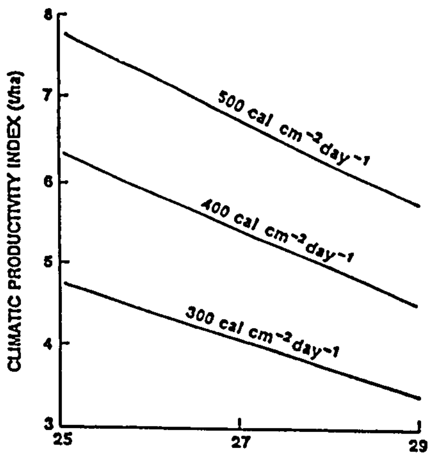

Fig. 20.9 Effect of increasing temperature on the productivity of rice at different rates of radiation (from Yoshida 1978)

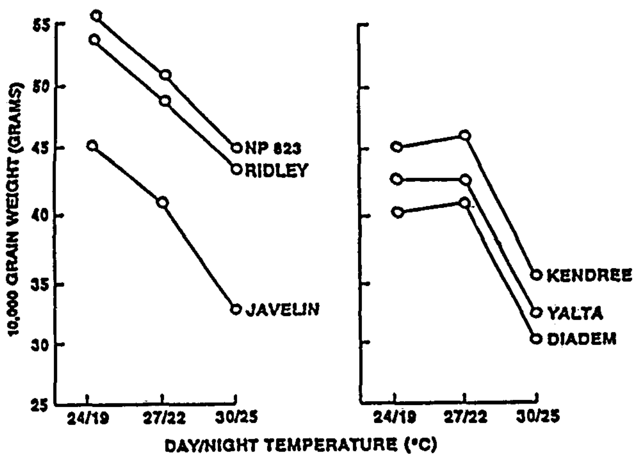

Fig. 20.10 Effect of increasing temperature on grain development in wheat (from Asana 1976)

As far as the rice crop is concerned, it has hitherto been assumed that it should thrive under conditions of high temperatures, so that global warming could even be conducive to a higher rice productivity. Unfortunately, this is untrue. Sinha et al. (1988) have shown that rice yields tend to decrease markedly as temperature rises above 28°C (see also Fig.20.9). Table 20.2 based on Stansel and Huke (1975) and quoted in Bach (1978) gives some indication of expected percent deviation from world rice production when influenced by changes in temperature and precipiation, and from this it can be seen that global warming will bring with it many conditions, some of which will be clearly undesirable, even for Africa where rice cultivation though still insignificant has been increasing in the last few decades.

*Table 20.2 Percent deviation from world rice production, as influenced by changes in temperature and precipitation**

P change in %	Temperature change in °C						Total P change in %
	-2°	-1°	-0.5°	+0.5°	+1°	+2°	%
-15	-19	-13	-8	-4	0	3	-8
-10	-17	-11	-6	-2	2	5	-6
-5	-13	-7	-2	2	6	9	-2
+5	-9	-3	2	6	10	13	2
+10	-5	1	6	10	14	17	6
+15	-3	3	8	12	16	19	8
Temp. change	-11	-5	0	4	8	11	

* Based on world production of 300 Mt. Source: Stansel and Huke (1975)

As far as agriculture in Africa is concerned, it is important to underline the fact that it is not the **absolute** magnitude of a climate change that will determine the nature of the effects as much as the change in climate relative to the existing or **baseline** conditions. For example, in tropical Africa, in theory, there will be a lengthening of the potential growing seasons in areas where it is now short due to the latitudinal as well as the altitudinal position. But in other cases there might even be a shortening of the required growing period because of local soil moisture and altitudinal circumstances. Such changes will also affect the maturation period of certian crops differently.

As far as changes in crop yields are concerned, moisture, and especially soil moisture has been paramount in tropical and subtropical Africa. Unfortunately, a look at the GCMs does not provide consistent or confident estimates (Parry et al. 1986 and 1990) of regional precipiation changes. Second to rainfall (and hence soil moisture) is temperature and higher temperatures may ultimately rule out some crops alltogether. The work by Sinha et al. (1988) already quoted shows that beyond 28°C, rice yields for instance will be depleted.

In the final analysis, if the climate changes projected are severe enough, the present crop cultivars may cease to be suitable for the changed circumstances. Fortunately for Africa, according to current GCMs, no conditions envisaged should be so severe as to rule out many crops.

Much of tropical Africa has tended to rely on crops such as cocoa, rubber, oil palm, coffee and tea. Some of these crops should be able to absorb increased temperature if there is a corresponding increase in rainfall. As a result, higher yields may even be anticipated, but one is not always sure how the crops will react because of the lack of specificity in the projected conditions. What is known for certain is that climate change will first and foremost be felt in soils, and in turn in plant growth through changed photosynthesis.

For those areas in Africa where there is currently high altitude farming (a.o. tea and coffee), global warming may bring drastic changes. It is possible that the current altitudinal zoning (agroclimatological zoning) may be seriously disoriented by increased temperatures, so that crops which now grow well at the higher altitudes (temperate crops) may totally disappear.

Experimental results in Africa as to what to expect in crop plant performance under the changed soil moisture and temperature conditions are few and it may be safer to make some inferences from work in the tropics in other parts of the world. For example, it is fair to assume that under increased CO_2 there should be an increase in leaf photosynthesis, but it is not clear how this will affect African plants. In general carbon dioxide fertilization effects can partially offset the adverse climate, particularly for C_3-plants (see also Chapter 13 by Sombroek), but it would be unwise to rush to conclusions before field and laboratory experiments are carried out in Africa to establish the expected scientific results. According to Sinha et al. (1988) the higher yields in C_3-crops are obtained around a daily mean temperature of 15°C and in C_4-crops around 30°C, but it is necessary to accompany such generalisations with more detailed information on physiological requirements of each individual crop.

AGRICULTURAL ADJUSTMENTS TO COPE WITH GREENHOUSE WARMING

Much of the agriculture practised in Africa is operated at a low to medium scientific level, so that even weather advises are rare. Because of this it would be unwise, if not impossible, to suggest very precise adjustments which could be made to cope with expected changes in climate. Among the existing options for adjustment, which are already being practised and some of which could be brought into full practice in the event of a climate change, would be the following:

- Germplasm improvements for drought-tolerance (this is already being implemented in Kenya with Katumani Composite Maize and other dryland maize composites like Taboran Composite in Tanzania), or for heat stress resistence could be undertaken;
- Appropriate research should now be commenced on simulated situations such as crop production responses to high temperatures to establish suitable germplasm requirements for the changed conditions;
- There is already the possibility for the substitution of crop species e.g. pigeon peas (*Cajanus cajan)* for soy beans (pigeon peas are already a very successful crop in the dryland areas of Kenya);
- Agricultural management changes could be introduced including multiple cropping already much practised in much of tropical Africa, and early planting, already a successful weather advisory practice in some countries like Kenya and Uganda;
- Africa (tropical) already has good experience with tree crops (e.g. coffee, cocoa, tea, oil palm etc.) and this should be the focus of intensified research to understand their place in a changed climate.

SUMMARY AND CONCLUSIONS

The likely impacts of a changed climate due to increased levels of (maily) CO_2 are still difficult to project, largely because the models of change are still rather vague. That there will be significant effects on African agriculture cannot be doubted. There is evidence of some existing resilience in African agriculture which could enable it to cope with a changed climatic situation, but it is quite clear that more intensive research will be required at national, regional, and global levels, to establish more accurate scientific facts which can form the basis for more informed policy formulation.

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