

Natural Resources, Communities and **Climate Change in West Africa:** **Impacts, Vulnerability and Responses**

**A literature review and data base compiled for CIFOR's
Tropical Forests and Climate Change Adaptation Project
(TROFCCA) in West Africa, with special focus on Burkina
Faso, Ghana and Mali**

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This literature review aims to cover the following 2 components of the TROFCCA start-up consultancy as defined in the consultancy ToR:

- 1. “A survey of relevant literature related to the responses of natural resources and communities to climate change and climate variability” (special focus on Burkina Faso, Ghana and Mali)*
- 2. “An assessment of the relevant studies of climatic impacts and vulnerability of natural and human systems to climatic impacts in West Africa”.*

Accompanying reports:

1. Summary conclusions
2. Country reports - current relevant work and potential for collaboration in Burkina Faso, Ghana and Mali.
3. What others are doing in the Region – data base
4. Background information

Index	Page no.
Glossary	3
1 Introduction – some basics	4
1.1 Terminology	4
1.2 Vegetation classification and zones – an overview	4
1.3 Regional climate – a brief overview of key characteristics.....	6
2 REGIONAL CLIMATE-VEGETATION DYNAMICS: LESSONS FROM THE PAST	9
2.1 Prehistoric climate and vegetation (Pleistocene and Holocene)	9
2.2 The Sahelian droughts of 20th century	10
3 Current climate and vegetation trends in the region	13
4 Driving forces of West African climate - Understanding variability and changes in rainfall 15	
4.1 Summary of current thinking.....	15
4.2 Vegetation-climate feedback loops.....	16
4.3 Dust.....	19
5 Predicting future climate scenarios in west africa	20
6 Impacts of climate change in the region	22
6.1 Evidence of impacts from prehistoric climate change events	22
6.2 Impacts of the 20th century droughts on biophysical systems	23
6.3 Impacts of the 20th century droughts on human systems and livelihoods	26
6.4 Projected consequences of climate change in the Region	27
6.5 Projected impacts of anthropogenic activities on Regional ecosystems	30
7 Vulnerability to impacts of climate change in the region	35
7.1 Introduction to the issues.....	35
7.2 Scientific assessments of vulnerability.....	36
7.3 Interpreting vulnerability narratives	38
7.4 Vulnerability as a result of poverty, inappropriate policies or weak governance	40
7.5 Concluding remarks on vulnerability	42
8 Adaptation	42
8.1 What is adaptation? (and adaptation to what?).....	42
8.2 Success stories to date -progress in Developing Climate Change Adaptation Strategies	44
8.3 Emerging conclusions and recommendations for adaptation	46
8.3.1 General recommendations.....	46
8.3.2 Holistic approaches to adaptation based on poverty alleviation.....	50
8.3.3 Community-level natural resource management.....	52
8.3.4 Sequestration and Clean Development Mechanisms (CDM).....	57
8.3.5 Seasonal weather forecasting	61
8.3.6 Artificial precipitation enhancement.....	63
8.3.7 Institutional Development for Climate Change Adaptation,	64
Annex 1 Fact Sheets for the three target countries of TROFCCA (World Bank 2005)	68
Annex 2 Range decrease of the ten species experiencing the greatest relative decline from ca. 1945 to 1993 in sites in northern Senegal (taken from Gonzalez 2001).	71
Annex 3 Examples of WFP food security related mapping exercises in Burkina Faso.....	72
Annex 4 Summarised from the WWF publication “BUYING TIME: A USER'S MANUAL”	73
References cited	75

Glossary

AGRYMET	
AIACC	Assessments of Impacts and Adaptations to Climate in Multiple Regions
CIFOR	Centre for International Forestry Research
CILSS	
GCM	General circulation model (computer global climate model)
GHGs	Green house gases
IPCC	
LDC	Least Developed Country
LULCC	Land-use and land-cover change
LULUCF	Land use, land use change and forestry
LEG	Least Developed Countries Expert Group
NAPA	National Adaptation Plans of Action
NCAR	National Centre for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
PANA	Plan d'Action de National Adaptation (French equiv. of NAPA)
PNGT	Programme National de Gestion des Terroirs (National Land Management Prog.)
PRSP	Poverty Reduction Strategy Paper
SBSTA	UNFCCC's Subsidiary Body for Scientific and Technological Advice
START	Global SysTems for Analysis, Research and Training
SURVAS	Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies
TROFCCA	CIFOR's Tropical Forests and Climate Change Adaptation Project
TWAS	Third World Academy of Sciences
UNFCCC	United Nations Framework Convention on Climate Change
UNFCD	
UNITAR	United Nations Institute for Training and Research

1 INTRODUCTION – SOME BASICS

1.1 Terminology

Discussion on the highly complex subject of climate-vegetation dynamics in West Africa is made even more confusing because of the inconsistent meanings attributed by different actors to commonly used terms. Confusion is further fuelled by the different meanings of similar sounding terms in French and English. Van Rompaey (2002) helps to clarify the terminology used for vegetation zones for West Africa in the French and English languages (see also Figure 1 below for translations).

One of the most confusing terms is that of the ‘Sahel’, an Arabic word for shore (referring as it does to the southern border of the Sahara). For most anglophone geographers, economists, social and political scientists, the Sahel refers to non-humid sub Saharan West Africa, thus including Chad, Niger, Burkina Faso, Mali, Senegal, Mauritania and the Gambia and northern Nigeria, Ghana, Togo and Benin. In *climatic* terms, Sahel is usually taken to lie between the 200-300 mm isohyets in the north and the 500-700 mm in the south (which is also how the term is understood in Burkina Faso and Mali). However, many climatological studies, when talking about the Sahel broaden the area considerably – some use it to refer to all of West Africa lying between 10° N and 20° N and sometimes stretching east to include Sudan (“*the transition region between the humid tropical rainforest to the south and the Sahara desert to the north*” (Nicholson 2001) and (Dai 2004). Then again, the *ecological* Sahel is defined by a certain mix of plant species and communities that while closely related to climatic conditions can move geographically with climate changes. Thus depending on climate (and man’s activities) the Sahel vegetation zone can move significantly – as described below, it has been found far north of its present range in what is now rainless desert and also many hundreds of kilometres south in what are now Sudanian and even Sudan-Guinean zones.

Annex 1 gives some background data for TROFCCA’s three West African target countries of Burkina Faso, Ghana and Mali.

1.2 Vegetation classification and zones – an overview

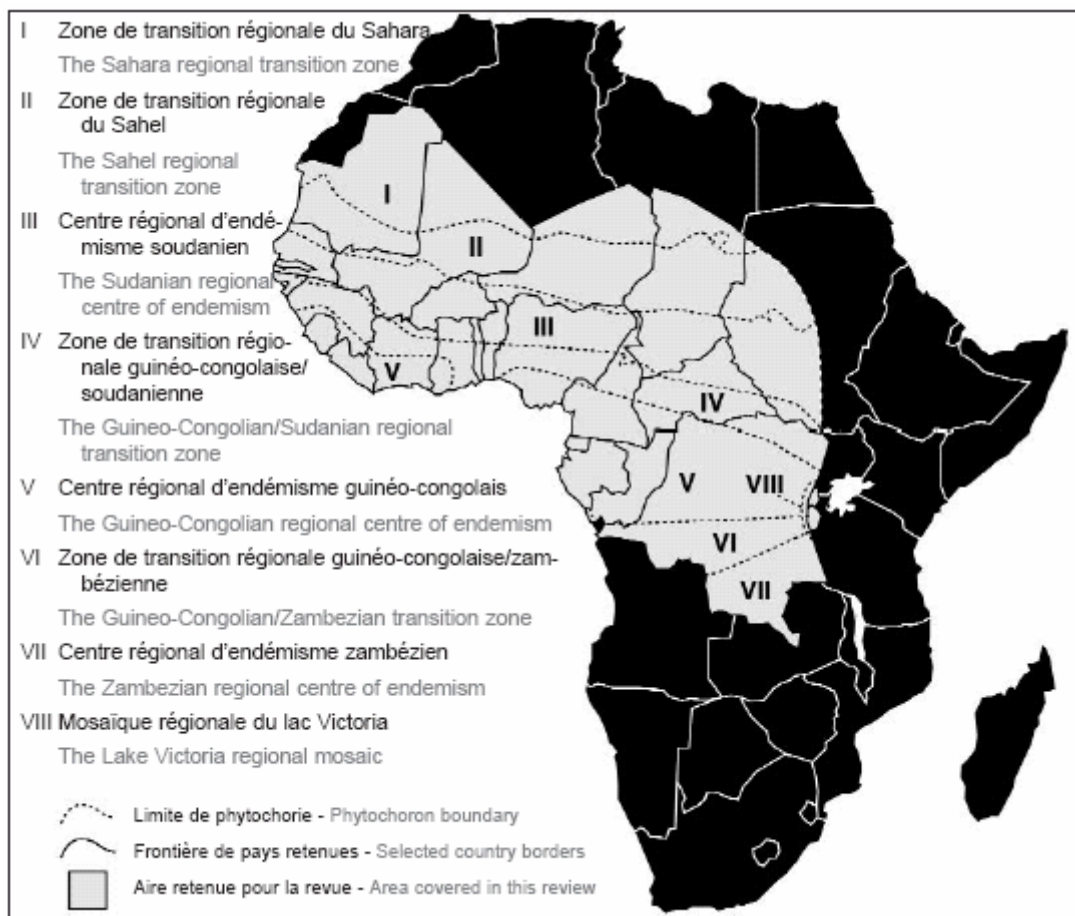
The standard vegetation classification for Africa is provided by White (1983) which uses physiognomic and chorological categories to subdivide African vegetation types into cohesive regions. The three target countries of the TROFCCA include what White classifies as five distinct phytochoric Zones (see Figure 1 below – chosen from many examples as it gives the English and French equivalents):

- 1) The **Sahara regional transition zone** (northern Mali) certain plants characteristic of wadis (e.g. *Tamarix*) and of shady, rocky, gravelly or saline faces (e.g. *Cornulaca*, *Calligonum*, *Fagonia*)
- 2) The **Sahel regional transition zone** (central Mali and northern Burkina) Semi-desert grassland and thorny shrubland (north) to wooded grassland and bushland (south), with *Acacia* spp., *Commiphora africana*, *Balanites aegyptiaca*, Euphorbiaceae, and abundant dryland taxa
- 3) The **Sudanian regional centre of endemism** (southern Mali, all the rest of Burkina and northern Ghana) Woodland and dry forest, with *Celtis integrifolia*, *Hymenocardia acida*, *Lannea*, *Prosopis africana*, *Myrtagyna inermis*, etc.

- 4) The **Guineo-Congolian/Sudanian regional transition zone** (central & south-eastern Ghana) Mosaic of dry, peripheral, semi-evergreen rainforest and woodland or secondary grassland
- 5) The **Guineo-Congolian regional centre of endemism** (south western Ghana) Lowland rainforest and swamp forest with very diverse endemic flora including *Chlorofora*, *Holoptelea*, *Uapaca*, *Musanga* and *Elaeis guineensis* (oil palm); montane rainforest and grassland (above 1000 m altitude) with *Olea hochstetteri*, *Podocarpus* and *Ilex*

Within these five Zones, a number of distinct vegetation types are described at a more detailed level White (1983).

Figure 1 Phytochoria of West and Central Africa, adapted from White by the African Ethnobotany Network (Dounias 2000)



However, it should be noted that these vegetation zones are based on the classical botanical interpretation of steady state climax vegetation types. Thus they remain valid as indicators of dominant plant communities in the Region under a given set of climatic (and anthropogenic) variables – namely the prevalent conditions over the last millennium or so. They should not be taken to represent the only possible equilibrium state for the Region; as will be discussed below climate-vegetation dynamics are now known to be much more complex and changeable. Semi-arid ecosystems especially are now recognised as being “*inescapably dynamic*” and while rainfall is known to be the main driver, many other factors are also implicated (Warren (2005).

It should also be understood that very little of West Africa's current vegetation cover actually corresponds to the species composition described by White's classification as so much has been altered by man's influence – e.g. pastoralism in the Sahel; the traditional agro-forestry systems found in much Sudanian Zone; the extensive fire-related savannahs of the Guineo-Congolian/Sudanian transition zone. Rasmussen's term for the Sahel as a 'cultural landscape' would seem highly appropriate (Rasmussen et al.,2001), shaped as it is as much by human influence as by climatic factors.

The scientific literature now leaves little room for doubt: semi-arid ecosystems are inescapably dynamic, and rainfall is the main driver Warren (2005).Recent analysis would also extend this description to the sub-humid savannas and even to much of what used to be thought of as 'pristine' rainforest belt of southern West Africa. Examining the rain forest of central Africa van Gemerden, for example, reveals that existing tree species composition of a structurally complex and species-rich Central African rain forest still echoes historical disturbances, most probably caused by human land use between three to four centuries ago. Human impact on African rain forest is therefore, contrary to common belief, an issue not of the last decades only. Their work also challenges the long held distinction between old growth and secondary forest (van Gemerden 2003). Likewise, Van Rompaey (2002) points out that the traditional distinction between primary (or virgin) and late secondary rainforests in West Africa is now recognised as being unhelpfully simplistic. Many of the canopy trees in the semi-deciduous forest in Ghana for example are in fact pioneer, light demanding types; this is due not to logging activities so much as the frequent and dramatic oscillations between wet and dry climates over the last million years.

Having said this, Warren (2005) suggests that a trend of increasing equilibrial vegetation dynamics can be observed as one moves from arid to humid zones. He considers that the boundary defining dry areas that are more likely to be "non-equilibrial" and wetter areas, which are likely to be more 'equilibrial' may occur somewhere between 250 and 300mm mean annual rainfall. There is no doubt that the climate is the dominant biophysical influence on the spatial distribution of the major vegetation types on a global scale (Brovkin 2002). Due largely to the very steep rainfall gradients in the Region, the dominant determinant for vegetation is precipitation (although of course temperature, soil, hydrology, wind and dust, altitude all remain important. Figure 2 below shows the close relationship between isohyets and vegetation types.

1.3 Regional climate – a brief overview of key characteristics

A dominant theme of this paper will be the dynamic nature of climatic patterns in the Region and especially of rainfall, with enormous variability, spatial and temporal, evident over all timescales (from intra-seasonal, annual, interdecadal, centuries and millennia). However, it is of course still pertinent to describe the current broad climatic patterns of the Region.

The climate of West Africa is dominated by the seasonal movement of the West African Monsoon. Annual precipitation in the Region (currently!) peaks along the south West Coast, where Guinea, Liberia and Sierra Leone have rainfall of over 4000 mm per year. For the three TROFCCA target countries, annual precipitation ranges from 2,200 mm (in south west Ghana) to less than 50 mm in the Sahara of northern Mali. The single rainy season, peaking in August, varies from less than 3 months north of the 14th parallel to over 9 months along coastal Ghana. A steep north south rainfall gradient exists with roughly parallel latitudinal isohyets, except in the so called "Dahomey Gap" (resulting in significantly lower rainfall in

southern parts of Ghana, Togo and Benin) and also in parts of northern Ivory Coast/Ghana. The isohyet map of the Region produced by ORSTROM showing annual means for the period 1951 to 1989 shows these trends most clearly (L'Hote 1995)¹.

While the climate in the humid areas (precipitation greater than 2000 mm per year) is relatively stable, variability increases as one moves north through the sub-humid and semi-arid zones. Thus in the northern Sahel the standard deviation of the mean annual precipitation is over 50% (Nicholson 2001) and the zone is renowned for having one of the highest levels of climatic variability (spatial and temporal) in the world (Wang 2004). As one leading climatologist puts it “*what is normal to the Sahel is not some annual rainfall total averaged over 10, 50 or 100 years, but variability of the rainfall supply in space and from year-to-year and from decade-to-decade*” (Hulme 2001). For the much of Burkina Faso and Mali therefore, this dominant characteristic of rainfall must be borne in mind. As we discuss later, the adaptability of natural and human systems is thus unsurprisingly already well developed

The Harmattan wind is of course a defining characteristic of Sahelian climate. Blowing NE to SW, usually from December to February. Among many others, Le Houérou (1995) and Brooks (2000; 2004) review its role in defining soil and vegetative characteristics in the Region.

As discussed below, the Region has seen enormous changes in climate and vegetation over the last 100,000 years, not least in the last 5,000 years. While acknowledging this and the shorter term variability, any introduction to current West African climate must mention both the unusually high rainfalls of the 1930s and 1950s and the drought period of the latter part of the 20th century. This 30 year period, from the 1960s to the 1990s, saw mean annual rainfall drop by as much as 30% with devastating effects on local populations (Hulme 2001; Hulme 2001; Nicholson 2001); (Le Barbe 2002; Dai 2004). While considerable debate still exists over the current climatic (and ecological and economic) situation of the Region in general and the Sahel in particular, it seems clear that since the mid 1990s there has been a gradual recovery in rainfall (Nicholson 2005).

¹ See CIFOR library in Ouagadougou - copies of this map are also available from IRD (in Ouagadougou)

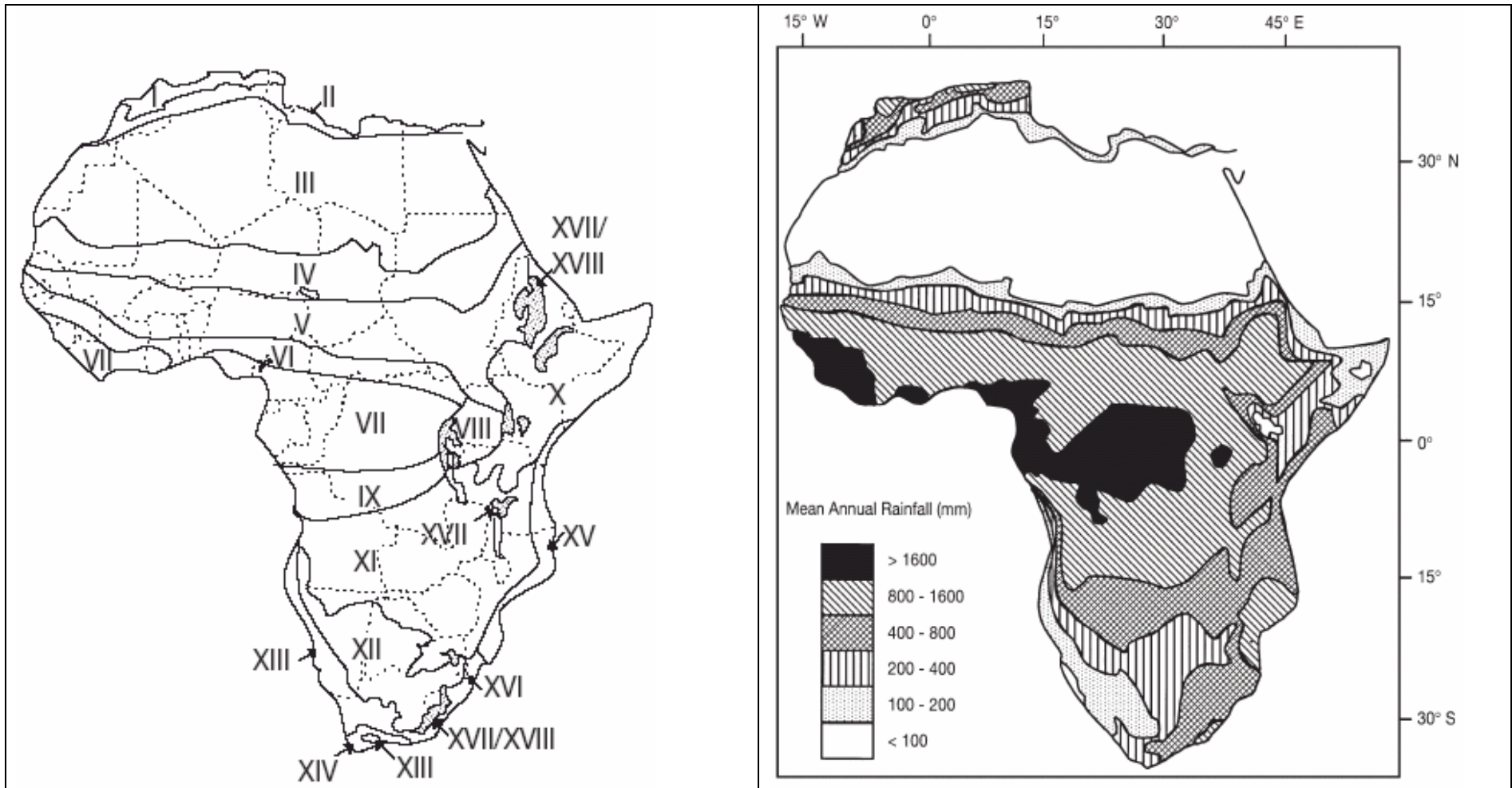


Fig.2 a. Major floristic regions of Africa (Olago 2001 after White 1983)

Fig. 2 b Rainfall map of Africa (from Olago 2001 after Nicholson 1980)

Key for Figure 2 a: Zone III Saharan Desert; IV Sahelian; V Sudanian; VI Sudano-Guinean; VII Guinea-Congolian

2 REGIONAL CLIMATE-VEGETATION DYNAMICS: LESSONS FROM THE PAST

2.1 Prehistoric climate and vegetation (Pleistocene and Holocene)²

Paleo-climatological work is providing amazingly insightful work on climate-vegetation dynamics in West Africa and much of the current understanding of the various forces driving regional climate is coming from paleo-climatic research. Recent technologies and practices can provide temporal resolutions as high as 50 years from the Holocene and Pleistocene (see for example (Nguetsop 2004) allowing very accurate reconstructions of historical changes in both climate and vegetation types.

Dupont et al (2000) give an overview of vegetation change in equatorial West Africa for the last 150 thousand years. This is characterised by the significance and frequency of changes and regime shifts (see also Bonnell 1988; Salzmann 2000; Foley 2003) driven primarily by climate. The same pattern emerges from a useful and up to date annotated environmental bibliography of mainly paleo-climatic literature (with a focus on meteorology, environmental history, recent geology, geomorphology and dust), provided by Oxford University's School of Geography (geog.ox.ac.uk 2005). Schröder also provides a comprehensive set of references and geographical data base for vegetation cover in Africa up to 18,000 years before present (Schröder 2003)³.

Olago gives a useful synthesis (Olago 2001). From 22,000 to 14,000 yr BP (years before present) Africa was, on average, considerably drier and cooler than present, perhaps by 4°C to 7°C. From the late Pleistocene the climate began to become warmer and wetter so that up to the middle Holocene (roughly 14,500 to 5,500 ago), the Western Sahara and Sahel were much wetter than today, with extensive vegetation cover, lakes, wetlands and thriving animal and human communities. Salzmann demonstrates that markedly wetter conditions from c. 10,000 B.P. to c. 6800 B.P allowed a dense Guinean savanna to persist in north eastern Nigeria some 700 km north of current positions (Salzmann 2000).

Foley et al (2003) provide a useful review of the palaeontological and archaeological evidence for this dramatic change and the very rapid process of desertification that then occurred between 6,000 and 5,000 yr BP in West Africa. The dramatic decrease in vegetation cover, the replacement of mesic species by xerophytes, the increase in windborne dust and the change from sedentary lake-side to mobile pastoralist livelihoods are all evident. Olago (2001) suggests that tropical savannas that had shifted up to 700 km north of their current positions between 7,000 and 6,500 years ago had retreated south to their current positions by 3,300 yr BP. During the last glacial period, the increased strength of Harmattan and North African continental trade winds, the southward depression of the ITCZ, and weakened summer monsoon strength resulted in increased regional aridity and greater dust flux out of Sahel source regions (Okin 2004).

Work by Nguetsop suggests that in the rainforests of coastal Cameroun the modern climate settles only at about 600 years before present (BP) with significant shifts at 2700 and 1300 yr BP (Nguetsop 2004). Salzmann (2005) show that the Dahomey Gap, a savanna corridor interrupting the West African rain forest, did not exist during the mid-Holocene. The pollen diagram indicates that in southern Benin a semi-evergreen rainforest prevailed between c.

² The Pleistocene epoch covers from 1.8 million to 8,000 yr BP; the Holocene from 8,000 yr BP to present.

³ This is available on line at <http://www.uni-mannheim.de/phygeo/Ref18ky.htm>

8400 and 4500 yr BP. The mid-Holocene marine transgression caused a spread of mangrove forest along the inland lagoons.

As Maley's work indicates, the tropical forests of West and Central Africa have proved very susceptible to climate change over the last few thousand years (Maley 2002). Indeed he considers that tropical forests in the Region are still recovering from severe periods of dessication that lead to the formation of the Dahomey Gap some 4,500 years ago and which resulted in huge areas of central African rain forest being converted into open savannas.

Pollen analysis and geochemistry indicate that the Dahomey Gap became established at the onset of the late Holocene due to an abrupt climatic change between c. 4500 and 3400 cal. yr BP. Drier climatic conditions led to a rapid deterioration of the rain forest and subsequent spread of Sudano-Guinean savannas. A return to wetter climatic conditions between c. 3300 and 1100 cal. yr BP resulted in a rise in the lake level and a renewed spread of forests into the savanna. During this time the Dahomey Gap consisted of a forest-savanna mosaic with a high number of pioneer tree taxa including the oil palm *Elaeis guineensis*. After c. 1100 cal. yr BP drier environmental conditions resulted in the establishment of an open savanna which persists until present. Based on these findings, Maley therefore suggests that the early role of humans on shaping savannas in the Region has been over-estimated. He concludes the opening of the Dahomey Gap and spread of the oil palm *E. guineensis* can now be confidentially attributed to climatic change and was not initiated by humans (Maley 2002).

2.2 The Sahelian droughts of 20th century

The infamous droughts across the Sahelian countries during the latter half of the 20th century have had a profound impact at many levels. In addition to their devastating effect on local populations and livelihoods (with estimates of up to 500,000 people dying as a result), they have had an enormous effect on shaping popular and scientific understanding of climate and environmental issues in the Region – and indeed globally. The whole desertification paradigm was generated as a result of these droughts and to this day the debate continues as to what is fact and what is 'narrative'. However, it would seem that the huge amount of research and analysis that was – and continues to be – generated is largely focus on the semi-arid and sub-humid zones. The literature thus appears much thinner concerning climatic influences and trends in the humid Guineo-Congolian zones of southern West Africa.

The reduction in precipitation that occurred across the Sahel between the 1960s and 1980s followed a period of sustained increase in precipitation during the 1920s to 1950s. This is the largest multi-decadal regional climate perturbation that has been observed in the instrumental period (Hulme 2001) and provides a good example of a (sustained) directional change in regional climate. Thus even within a region that already is known for having probably the highest climatic variability in the world, these years of drought were remarkable.

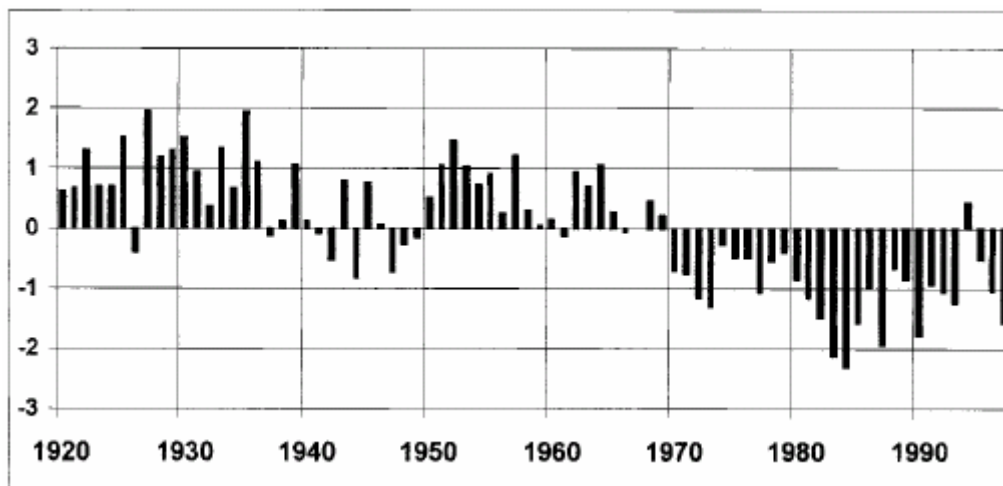
This period saw up to 30% reductions in 30 year rainfall averages, from 512 mm (1931-60 average) to 410mm (1971-2000) and culminated in devastating Sahelian droughts of 1973, 1984 and 1990. Isohyetes have moved south. Mean isohyetal lines showing twenty year averages (in millimetres) have migrated south by as much as 250 km during the 20 year periods between 1950s and 1980s (L'Hote 1995). Over the same period some locations have seen 20 year averages of annual precipitation drop by as much as 200mm (ORSTOM, 1996). AGRHYMET, the institution that maintains the rainfall for the Sahel countries, concludes that

the 300 mm/yr isohyte shifted south by 100 km between the period 1950-67 and 1968-97 (Gonzales 2001).

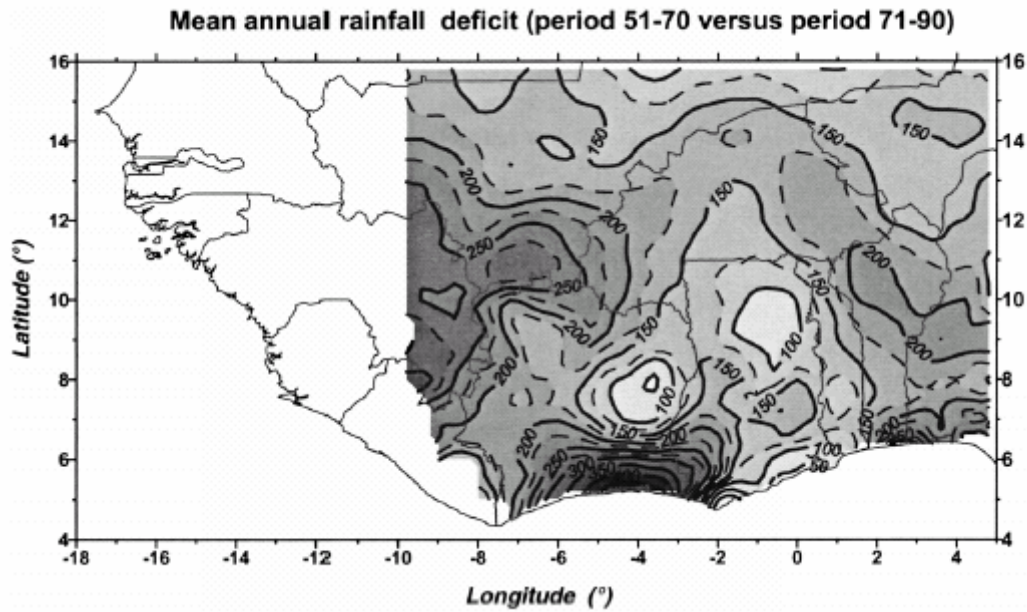
Le Barbe et al examined the data from 300 daily rain gauges covering a 1 700 000 km² area in order to characterize the rainfall regimes of the sub-Region covered by 9 West African countries (including Burkina Faso, Ghana and Mali) during the 40 year period 1951 to 1990. Analysing two rainfall variables (the average number of rainfall events over a given period of time and the average cumulative rainfall per event) they found that the drought years were a result in the number of rainfall events and not their relative size (Le Barbe 2002). They also showed that a distinct shift in the time of the second rainy season in the south (see Figure 3 below).

Dai et al (Dai 2004) strenuously refute claims by one piece of research that the Sahel drought of the late 20th century was an artefact of rainfall changing station networks than a reflection of actual climatic realities (Chappell 2004). All the literature accessed by this review would support this rebuttal. Interestingly, their work also revealed that large multi-year oscillations appear to be more frequent and extreme after the late 1980s than previously. However, Nicholson (2001) does point out that such protracted dry spells are not unprecedented in West Africa even in recent times. Using proxy indicators she postulates that a similar dry episode prevailed for most of the first half of the nineteenth century and that it was not until the 1850s that conditions equivalent to the perceived norms of the twentieth century were seen. Hoerling et al (in press) also suggest that paleo-climate records show that even greater climate swings have occurred in Africa's monsoons, most likely related to past variations in solar output and in Earth's orbit, concluding that "*from a paleo-climate perspective, the recent African dryings appear to be neither unusual nor extreme*".

Figure 3 Evolution of the standardised rainfall index⁴ over the Sahel between 1921 and 1994, taken from (Le Barbe 2002).



⁴ The SRI is an average of rainfall standardised at each rainfall station with respect to the mean of the station



Map of the absolute rainfall differences between the wet period P1 (1951–70) and the dry period P2 (1971–90) over the region of study. Isolines are in mm/yr, taken from (Le Barbe 2002)

Figure 4 Taken from (Dai 2004)

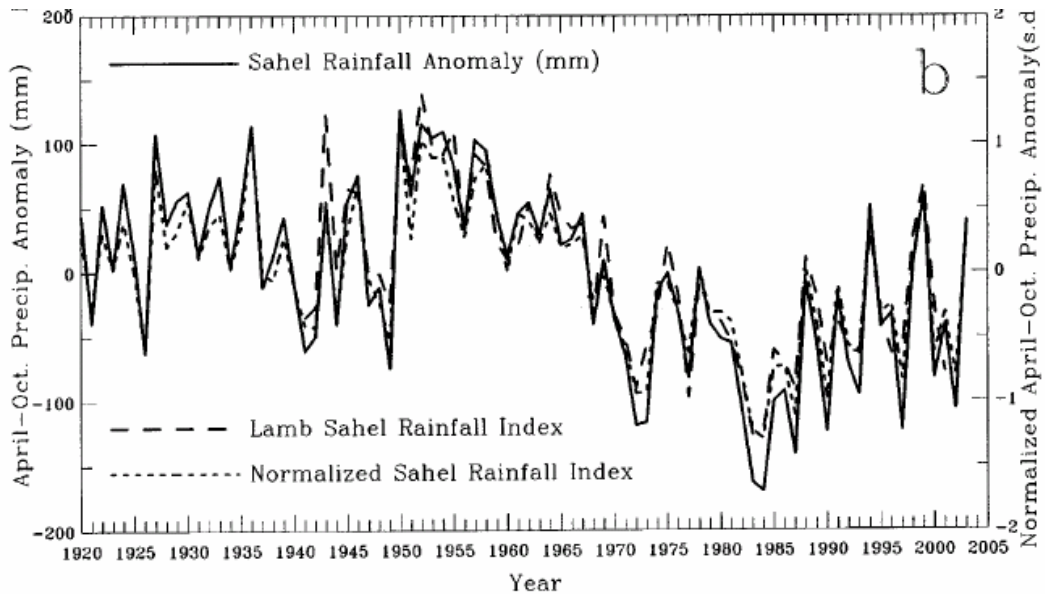


Figure 3. (a) Time series of total number of Sahelian rain-gauge stations with data for months April–October. (b) Time series of Sahel regional rainfall for April–October from 1920 to 2003 derived from by gridding station anomalies (solid line) and normalized static anomalies (short-dashed line) and then averaging them using area weighting. Also shown (long-dashed line) is the Lamb Sahel rainfall index for 1941–2001 derived from 20 fixed stations (Tarhule and Lamb, 2003)

The climatologists all seem to agree that the extent to which the variations in rainfall witnessed over the last 40 years are an example of greenhouse gas global warming remains uncertain. Indeed, as described below, much current evidence now suggests that the Sahelian droughts of the last century were caused by oceanic fluctuations in SST that actually masked underlying trends related to global warming.

3 CURRENT CLIMATE AND VEGETATION TRENDS IN THE REGION

A recent special issue of the *Journal of Arid Environments* (2005, vol. 63) presents the views of a group of scientists on the theme of “Changes in the Sahel” presented at a UNEP/FAO/UNCCD/ICRSE workshop held in Nairobi in 2003 (ICRSE 2003). It is perhaps illustrative of the complexity of the subject (and the fact that the more we research into the interactions between climate, ecology and humans the more we realise how little we really understand) that the conclusions from this collection of 8 papers by some 16 recognised experts can be boiled down to:

- Rainfall has improved over much of West Africa during the period of 1998-2003 in comparison to the 30 year mean for the dry period of 1966-1997. In some areas (including Burkina Faso and Mali) the recent 5 year mean matches that of the notoriously wet decade of the 1950s.
- Satellite images of the Region show an associated increase in vegetative cover over much of the Sahel during this period. However, although shown to be primarily a cause of increased rainfall, there is some evidence that other secondary drivers may also be at work, possibly changes in land use.
- It has yet to be studied whether this increasing greenness represents the same or a different species composition to the pre drought (pre 1960s) vegetation types. It is not yet known whether the observed rainfall “recovery” will result in a corresponding return to the previous ecological mix or to one or more new ‘steady states’
- The general consensus from the contributors is that non-equilibrium dynamics are probably more useful in helping us to understand Sahelian ecology and livelihood systems than conventional steady state models. However, as Herrmann and Hutchinson (2005) point out, one model need not rule out the other. They cite Briske (2003) in suggesting that the key question is not whether equilibrium or non-equilibrium dynamics apply, but which dynamic applies within a given situation.
- In a similarly convention-challenging vein, the consensus conclusion leans significantly towards the positivist view regarding the resilience and encouraging performance of the Sahelian agro-ecology and livelihoods.

It appears that all researchers agree that since the early 1990s, rainfall patterns throughout most of the region have been characterised by an increase in precipitation, albeit not yet regaining the pre 1960 annual rainfall means.

Nicholson (2005) has studied rainfall during the period of 1998 to 2003 from 12°N to 20°N (which covers most of Mali and Burkina Faso but includes only the most northerly part of Ghana). While still being below the wetter conditions that prevailed in the region from 1930 to 1965, the data reveals a clear recovery in rainfall compared to the 30-year climatological “normal” for the very dry period 1968–97. The recovery was most marked in the western Sahel. With the exception of the northern-most zone (the Saharan margin, 18–20°N), which remained relatively dry. In the southern-most zone (the central Sahel, 12–14°N), conditions in recent years seem to have been particularly favourable and comparable to the 1950s and

1960s., these trend patterns reflect a gradual recovery from extreme drought conditions that peaked during the 1983–1985 period. See also (Dai 2004) for a conclusive review of evidence for an increase in rainfall over the last decade or so.

Anyambaa and Tucker showed a significant increase in Sahelian vegetation cover for the 1994–2003 period as compared to the 1982–1993 period (Anyamba 2005). These patterns agree with the improved rainfall trends described by Nicholson above. However, analysis reveals that this so called greening of the Sahel may not be fully explainable by improved rainfall alone (Olsson 2005), (Eklundh 2005). More research is needed to understand the data, but it may be possible that it reflects an increased planting or protected regeneration of trees on farm land. This would support the analyses of Reij, Mortimore and others who consider that the level of farmer assisted tree regeneration over the last two decades is only now beginning to be acknowledged (Herrmann 2005; Mortimore 2005; Reij 2005).

While clearly significant, satellite imagery alone can not give a reliable or complete understanding of changes in land cover. It must be relaised that considerable technical difficulties remain in interpreting such data. In his editorial of the special issue of Arid Environments in which the greening trends are presented, Warren (2005) cautions that “*the changes detected with satellite imagery are patchy, erratic and difficult to explain, in themselves, inadequate measures of productivity, and that the models through which they can be assessed do not yet make adequately statements about productivity*”.

The NDVI is the oldest remotely sensed vegetation index in use and remains, despite its shortcomings (sensitivity to soil colour, atmospheric effects, illumination and observation geometry), the most widely used by the remote sensing community. Herrmann et al give a useful overview of the NDVI and its potential and limitations as a proxy indicator of vegetation cover and some of the alternative tools available (Herrmann 2005). Box 1 below provides a brief introduction.

Box 1 What is the NDVI?

The NDVI (normalized difference vegetation index) is based on the difference between infrared reflectance (730–1000 nm, arising from vegetation) and visible band reflectance (550–700 nm, which arises from bare ground), expressed formally as: $NDVI = (\rho_{infrared} - \rho_{visible}) / (\rho_{infrared} + \rho_{visible})$. It is sensitive to the presence, density and condition of vegetation and is directly correlated with photosynthetically active radiation (PAR) and vegetation primary production. It exploits the different spectral characteristics of bare soil and green vegetation in the red and near infrared portions of the electromagnetic spectrum, with reflectance in the red decreasing with increasing chlorophyll absorption and reflectance in the near infrared increasing with increasing green plant biomass. Being a standardized index, NDVI allows comparisons between relative vegetation cover to be made spatially and temporally. A high NDVI thus indicates high vegetation cover, a low one sparse vegetation cover.

A time series for NDVI in West Africa is available from 1982 when collection of satellite vegetation measurements using the Advanced Very High Resolution Radiometer (AVHRR) sensor on board the National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellite begun.

A substantial body of work has also demonstrated that, despite a degree of relatively well understood interference, the NDVI happens to correlates particularly closely with rainfall in the Sahel. This is significant as it allows accurate comparative analysis to be undertaken over large areas without terrestrial rainfall stations. It also allows ecosystem dynamics to be studied in relation to known climatic phenomena and provides a good estimation of changes in vegetation parameters, including green leaf area index, biomass, percent green cover, green biomass production and the fraction of absorbed photosynthetically active radiation.

In conclusion, it would appear that a cautious optimism is justifiable that rainfall in the Region has not only increased since the later half of the 20th century it has also contributed to increased vegetative cover. Equally important however is the growing realisation that local farmers may have contributed to this greening.

A study of the dry season grazing pressures around watering points in rangelands in northern Senegal using time series data from demonstrates the complexity of assessing vegetation change and also the interpretation of using satellite imagery (Lind 2003). The study found, to its surprise, that NDVI actually increased around boreholes. While suggesting a series of agro-ecological explanations for the apparently improved vegetative productivity (e.g. animal manure or increase in unpalatable species) the authors also conclude that the use of NDVI gradients are not appropriate as a simple indicator of degradation.

Recent work by Snyder and Tartowski (2005 in press) demonstrates yet another level of complexity, in arid and semi-arid systems. They show how the oscillation between pulse/interpulse periods of rainfall, interacting with decadal and longer variation in climate and weather, is a primary driver of variation in plant community composition across a range of temporal scales. This temporal variation interacts with spatial variation in drivers and processes to generate the complex patterns and dynamics observed at multiple spatial and temporal scales. They argue that understanding this variation will help to identify thresholds of resource availability that determine species-specific responses, integrate species responses through time as a function of resource availability, and predict dramatic shifts in community composition from episodic recruitment events generated by complex cross-scale temporal interactions in water availability. This understanding is essential for predicting the effects of directional climate change on ecosystem structure and function.

4 DRIVING FORCES OF WEST AFRICAN CLIMATE - UNDERSTANDING VARIABILITY AND CHANGES IN RAINFALL

4.1 Summary of current thinking

The climate of West Africa is dominated by the seasonal movement of the West African Monsoon; but what drives the monsoon. It seems that there is now a broad consensus that differential changes in SSTs (sea surface temperature) of the Atlantic (north and south) and the Indian Ocean represent the primary driver of climate change in the Region (for reviews see Hulme 2001; IPCC 2001; Brooks 2004). Changes in land surface, vegetation dynamics, moisture flux and possibly dust production possibly contribute via secondary feedback mechanisms. Nick Brooks of the Tyndall climate Centre has carried out one of the more recent literature reviews on the subject of reasons for rainfall variability in the Sahel, the recent droughts and future projections; he cites much of the relevant research leading to this broad consensus (Brooks 2004).

It appears that there are two distinct components to this oceanic forcing. One, representing the Gulf of Guinea coast, is tied to the oceanic Intertropical Convergence Zone (ITCZ), while the other, representing the Sahel, defines the continental monsoon (Giannini 2005). This also helps to explain the high degree of intra-seasonal variability, since the character of convection along the Gulf of Guinea, at 5°N, and across the Sahel, at 15°N, with a “jump” occurring

between the two—from the Gulf of Guinea poleward into the Sahel—in June. Migan (2000)⁵ describes three aerological factors influencing precipitation in southern West Africa (around latitude 5°N):

- i) the northern interface of the Harmattan winds (coming from the East) with the westerly monsoon, which shear the cloud bearing formations and prevent rain;
- ii) the Inter-tropical Convergence Zone (ITZ) where the confluence of boreal trade winds with southern trades result in dense rain bearing cloud formations;
- iii) to the south of the ICS, the standard structure of the southern trades characterised by rigorous layering (and thus unproductive) whose penetration into the coastal areas in mid-summer results in the short dry summer season (August) in the coastal zones.

A number of authors provide evidence for the interaction between Northern and Southern Atlantic SSTs having a key role in driving changes in West African monsoon activity (Nguetsop 2004) (Foley 2003) (Giannini 2003). The differential of oceanic temperatures (cooler northern Atlantic combined with warmer warmer-than-average low-latitude waters around Africa provokes the establishment of deep convection over the ocean which weakens the continental convergence associated with the monsoon. This can lead to drought right across the Sahel from Senegal to Ethiopia.

Hoerling et al (in press) also provide evidence that when sea-surface temperatures are warmer in the South Atlantic than in the North, it pulls the Sahelian monsoon cycle south as well, depriving the region of its usual rains. This was the situation during much of the latter half of the 20th century, with the North Atlantic Ocean cooling possibly as a result of natural (i.e. non-forced oceanic processes). Since 1990, the sea-surface temperature pattern has reversed, warming more rapidly in the North Atlantic than in the South.⁶ Lau also considers the main driving force as trends of the north/south Atlantic Ocean SST differential and Indian Ocean SST (Lau submitted).

4.2 Vegetation-climate feedback loops

The effect of rainfall on vegetation is obvious. It is also known that vegetation cover can, in theory, affect climate via alteration of the physical characteristics of the land surface (like albedo, roughness, water conductivity) and by changing atmospheric gas composition, for example, CO₂ and CH₄ (Brovkin 2002). However, it is only recently that any sort of consensus seems to be appearing concerning the effect of vegetation on Regional climate in West Africa and this feedback mechanism remains imperfectly understood.

The majority of researchers now consider that the evidence for positive feedback loops between vegetation clearance and aridity is sufficient to acknowledge it as an important, albeit secondary, climate driver in the Sahel (Brooks 2004). The belief generated by some researchers during the 20th century that anthropogenic changes were the main causes of the drought in the Sahel is now widely discredited. While the evidence seems convincing that vegetation can be an important secondary driving force, it seems that no climatologists would now feel confident to say that this impact “*is the main cause for the severity and persistence of drought in the Sahel*” (quoted from (Savenije 1996).

⁵ This work by Migan is a synthesis of French hydrology work carried out in West Africa, primarily in the 1980s and 90s.

⁶ Their research used data from NCAR, NASA, NOAA, the European Centre for Medium range Forecasts and France’s National centre for Meteorological Research (CNRM)

Foley's review (Foley 2003) cites some 22 published studies (from 1990 up to 2002) by different groups of scientists that support the general conclusion that the extent and duration of the monsoons of north west Africa can be reinforced by increased vegetation cover and weakened by land clearance. However, the mechanisms and relative strength of the interaction remain under discussion, their existence and significance now appears undisputed in the most recent reviews (Brooks 2004) (Brovkin 2002; Wang 2004) (Nicholson 2001).

Foley et al (2003) hypothesise that the climate and ecosystems of the Sahara can exist in two alternative stable states (wet and dry) that can rapidly interchange when *nonlinear* interactions between atmosphere and vegetation exacerbate the effects of slow changes in sea surface temperatures (and possibly land degradation). They showed that two instances of such rapid 'regime' shift (5,500 years ago and the onset of the 30 year drought in the 1960s) can only be successfully replicated by climate models which include positive feedback loops between vegetation cover and precipitation. This is based on imperfectly understood dynamics of water and energy balance that may include albedo, rooting depth, surface roughness and evapo-transpiration. Expanding vegetation cover results in reduced albedo, increased surface roughness length and increased evapo-transpiration which both help to fuel the monsoon with additional energy and moisture. The converse is true: land clearance increases reflection of solar radiation and decreases evapo-transpiration so that a significant reduction in land-surface water and energy balance dampens monsoon development and reduces rainfall. Zeng et al show that both vegetation and interannual variability play active roles in shaping the subtropical savanna ecosystem and describe in detail how the non-linearities in the coupled system can effect wetter forest and drier zones in different ways (Zeng 2000; Wang 2004).

Hoffman and Jackson (2000) also postulate an interdependence of climate and vegetation and a positive feedback loop between declines in rainfall and anthropogenic vegetation clearance. They used NCAR GCM and Land Surface models to model the effect of converting wooded savannas into open grassland and agriculture. Their results suggested a 10% reduction in rainfall and an increase of 0.5 °C in mean surface air temperature, which they considered to be consequences of increased albedo and reduced surface roughness length.

Gonzales and others also support the theory first proposed by Aubréville in 1949 that deforestation of the humid rainforest along the southern belt of West Africa may have significantly reduced the strength of the southwest monsoon that ultimately effected most the northerly Sahel zone (Bonell 1988; Gonzales 2001). Modelling work suggests that the location of the vegetation change in relation to that of the Inter-Tropical Convergence Zone is particularly important. Their modelling indicates desertification along the Sahel-Saharan border has only a minor effect on simulated monsoon circulation, whereas coastal deforestation can cause the complete collapse of the monsoon with dramatic impacts on regional rainfall. They postulate that clearance of humid forest during the twentieth century may have contributed to the drought period.

Similarly, Zheng and Eltahir describe simulations of the West African monsoons that suggest that the potential impact of human induced change of land cover on regional climate depends critically on the location of the change in vegetation cover. That is, desertification along the border with the Sahara (e.g., in Chad, Niger, Mali and Mauritania) leaves a relatively minor impact on monsoon circulation and regional rainfall; deforestation along the southern coast of West Africa (e.g., in Nigeria, Ghana and Ivory Coast) may result in complete collapse of monsoon circulation, and a significant reduction of regional rainfall (Zheng 1997; Zheng 1998).

What might be the mechanisms for these feedback loops? A useful standard review of the hydrological processes involved in possible vegetation-precipitation interactions is given by (Bonell 1988). He concludes that despite the questionable methodologies of some studies, there remains a strong case for local evaporation contributing significantly to total precipitation across West Africa. This increased evapo-transpiration is due to a number of factors, including higher (wet canopy) evaporation rates due to increased roughness, and higher transpiration rates due to increased sunlight interception and access to deeper soil water stores. It appears that the rainfall recycling ratio (the contribution of local evaporation to precipitation in a specified Region) may increase significantly as one moves from the humid coastal zones northwards into the Sahel.

Bonell also discusses work done on evapo-transpiration rates from different vegetation types, supporting the view that forested vegetation tends to recycle more water (per unit area) back into the atmosphere more than non-woody vegetation types and noting that millet fields generate substantially less evaporation than the uncultivated vegetation types that they replace (e.g. tiger bush and fallow savanna). He points out the level of complexity of interactions both within and between different scales (from local sub-catchments up to Regional) underpins the enormous temporal and spatial variability that characterizes the Sahelian/Sudanian climate. Given the general consensus in the climatic literature regarding the (secondary) influence of increased local humidity on West African Monsoon activity (as discussed above), one can speculate that removal of forests and woodland could contribute to reduced monsoon activity in the Region (although at what scale this impact might be felt remains unknown).

Brostrom et al (1998) ran a sequence of climate model experiments for 6000 years ago to quantify the effects of land-surface feedbacks in the Saharan region. They show that while vegetation-induced albedo and moisture flux changes do have significant effects on monsoon activity they are not sufficient to explain observed climate-vegetation patterns. Albergel et al (1992) carried out trials in Burkina Faso to demonstrate the extent to which infiltration is affected by drought through the reduction of grass cover. They showed how the infiltration capacity of soil is reduced and suggested that a positive feedback loop between edaphic aridity and vegetation cover can serve to maintain drought conditions over time.

Rompaey (cited in Bonell 1998) suggests there is no difference in the decadal variations between areas still dominated by close canopy forest (as found in Liberia) with extensively deforested lands (as found in Côte d'Ivoire). They attributed to the fact the main driving force are SST anomalies. The effect of deforestation in closed humid forest depends on the scale at which it is studied and is seen to be largest for smaller

The complexity of feedback systems is enormous. Semazzi and Song(2001) modelled the potential climate change which would result from totally clearing the tropical rain forests. The model results show that replacement of tropical rain forest vegetation with savanna grassland vegetation results in a significant reduction in averaged rainfall throughout the year *over the deforested areas*, while increasing rainfall in various parts of southern Africa.

Recent work in boreal forests suggests that very significant feedback mechanisms also exist for increasing temperature. Research by Beringer et al (2005) for example suggests that transitions in vegetation that result from climate warming will result in a positive feedback to further local warming and that this biotic feedback to increased warming will be regionally

significant – perhaps equivalent to a doubling of CO₂. This literature review has not found any research for West Africa looking at such feedbacks on temperature per se.

Evidence from eolian sediment deposition in Mauritania indicate the remarkably abrupt nature of large scale changes in subtropical North African climate (de Menocal 2000; deMenocal and Baker 2000). Between 14.8 and 5.5 cal. ka BP associated with the African Humid Period, when the Sahara was nearly completely vegetated and supported numerous perennial lakes. The African Humid Period has been attributed to a strengthening of the African monsoon due to gradual orbital increases in summer season insolation. However, the onset and termination of this humid period were very abrupt, occurring within decades to centuries. Both transitions occurred when summer season insolation crossed a nearly identical threshold value, which was 4.2% greater than present. These abrupt climate responses to gradual insolation forcing require strongly non-linear feedback processes, and current coupled climate model studies invoke vegetation and ocean temperature feedbacks as candidate mechanisms for the non-linear climate sensitivity. The African monsoon climate system is thus a low-latitude corollary to the bi-stable behaviour of high-latitude deep ocean thermohaline circulation, which is similarly capable of rapid and large-amplitude climate transitions.

Taylor et al (2002) also demonstrate the influence of land use change on Sahelian climate and its secondary nature compared to primary drivers linked to SSTs. Their work indicates that increased albedo (resulting from conversion of woodland to agriculture) contributes to lower rainfall by provoking a late onset of the core rains of July (but once the rains are well established, changes in land use and land cover have little impact). However, Fuller and Ottke confirm that albedo has a relatively minor role in land-atmosphere feedback (Fuller 2002).

4.3 Dust

It is possible that dust is also a plausible secondary mechanism for rainfall suppression (Brooks 2000) playing a parallel, but probably lesser, role to that of the land surface. Once drought conditions are established by primary drivers, they may be reinforced by high atmospheric loadings in positive feedback driven predominantly by atmospheric mechanisms. Harrison et al (2001) discuss the relationship between atmospheric dust-loading, vegetation cover and climate in the Holocene and in the future. They also postulate the existence of feedback loops whereby warmer, wetter conditions may decrease dust-loading to offset any increases in dust generation caused by changes in land-use and anthropogenic devegetation. Similarly, Lau et al postulate that a dust layer over the ocean will intercept sunlight reaching the ocean, causing the SST beneath the dust layer to be cooled, consistent with this image. They suggest that the Saharan dust may provide a positive feedback mechanism, further sustaining the Sahel drought (Lau submitted). It appears that air-borne dust causes droplet size in clouds to drop below the 14 micron radius needed for the onset of rainfall (Foley 2003)

Okin et al provide evidence that dust-borne P inputs may have significant influences on soil productivity in the Sahel therefore also provide another layer of complexity to possible feedback loops over longer time periods (Okin 2004). Recent studies in India suggest that domestic biofuel combustion results in such high concentrations of pollution particles, including "soot" or black carbon that its control would be "*central to climate change mitigation in the south Asian region*" (Venkataraman 2005). However, no similar studies were found for Africa.

Prospero highlights the great sensitivity of dust emissions to climate; regression estimates based on long-term rainfall data suggest that dust concentrations were sharply lower during much of the 20th century before 1970, when rainfall was more normal (Prospero 2003). The same research also shows that large inter-annual changes in dust carried by wind across the Atlantic from Africa are highly anti-correlated with rainfall in the Sahel. (Gray 1990). The influence of West Africa climate on the Americas through the generation of hurricanes should now be a topical issue of great importance in the US. Work in the 1980s demonstrates the links between increased Sahelian rainfall and US landfall of more intense hurricanes (Gray 1990).

5 PREDICTING FUTURE CLIMATE SCENARIOS IN WEST AFRICA

The single clearest conclusion emerging from the literature is that Regional climate models for West Africa are still inadequate to predict the impact of increased temperature on rainfall with any accuracy. Key analysts and reviewers (Hulme 2001, Brooks 2004; (Boxel 2004) conclude that it is unwise to predict regional trends with any confidence based on current climate models. At the same time, there are no shortages of papers that assert that the Region will either become hotter and wetter or hotter and drier as a result of global warming. Jones gives a useful overview of the problems (and possible solutions) associated with modelling local climate change in Africa (Jones 2005).

It can be safely assumed that the atmospheric concentration of greenhouse gases, notably carbon dioxide, will continue to rise during this century and that there will be associated climate changes of some sort. Hulme et al (2001), using a range of greenhouse gas emission rates and other variables, generated continental scenarios ranging from increases of 0.2°C to over 0.5°C per decade. Thus by 2100 Africa could on average be from 2°C to 6°C hotter than present. This projected range of increased temperature, resulting from anthropogenic greenhouse gas emissions, is now almost universally accepted (see (IPCC 2000), 2001 and also (Brooks 2004) for a review). Similarly all models predict corresponding increases in mean global precipitation (from 2.5 to 5.1%) with regional differences that include significant localized reductions in annual precipitation. Unfortunately, the predictions for West Africa vary considerably with some models (e.g. CCSR-98 and HADCM2) predicting continuing aridification and others (e.g. CSIRO and CGCM1) anticipating more favourable trends of increasing rainfall. Thus, Hulme and other researchers admit that at present models are unable to predict the magnitude, or even the direction, of regional rainfall changes in West Africa with any certainty.

Having said that, the last few years have seen an increasing body of evidence suggesting that *increased* rainfall in the Sahel may be more likely than initially considered. (Brooks 2004) provides a useful review of recent research on scenarios in the Sahel. The key factors seem to be that increased temperature and CO₂ concentrations can cause both a northward shift of the West African Monsoon and increased vegetative (physiological) production, with a positive feedback loop between increasing vegetation cover and precipitation. There is also increasing evidence that increased CO₂ concentrations can decrease plants' vulnerability to moisture stress. However, it appears that still all papers conclude by admitting that the level of understanding of all variables driving climate changes and variability (especially at Regional level) are still insufficiently understood for any one prediction to be sufficiently reliable to become the basis of a clear adaptation strategy.

Modelling work by Paeth and Hense (2004) suggest that southern West Africa will become wetter into the 21st century but are less clear about northern Sub-Saharan Africa. The models examined by Hoerling et al (Hoerling in press) show this trend intensifying in future decades. They project that the Sahel monsoon will be some 20% to 30% wetter by 2049 compared to the 1950-99 average. Sub-saharan drying of the late 20th Century appears not to herald a major change in that region's monsoon climate. Greenhouse-gas forced experiments, conducted as part of the Third Assessment Report, do not yield a northern African drying trend in 1950-1999, and instead generate a wet trend that emerges in the last decade of the 20th Century and accelerates during the 21st Century. The greenhouse-gas forced wet trend is also a consequence of an interhemispheric Atlantic SST change, but one in which warming of the North Atlantic compared to the South Atlantic favours abundant monsoon rains over northern Africa.

The same piece of research also illustrates the complexity of climate modelling in Africa (see also (Jones 2005)). The authors show that regional climate for southern Africa is dominated by progressive Indian Ocean warming, with enhanced atmospheric convection over those warm waters yielding compensating subsidence and drying over the adjacent continent. Southern African drying in the latter half of the 20th Century does appear to foreshadow a climate change, one that is consistent with a greenhouse gas influence. Analysis of the Third Assessment experiments reveals a weak 1950-1999 drying trend over southern Africa during austral spring and summer, but one which intensifies in the 21st Century. This drying occurs in tandem with a greenhouse-induced warming of the Indian Ocean, a projected ocean change resembling the observed 1950-1999 warming trend, and one that is projected to continue (Hoerling in press).

Wang and Eltahir (2002) use models to predict increases in rainfall as CO₂ levels rise. Significantly, using the same models they have accurately simulated the 30 year drought period of the late 20th century, with sea surface temperatures as the primary driver. They find that an increase of CO₂ concentration and SST causes the regional biosphere-atmosphere system to become wetter and greener, with the radiative effect of CO₂ and improved plant-water relation dominant in the Sahelian grassland region and the direct enhancement of leaf carbon assimilation dominant in the tree-covered region to the south. They also show that biosphere-atmosphere systems under constant SSTs at higher CO₂ level are more resilient to drought-inducing external forcings. This finding suggests that the regional climate in Sahel, which tends to alternate between dry and wet spells, may experience longer (or more frequent) wet episodes and shorter (or less frequent) dry episodes in the future than in the past see also (Wang 2004). However, recent research by Held et al, using new global climate model, both simulates the 20th century drought years and predicts a significantly drier Sahel by the end of the 21st century, due primarily to greenhouse gases (Held 2005).

The development any long term climate change scenarios remains problematic due to incomplete understanding of the different climate drivers, the dynamics of their interactions and their geographic variation. West Africa appears particularly problematic. Seasonal climate predictions are made by using coupled or forced General Circulation Models (GCMs) to produce monthly or daily weather on scales with a spatial resolution of 200 km (Baron 2005). A recent paper by Zhang and Liu is worth reading as it gives a good overview on the role (and limitations) of modelling the impacts of climate change on biophysical processes associated with crop (or tree) production (Zhang 2005). They discuss the difficulties involved in generating useful impact assessments, including:

- The spatial and temporal scale mismatches between coarse resolution projections of general circulation models (GCMs) and fine resolution data requirements of agricultural systems models
- With the existence of multiple pathways (of impact of CC) because the effects of many climatic variables such as precipitation, temperature, and CO₂ concentration as well as their interactions are often complex, dynamic, and nonlinear.
- The fact that different GCMs generate quite different results for different Regions (even if they have similar global predictions)

However, they also discuss the extent to which these problems can be overcome. Their conclusion is that sufficiently accurate models can be generated that allow complex biophysical processes such as hydrology, soil erosion and crop growth to be usefully predicted under different climatic variables. Thus for their research in the Loess plateau in China they predicted a 23–37% increase in annual precipitation, 2.3–4.3 °C rise in maximum temperature, and 3.6–5.3 °C rise in minimum temperature for the region over the century. Cite therefore what might be the most useful land husbandry systems to introduce (they actually recommend conservation tillage as the best option) (Zhang 2005).

IPCC Special Report on The Regional Impacts of Climate Change: An Assessment of Vulnerability ((IPCC 2000) on UNEP/GRID-Arendal web site) considers rainfall is likely to increase, but that such increases would be “*relatively modest, at least in relation to present-day rainfall variability*”. The report admits that insufficient evidence is available to comment on likelihood of changes in variability or frequency of extreme events.

6 IMPACTS OF CLIMATE CHANGE IN THE REGION

6.1 Evidence of impacts from prehistoric climate change events

Geo-archaeological work in Gilf Kebir Plateau in southwest Egypt (in what is now the centre of the largest hyper-arid area on earth) reveals the effect of climate change on the land use strategies of prehistoric settlers there some 5,000 years ago. Linstadter et al provide evidence for major shifts in agriculture as a result of changes in seasonal rainfall distribution to highlight the importance of distribution rather than annual precipitation rates (Linstadter 2004).

As Maley’s work indicates, the tropical forests of West and Central Africa have proved very susceptible to climate change over the last few thousand years (Maley 2002). Indeed he considers that tropical forests in the Region are still recovering from severe periods of desiccation that led to the formation of the Dahomey Gap some 4,500 years ago and which resulted in huge areas of central African rain forest being converted into open savannas.

Equally, evaluating ‘degradation’ in terms of a particular vegetation climax is revealed as inadequate when one takes the impact of long term climate history into account. Given that West Africa has experienced both long period, deep climatic fluctuations and changes in climatic variability (Brooks 1986), the history of vegetation form begins to appear as a history of continual transition, rather than of divergence from a single, once extant climax. Recent ecological analysis suggests that such ceaseless transitions depend on multifactor complexes rather than trends in one particular variable; if a transition-causing factor reverts to its pre-

transition level, vegetation may move to another state, but need not return to its original one (Fairhead 2000) see also (Turner 2000) for a critique for Sahelian side..

However, (Marret 2004) the expansion of the lowland rainforest and dry forest that started around 13 cal ka BP was at its greatest around between 9 cal ka BP and 4.5 cal ka BP. The late Holocene period is marked by abrupt and possibly rapid climatic changes as reflected in the grass and afro-montane vegetation signals. These major change in the vegetation show a rapid increase of herbaceous vegetation all over the Atlantic central Africa. This general regression of the forest is probably linked to deterioration of climate rather than anthropogenic influence. However, this opening of the vegetation may have initiate human population movements. The study of this integrated record of marine and terrestrial proxies illustrates the complexity of interactions between land-ocean and atmosphere systems and emphasize the need of high-resolutions records for enabling satisfactory explanations of our palaeodata reconstructions.

6.2 Impacts of the 20th century droughts on biophysical systems

Gonzalez offers one of the few detailed studies of tree species change as a result of a process of desiccation (Gonzales 2001); (Gonzalez 2004). His work in northwest Senegal demonstrates a drop in average forest richness from 64 to 43 species during the period of ca 1945 to 1993 with a drop in standing biomass of over 2 tonnes per hectare. He estimates that as a result vegetation zones have shifted south towards areas of higher rainfall at an average rate of 5-6 km per decade. While arid Sahel species expanding in the north of this study area, mesic Sudanian and Guinean species have retracted to the south. Annex 2 shows the species change that he encounters.

Togola, Cisse and Breman (1975) studied changes in vegetation on a protected ranch in Mali between 1969 and 1974 (a period that covered one of the worst drought periods in the area). The Niono ranch is situated in the transition zone between the Sahelian and Soudanian zones (at 14°20' N. and 5°50' W) They recorded significant mortality of *Bombax costatum* and the perennial graminaceae *Andropogon gayanus* during this 5 year period, with evidence that this was a result of climate change rather than anthropogenic activities. They concluded that following 4 years of drought (with a mean annual precipitation of almost 400 mm instead of the normal 575 mm) the vegetation had changed to that characteristic of a region with an average annual rainfall of 450 to 500 mm.

Wezel et al (2000) also concluded that clear southward shifts of vegetation zones were in Niger and Benin over the last four decades of the 20th century. However, their work generates a number of interesting observations. They found that no clear shift was discernable of the northern boundary between the northern Sahel and the Sahara between 1959 and 1990. They speculated that this may in part be due to the extreme variable inter-annual rainfall distribution that dominates this boundary, which results in enormous change in vegetation year by year. Clear southward shifts were visible however for the boundary between the southern Sahel and the Sudanian Zone, and for the Sudanian-Guinea transition zone over the same period. They suggested that these shifts were a result both of decreased rainfall and of vegetation clearance by humans.

Work by ORSTOM in the 1970s reports significant changes in Acacia and grass species following intense periods of drought of 2-3 years with evidence of a resulting regime shift in vegetation type that does not necessarily 'recover' to the original (Leisinger 1982).

Figure 5 Forest species changes in the Sahel from 1960 to 2000 reported by Gonzales (taken from (Gonzalez 2004)

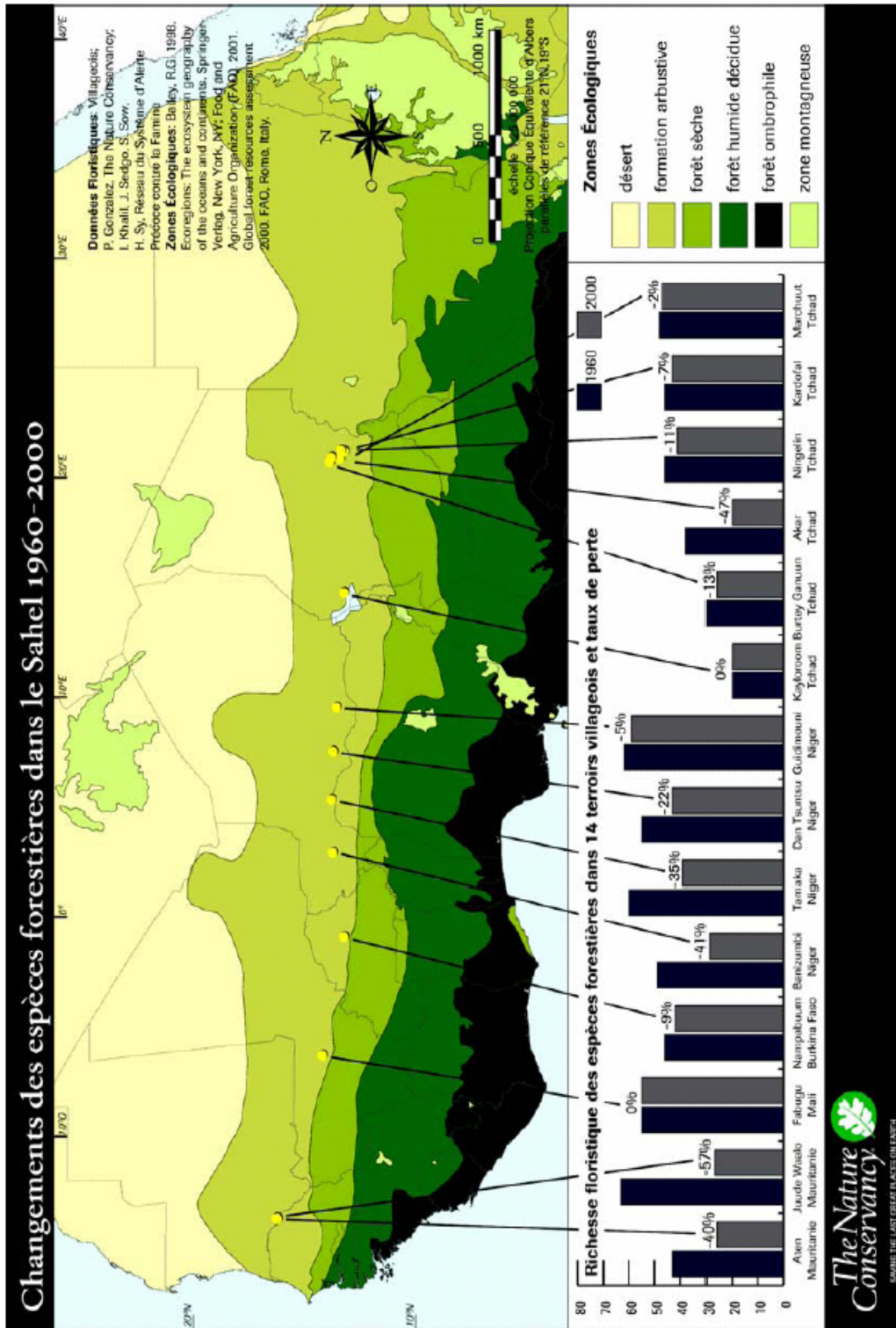


Figure 2. Forest species changes in 14 villages across the Sahel, 1960-2000. In the graph, the black and grey bars show the total number of forest species in the village lands ca. 1960 and in 2000, respectively. The percent decrease in species richness ranged from 0% at Fabugu, Mali to 57% at Juude Waalo, Mauritania.

Mean annual discharges of all central and West African rivers have decreased since the 1970s, with associated drops in ground water frequently being found a few years later (Mahé and Olivry, 1991 on ORSTOM rainfall map). Species change along the wide margins in the delta regions of the Niger River in Mali has been recorded as areas once predictably flooded for many months a year are now remaining above the water line (Mary Allen, pers. com⁷).

(Folke 2004) reveals that the likelihood of regime shifts (in ecosystems) may increase when humans reduce resilience by such actions as removing response diversity, removing whole functional groups of species, or removing whole trophic levels; impacting on ecosystems via emissions of waste and pollutants and climate change; and altering the magnitude, frequency, and duration of disturbance regimes. The combined and often synergistic effects of those pressures can make ecosystems more vulnerable to changes that previously could be absorbed. As a consequence, ecosystems may suddenly shift from desired to less desired states in their capacity to generate ecosystem services. Active adaptive management and governance of resilience will be required to sustain desired ecosystem states and transform degraded ecosystems into fundamentally new and more desirable configurations.

The analysis described above in Chapter 3 on the “greening” of the Sahel represents just collection of articles describing supposedly ‘desertified’ areas that have shown signs of recovery over the last 10 to 20 years. The findings challenge the notion of irreversible desertification in the Sahel and the assumption that local populations have promoted degradation on a large scale. However, all authors advise caution in interpreting the greening phenomenon recently reported (Herrmann 2005) Warren 2005). While it may be true that climatic conditions are improving, it is certain, though, that drought will return and that policy should be flexible enough to accommodate that certainty and the non-equilibrium conditions that accompany it.

Rasmussen’s studies in northern Burkina Faso reveal that (at least in the particular study site in Oudalan Province) areas that were cited as examples of severe desertification during the 1970s and 80s have shown increases in vegetation cover since the mid 1980s (Rasmussen 2001). The methodology he used (time series analysis of aerial photos and satellite images, field studies of vegetation, interviews with local people and review of relevant literature) is very similar to that used by Gonzales in Senegal to show an opposite trend. This review supports his conclusion that “*the environmental history of the region is complex and cannot be boiled down to ‘human-induced irreversible degradation’*. Rather they support the idea of *semi-arid cultural landscapes undergoing constant change in response to both human impact and climatic trends and fluctuations*” (Rasmussen 2001). Anyambaa and Tucker recommend that high resolution satellite data sets (such as those from LANDSAT, SPOT and MODIS) will provide a detailed spatial quantification and description of the recovery patterns at local scale. This would allow an assessment of how particularly forest ecosystems and woodland types are recovering in terms of biomass and green leaf index (but not species composition) (Anyamba 2005).

Many authors refer to the trend of increased pressure on natural systems as a result of drought induced human pressure. Many of these assume that the end result is degradation (Thiam 2003). However, an increasing number of authors are challenging this assumption or at least advising against unsubstantiated generalisation. They describe examples of local farmers succeeding in enriching farmland through improved soil and water conservation and

⁷ Director of Malian NGO ‘Sahel ECO’; mary.sahelco@afribonemali.net

management of trees, both by planting but especially through assisting natural regeneration. Some (Boubacar 2005; Mortimore 2005; Reij 2005),) stress that this was starting during the 1980s when rainfall means were still well below longer term norms. These issues are discussed in more length below.

6.3 Impacts of the 20th century droughts on human systems and livelihoods

While concurring that the dry period between the 1960s and 1990s do not signify a long term climate change, Dietz et al (2004) point out that many local farmers still perceive evidence of long term climate change, with changes in natural vegetation and the gradual disappearance of some important species and changes in the commencement, duration and reliability of the rains themselves. Such observations are indeed common when the issue of climate is raised with local farmers and pastoralists anywhere in West Africa (see also (Gonzales 2001), for example) and there seems no doubt that the changes in vegetation resulting from the droughts of the last century are still being experienced. To what extent however, such local perceptions accurately represent the present climatic situation is less clear – they would seem to be at odds with recent analyses of rainfall data as presented for example by (Hulme 2001).

Dietz et al (2004) discuss in more detail the issue of local perceptions of climate compared to local records of rainfall and temperature (see especially chapter 15). They point out, for example, that in northern Burkina Faso, the worst climatic years (indeed the only time that evapo-transpiration exceeded precipitation) were in the late 80s, while local perceptions indicate that the 70s and early 80s were the most disastrous. They speculate that by the late 80s people had already adapted their livelihoods, both through migration and changes in crop-livestock management.

Forced (as opposed to voluntary) urbanisation seems to be a wide spread result of the Sahelian droughts (see Clarke and Noin 1998 for a selection of examples), and West Africa continues to have one of the highest urbanisation rates in the World. Randall examined the effects of the 1970/80s droughts on nomadic populations in the Gourma area of Mali (Randall 1998). She describes the creation of a deeply impoverished, peri-urban population with few opportunities either to return to traditional pastoral livelihood or learn new skills and/or accumulate resources necessary for economically successful alternatives. Three years after the 1984/5 drought, she reports up to 40% of some nomadic communities remaining in urban peripheries with out the opportunities to earn enough to return to nomadism (a donkey, a tent and a few goats being the absolute minimum prerequisites for such a move). Dependence on child labour for survival in the peri-urban slums (not least for collection of wild foods) seriously reduces longer term opportunities for education needed by the next generation to escape the classic poverty trap provoked by the drought-induced loss of traditional livelihoods.

There is a growing school of thought (as typified by the writings of Mortimore, Tiffen, Reij, Turner and others) that is challenging the description of Sahelian farmers as being helpless victims during the drought years; “*the biophysical and management changes that have been identified suggest that they are less the helpless victims of environmental change than agents who try to make the best use of productive and investment opportunities*” (Hutchinson 2005). This review welcomes this discourse as it highlights the indigenous adaptive capacity of Sahelian people and can lead to seeking local solutions and supporting existing capacities. However, it is important that we do not forget that West Africa continues to represent some of the most impoverished populations on the planet, with both Mali and Burkina Faso have rural stunting rates of 40% or more (WFP 2005) and a growing urban poor whose

opportunities for escaping poverty remain as formidable as ever. In addition, with perhaps 500,000 people dying as a result of the drought years, and many more animals, we should not lose sight of those that fail to adapt.

Nyong and Fiki (2005) examine the extent to which the Sahelian droughts of the last century provoked local conflicts within rural societies. They present strong evidence that the number and severity of conflicts increases, often with significant adverse consequences for livelihoods and poverty alleviation strategies. This in turn impacts negatively on the opportunities for sustainable NRM and highlights the need for integrated responses to climate change as traditional conflict resolution mechanisms become over loaded.

6.4 Projected consequences of climate change in the Region

The projected impact of climate change is of course one step *more* uncertain than the projected climate change itself, being a projection based on a projection. It is largely a matter of which model of Regional climate change is used: one that predicts wetter conditions or one that predicts drier conditions. While many authors assume increase variability in either scenario there is actually no clear basis for this prediction either at this stage. The discourse is further complicated by the near impossibility of disaggregating climatic from anthropogenic influences, as a whole range of variables other than climatic ones (e.g. demographic, political, economic, technical) are influencing land-use change throughout the Region.

It would appear that the majority of reports and articles in the literature assume that climate change will have a net negative effect on ecosystems and livelihoods in Africa in general and in the Region (Fischer 2002; (Desanker 2003)Desanker 2003; Dietz, Ruben et al. 2004; Sims 2005). However, this is not necessarily based on a clear scientific rationale that rainfall will deteriorate. A recent CIFOR publication (Robeldo et al 2005) brings together the findings of a 2004 workshop on ‘Adaptation to Climate Change, Sustainable Livelihoods and Biological Diversity’, which looks in some detail at projected impacts of climate change, not least in Africa and the Sahel (see for example Jones 2005, and Jones and Thornton (2005)). However, while the maps of changes in maize production, or discussions related to biodiversity and livelihoods are thought provoking, the localised rainfall predictions on which all these tools are based still remain far too uncertain for any dependable directional forecasts to be made.

There is much variation. Thus the National Communication for Burkina Faso to the UNFCCC (SP/CONAGESE 2001) (SP/CONAGESE 2001) suggests that both cotton production and the forestry sector will actually benefit from anticipated climate change. The National Communication for Mali offers a range of scenarios, which in balance have a negative effect on rainfall and agricultural production. A study undertaken by the International Institute for Applied Systems Analysis using a range of different GCM models, predicts that the cereal production potential of Ghana will increase, while that of Mali and Burkina Faso will decrease (Fischer 2002). The Ghanaian national communication predicts different scenarios for different parts of the country.

In many cases, predicting the impact of climate change would seem to be a political issue. Care must be taken in interpreting some of the generalisations made by high profile reports and their selective citation of particular references and use of existing research findings. Thus, a recent, major report by an alliance of large NGOs (the Working Group on Climate Change and Development) consistently depicts a very negative picture of climate change throughout

Africa (Sims 2005), but fails to point out that the very same research which it cites for 10-20% reductions in rainfall in Southern Africa also predicts a progressively wetter Sahel.

A recent report by the IUCN (Niasse 2004)⁸ analyses in detail the negative impacts of continued rainfall reductions in the Region and increased severity of climatic extremes. This is fine, but it is unfortunate that the report so subjectively chooses to assume one certain future scenario. It provides a classic example of a well intentioned report wishing to increase environmental awareness by asserting a particular outcome. It is just not true that “*most climate change scenarios predict a decline in precipitation of 0.5-40% with an average of 10-20% by 2025*”. While this review may sympathise with the underlying wish to raise awareness of the problems associated with continued carbon emissions, such assertions do not necessarily help the development of relevant adaptation strategies.

At a course level, distributional shifts in forest types have been predicted for a number of tropical forest regions using Global Circulation Models that focus on temperature and precipitation changes. A 1 °C rise in temperature would increase the productivity of rainforests as a whole as long as all other factors are held constant. However, changes in rainfall patterns combined with warming can produce sizeable shifts in the distribution of forest types. Increased rainfall enhances growth of tropical moist forests (holding fire, pests, and the effects of other factors constant), while decreased precipitation could shift existing tropical moist forests to favour woodlands and tropical dry forests. (Hilbert in press) WWF’s “A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems” (WWF 2003) (Hansen 2003). As Forner points out, little analysis has yet been undertaken on the feedback of climate change on forest pests and fires (Forner 2005).

A recent ecological simulation approach compares the climate in 1975 to future scenarios predicted for 2025, 2055 and 2085 (using climate models created by the UK Met Office's Hadley Centre) coupled with three distinct computer models to predict which plants would be affected by changing climate (McClellan et al 2005). From a total of 5,197 species of African plants examined, they concluded that by 2085, the habitats in which nearly all of these plants can live would either shrink or shift, often to higher altitudes, as a result of anticipated changes in Africa's climate. They say that for between one-quarter and one-half of the species they studied, there will be no part of Africa with a suitable climate by 2085.

Higher temperatures will increase the rate of evapo-transpiration, thereby reducing soil moisture availability for a given rainfall regime. Increases in rainfall may or may not be enough to compensate for increases in surface temperature. Clearly, any increase in temperature coupled with a decrease in rainfall would have potentially disastrous consequences for many crops (and related livelihoods and economies). Fischer et al (2002) discuss different scenarios for agricultural production in Africa (including Burkina, Ghana and Mali), in which both positive and negative outcomes for cereal production are possible depending on which climate model is used.

Baron et al discuss the challenges facing modelling of agricultural productivity from translating GCM outputs into attainable crop yields is difficult because GCM grid boxes are of larger scale than the processes governing yield, involving partitioning of rain among runoff, evaporation, transpiration, drainage and storage at plot scale (Baron 2005). Seasonal climate predictions are made by using coupled or forced General Circulation Models (GCMs)

⁸ The same report considers CILSS to be one of the most important developments for climate change adaptation in West Africa.

to produce monthly or daily weather on scales with a spatial resolution of 200 km (Baron 2005).

Brovkin et al use sensitivity simulations to show that some expansion of vegetation cover into the Sahara is possible under CO₂-induced climate changes (Brovkin 2002). Modelling by Cao et al (2001) also suggests that continental reductions in plant growth shown by some climate change scenarios for Africa, will be more than off set by the fertilisation effects of increased atmospheric CO₂ levels. In theory this would result in Africa being a net carbon sink. However, the study suggests that projected human land use change will prevent Africa from being a significant carbon sink, because a large part of the carbon sequestration is offset by the carbon release arising from land use changes.

However Cao et al are quick to admit that fertiliser effect of CO₂ at landscape and ecosystem level is still poorly understood, but it is likely that they will respond differently to the tree seedlings or annuals usually used in the controlled experiments from which rates of increased photosynthetic activity are observed (Cao 2001). Thus the CO₂ fertilization at the ecosystem level may be smaller than that at the individual plant level. Early increases in plant photosynthesis and growth due to elevated atmospheric CO₂ may disappear as plant growth becomes limited by other environmental factors, such as nutrient supply. Increasing atmospheric CO₂ also affects the carbon/nitrogen ratio of plant tissues, rates of organic decomposition, and nitrogen mineralization in the long term.

The issue is also complicated by the research finding that increased carbon dioxide levels substantially increase woody plant growth and may enhance ‘bush encroachment’ in many parts of tropical and subtropical Africa with important impacts on biodiversity (Lovett 2005). Changes in climate and atmospheric CO₂ can cause variations in vegetation composition and distribution because they determine which plant species survive and prevail in a given region. For example, variations in precipitation can lead to shifts of the boundaries between tropical evergreen and deciduous forests and the tree-grass balance in savannas. Warming favours C4 plants, but elevated atmospheric CO₂ favours C3 plants. Increasing atmospheric CO₂ may cause expansion of tropical forests but shrinkage of savannas because high CO₂ concentration favours C3 trees more than C4 grasses. Therefore, more accurate quantification of African ecosystem carbon cycling requires that the effects of ecosystem structural changes arising from both natural and anthropogenic disturbance be taken into account.

(Maseyk 2005) demonstrate the phenological and physiological responses by semi-arid trees can allow significant increased growth rates with increased atmospheric CO₂ loadings. Recent studies from the Weizmann Institute⁹ also suggest that rising carbon dioxide are having significant effects on increasing growth rates of dry land forests (see (Grunzweig 2003). Similarly, Lal (2005) considers that climate change may also stimulate forest growth by enhancing availability of mineral N and through the CO₂ fertilization effect (which may also partly compensate release of soil C in response to warming). However, carbon flux remains only partially understood – recent results from the Mojave desert suggest that net ecosystem sequestration rates may be lower than supposed (Jasoni 2005)

⁹ For more on this, visit http://wis-wander.weizmann.ac.il/site/en/weizman.asp?pi=371&doc_id=3192

6.5 Projected impacts of anthropogenic activities on Regional ecosystems

It is important that the issue of projected climate change *impacts* on West African ecosystems and societies is examined within the context of other forces of change in the Region. Given the intense and long-standing nature of the debate on desertification, LULCC and poverty in the Sahel (coupled with more recent discussions related to humid forest zones), this broader context is especially important in West Africa. All reports highlight the importance of anthropogenic activities on local ecosystems and acknowledge that it is not easy to disaggregate them from climatic factors.

However, there is still considerable debate concerning trends of LULCC and livelihood security in West Africa, in which both the rate of change and even the direction of change remains unclear. Two key questions are driving this debate:

- To what extent will other forces of change (i.e. apart from climate change) be effecting natural and human systems in West Africa during the 21st century?
- How do their projected impacts compare, qualitatively and quantitatively, with those of climate change?

The literature reveals two main schools of thought regarding these issues:

- i) The more traditional ‘neo-malthusian’-type thinking that sees West Africa dominated by continued negative trends of desertification caused by unsustainable land use, inappropriate policies and weak governance, increasing population, deteriorating livelihood security and poverty;
- ii) The more recent ‘adaptationist’ thinking that highlights how local populations and ecosystems are far less vulnerable than presumed and focuses on evidence to show how rural communities and ecosystems are adapting and evolving successfully to new biophysical and socio-economic conditions.

This review considers that there is truth in both camps and that it is important that the debate does not become too polarised as has sometimes occurred. The following articles give a general idea of current thinking.

The most recent report of FAO’s Forestry Outlook Study for Africa (FOSA) considers the driving forces affecting forests (both direct and indirect) and the likely consequences over the next 2 decades (FAO 2003). Interestingly, it considers climate change to be of only secondary importance as a driving force; while “the most fundamental of these [driving forces] are political, social and institutional changes, especially the emergence of democracies, the decentralization of administration, the increasing emphasis on transparency in the affairs of the public and private sectors, and the growing role of civil society in pursuing issues such as the protection of the environment”. Nowhere does it discuss the potential loss of forest as a result of climate change or the possibilities of forest-climate feedback loops. However it does discuss the potential of African forestry to play a greater role in mitigation strategies as carbon sinks. A recent review by FORNESSA and IUFRO¹⁰ of selected case studies of rehabilitation of degraded lands in Africa focuses very much on the severity of land degradation and its human causes (Blay 2004). Interestingly however, the 101 page document

¹⁰ Forestry Research Network for Sub-Saharan Africa (FORNESSA); International Union of Forest research organizations, Special Programme for developing Countries (IUFRO-SPDC)

refers only briefly to climate change and then only as an *impact* of land degradation and not as a cause!.

The recent report by the Millennium Ecosystem Assessment (2005) aims to synthesise current scientific thinking regarding desertification on a global scale. The report considers that the main causes of desertification over the coming decades are likely to remain anthropogenic. While it of course recognises the potential for climate change to contribute significantly to desertification in certain regions, the report suggests that it is still not possible to predict the outcomes with sufficient confidence. Conversely, it considers that for all demographic, political and socio-economic scenarios, the global desertified area is likely to increase. It also concludes that the relief of pressures on drylands is strongly correlated with poverty reduction. The report summarises its position as follows: “*Desertification is taking place due to indirect factors driving unsustainable use of scarce natural resources by local land users. This situation may be further exacerbated by global climate change. Desertification is considered to be the result of management approaches adopted by land users, who are unable to respond adequately to indirect factors like population pressure and globalization and who increase the pressure on the land in unsustainable ways. This leads to decreased land productivity and a downward spiral of worsening degradation and poverty. Where conditions permit, dryland populations can avoid degradation by improving their agricultural practices and enhancing pastoral mobility in a sustainable way.*”

(Keys 2005) carried out a meta-evaluation of 91 case studies to better understand regional and global trends and causes behind land-use and land-cover change (LULCC). While the cases reviewed covered a wide range of dynamics, the main processes of intensification captured were the adoption of new field crops, the planting of trees, and the development of horticulture. The main factors associated with these processes are demographic, market, and institutions, especially property regimes. However, the high number of case studies that gave no or inadequate information on precipitation and other climatic variables. The authors admit that they were unable to assess the importance of climate variability let alone change on LULCC.

(Tchamie 2002) examines in some detail the relationships between dense Guinean forest and the (degraded) Guinean wooded savannas (around 9°N, in Togo). He concludes that the existing mosaics of vegetation type can in part be explained by variations in micro-climate, soil and relief, but primarily as a result of human activity. In the humid areas of Ivory Coast, the pilot phase of the BIOTA West Programme¹¹ has used aerial and satellite based pictures to study the dynamics over the last 50 years of the Comoé National Park. The report considers that the exponentially increasing population pressure (30% increase between 1988-1998) has changed the faunal composition outside of the park (and in more recent times also within the park by poaching) and that the traditional mechanisms of seed dispersal have been strongly disrupted due to the elimination of nearly all mammals. The authors conclude that long-term changes in vegetation structure will be the result (Linsenmair 2004).

Gausset et al (2005) studied the different interests and strategies that men and women have in tree management in Péni, south-western Burkina Faso. While recognising the strength of traditional natural resource management in the area, they highlight the dominant demographic trends and socio-economic forces that are causing loss of natural forest and leading to an

¹¹ An interdisciplinary Co-operation of the Universities of Abidjan, Bonn, Bobo-Dioulassou, Cotonou, Frankfurt/Main, Mainz, Mannheim, Ouagadougou, Rostock, Ulm and Würzburg - Funded by the German Federal Ministry of Education and Research (BMBF)

observed “tragedy of the commons” situation in the study area. The increasing local population, the influx of people from the Ivory coast, the increase in mango and cashew plantation, the increase in livestock, the increase in charcoal production and felling of traditionally protected species, the changes in customary land tenure all point to a complex set of local adaptations directed at strengthening local livelihoods by men, sometimes sustainably and sometimes not.

Working with satellite imagery of 8 km resolution, Herrmann concludes that rainfall is the dominant causative factor in the dynamics of vegetation greenness in the Sahel (Herrmann 2005). Short term impacts such as pests can cause rainfall-independent deviations of the NDVI in individual years, long-term trends are more likely to be induced by human factors, such as changes in land use, exploitation of natural resources, production strategies and conservation efforts. However, throughout most of the Sahel, she finds no signs of large human-induced land degradation (i.e. at 8 km spatial resolution – which does not mean that pockets of land degradation are not present at local scales. Only parts of northern Nigeria and Sudan show areas where human impact hypothetically inhibited a greening trend in the order of magnitude expected from the positive trend in rainfall conditions. This would support the hypothesis that at the landscape scale, human contributions to desertification are small in comparison to rainfall. However, a finer resolution analysis would be needed to before any definite conclusions can be drawn.

(Dube 2001) attempt to separate out the contribute of grazing and climate change on observed changes in vegetation of range-lands in Botswana, with useful practical advice for interpretation of vegetation changes as shown by satellite images. They used Landsat Thematic Mapper and Multispectral Scanner data and mapped vegetation cover using the PD54 vegetation index. Significantly they also suggest that despite vegetation recovery following good rains, over many years, long term negative impacts of grazing can be detected.

(Thiam 2003) used the multi-temporal 1 km NOAA/AVHRR Normalized Difference Vegetation Index (NDVI) in combination with rainfall, soil types, and field survey data on dominant rural activities to assess the risk of land degradation in southern Mauritania. The results show that the pockets of below-normal NDVI values result from the combined impacts of frequent rainfall deficits, unproductive soils and unsustainable resource-base exploitation by the local population. Several pieces of research by soil scientists show net negative nutrient balances which, without more intensive soil management, would rendering existing cropping/livestock systems unsustainable compared to population increase (Manley 2000). Work by Malay et al in Senegal suggests that the semi-arid savannahs of West Africa that at village level existing farming systems are resulting in a modest carbon net outflow (Manlay 2003).

Since then the 1980/90s there has been a growing body of evidence that challenges the previously held assumptions about the severity and cause of land degradation in the Sahel and Soudanian savannahs. McCarthy et al (2004) using empirical data collected from some 15 villages in the Sahelian zone of Burkina Faso conclude that there is little evidence of pastoralists herding practices leading to devegetation. Several authors allude to increased productivity in the Sahel, despite the drought years of the last century: (Dietz, Ruben et al. 2004) (Mortimore 2001). *“Views of human-induced desertification, which have enjoyed extensive popularity, fail to do justice either to adaptive ecosystem management by smallholders or to the performance of their production systems”* (Mortimore 2005).

Several authors consider that the desertification and deforestation “narrative” promoted in West Africa was as much based on political interpretation as on fact (Amanor 2002) (Fairhead 2000). Fairhead and Leach (2002) re-examine the history of rainforests and climate in West Africa with to conclude that use of the term ‘original forest’ equated with ‘potential forest’, as a baseline against which to assess deforestation can no longer be upheld for this region. Its continued use they claim is “(a) *massively exaggerating forest cover loss, (b) misrepresenting forest status and trends, (c) misconstruing the impact of land use on the region’s vegetation, and misrepresenting the social history of the region*”. They advocate the use of a much more dynamic landscape perspective on forests and analysis if useful policy is to emerge. As an example they cite many analyses that in Ghana the potential forest area of 8-10 million ha (i.e. the area where forest might be expected to occur today in the absence of humans, based on climate, topography, and other variables was forested around 1900, with forests now being reduced to less than 2 million ha.

Similar conclusions are beginning to emerge from some analysts in other Regions. Studies by Wang et al (2005 in press) for example in semiarid North China suggest that human activity may not be principally responsible for the rapid desertification that occurred between the 1970s and 1980s, as previously assumed. Human pressure has continued to escalate, although there has been a clear recovery of vegetation and ecological productivity since the mid 80s. . Their work suggests that this wind erosion is primarily caused by two climatic factors related to sand transport (drift potential and the frequency of sand-driving wind). They point out that “*although numerous field observations have led researchers to propose that human activity drove the rapid desertification in semiarid North China, our analyses show that politico-economic agendas may also have influenced the interpretation of ambiguous results or casual observations*” (Wang 2005 in press).

Fairhead and Scoones (2005) review a wide range of case studies from the humid and sub-humid Guinea savannas of West Africa to show how farmers’ activities can often lead to dramatic speeding up of natural forestation processes. Fairhead’s (2005) conclusion that “*the upgrading of savanna fallows and their enrichment through farming is common, at least in West Africa*” is clearly challenging others interpretations that have focused on the negative impacts of farming on ecosystems.

A special edition of the Journal of Land Use Policy “Soil degradation in Sub-Saharan Africa” (Issue no22, 2005) provides a good range of articles and representative opinions on the debate regarding the underlying trends and causes of land degradation. The conclusions in the editorial by Koning and Smaling are worth quoting:

- *The dynamics of agricultural and environmental change are more complex than appears from much agronomic research.*
- *The direct link that is sometimes made between soil degradation and population growth is unwarranted.*
- *There are cases where ‘more people’ accompanied ‘less erosion’, as well as cases where soil degradation occurred in spite of declining population pressure.*
- *Farmers may not invest in the soil in newly settled areas. They will attempt (though not necessarily successfully) to introduce more sustainable land management practices as the pressure on the land increases.*
- *Many low-external-input techniques are rational responses to the conditions that farmers face. Farmers use their room for manoeuvre by exploiting variation in terrain and microclimates, synergies between crop and livestock activities, and locally available inputs.*

- *Many top-down policy interventions that try to combat soil degradation by directly interfering with farmers' decisions have failed. Environmental controls in colonial times have often frustrated rather than stimulated farmers' attempts to cope with environmental problems. More recent initiatives like the Soil Fertility Initiative for Africa still have to prove themselves.*
- *In this situation, population growth caused vicious spirals of poverty and soil degradation rather than sustainable intensification. This dynamic cannot be changed by participatory approaches alone: public investment in infrastructure and a reversal in price policies are also needed.*

“Participatory approaches of expert-farmer co-operation are highly desirable. They require a rehabilitation of agricultural knowledge services, which are in an abominable state in many countries. However, participatory approaches will only help if the terms of trade for farmers are also improved. Public investment in roads and other infrastructure is a vital condition for this, but protective tariffs on agricultural imports may also be needed. Tariffs will improve farm-gate prices near the ports and induce investment in transport, storage, and processing that will extend this price effect to larger areas. The government revenue from tariffs can be used for employment projects that support this investment while compensating poor net-buyers of food for increased food prices”. (Koning 2005)

Relevant research into changes in vegetation cover in the Karoo of South Africa show that land-cover changes in appear to be the product of the synergies between changes in precipitation and land-use as captured in stocking strategies (Archer 2004). Neither stocking strategies alone, nor rainfall changes alone can account for observed vegetation dynamics. Once again we see an example of a semi-arid environment that maintains multiple equilibrium states.

All the recent studies on greening seem to agree that while increasing rainfall is the main driver of this process of increasing NDVI, climatic change alone can not account fully for the observed greening trend (Herrmann 2005; Olsson 2005; Anyamba 2005). If true this observation would also indicate a more positive interpretation of human impact on vegetation cover. However, again one must remember that ‘greening’ is not necessarily synonymous with either biodiversity or successful forest management. It shows that vegetation productivity is increasing but not what types, associations, species etc. Mortimore (and like-minded analysts) provide an extremely important counter point to any unqualified accounts of human-induced desertification as the predominant trend in the Sahel. However, it must be noted that much of the empirical evidence cited is related to sustainable tree, range and soil management on locally owned or affiliated land – and not from uncultivated forests, be they State reserves or not. While some theoretical analyses consider that sustainable supplies to urban centres of wood fuel from natural forests are possible, the evidence is much less compelling than the real success stories presented from case-studies on agricultural lands.

As his recent report (Mortimore and Tucker 2005) puts it: *It is not suggested that all Sahelian farmers have surmounted the barriers, nor that even in [success stories], land use management is ideal. However, the trends deserve the attention of policy makers, and could be accelerated under supportive policies. Given the impossibility of stopping the progressive clearance of natural woodland, except in uninhabited reserves of limited extent, the aim of policy should be to accelerate such a transition, in which smallholders have incentives to conserve biodiversity and biological productivity. These need not be incompatible with a dense rural population”.*

The conclusion of this review is that the evidence clearly indicates that the rural communities of the Sahel do not tend to practice unsustainable land use management unless there is no choice. It would also seem that regardless of climate change, the forces effecting natural and human systems in West Africa will be profound. Unless the core issues of governance, economic opportunity and access to key services are solved it seems that land degradation will continue. Deterioration in rainfall (amount and/or distribution) will exacerbate these problems; conversely, improved rainfall trends will increase the opportunities and speed for generating solutions.

7 VULNERABILITY TO IMPACTS OF CLIMATE CHANGE IN THE REGION

7.1 Introduction to the issues

Vulnerability is the susceptibility of a system to the adverse impacts of a change and is determined by the level of damaging impact, the inherent sensitivity of the system to the impacts and the degree its adaptive capacity (ADAPTIVE 2004). Hammill et al (2005) also give a theoretical overview of vulnerability and resilience, drawing largely on the sustainable livelihoods approach (Hammill 2005). The IPCC's Third Assessment Report gives the standard overview of issues related to vulnerability (IPCC 2001). It considers that the extent to which a country is vulnerable to climate change depends on three factors:

- i) The severity of the climate change experienced
- ii) The sensitivity of local systems (ecological, economic, social etc) to the particular change
- iii) The ability of those systems to adapt to the new conditions

Assessing vulnerability (of ecosystems or human systems) to impacts of climate change clearly presents some significant challenges. First, as discussed above, we can not say as yet what sort of climatic impacts we are expecting. Warmer definitely, wetter possibly - but with what effect on ecosystems, water tables, soils, agriculture etc we can not yet predict with any real confidence. It is not even clear that intra/inter-seasonal variability will increase or that climatic extremes will become more severe (as expected in other parts of the world). Perhaps the most confident prediction we can make is that coastal communities are likely to face increase risk of storm damage and flooding and that as a result coastal populations will become more vulnerable to livelihood threats.

At the same time, we can be certain that harmful climatic events will continue (as part of 'normal' meteorological variability if nothing else) and that local communities will be highly vulnerable where ever the driving forces continue that cause poverty: lack of services, lack of access to new technologies or livelihood options, inappropriate policies, bad local governance, unjust global forces (markets, unethical corporate behaviour) and, in some cases, increased population density. A greater proportion of the Least Developed countries (about 70%) are in Africa, and most of them are in West Africa (see Annex 1). In addition to this, the West African Sahel has one of the highest population growth rates in the world.

Where these conditions do occur, ecosystems also highly vulnerable to unsustainable land use. These causes of vulnerability can be significantly exacerbated by adverse climate changes and possibly somewhat alleviated by beneficial ones, but most would assume they remain far stronger than climate change alone. At least in the context of developing adaptation strategies this would be the case¹². While the literature reveals not one assessment that

¹² Brooks 2005 and others have looked at the possibilities of sudden-onset, cataclysmic weather events and they

predicts a return to a 30 year drought period like that of the last century, all affirm that life threatening droughts will reoccur.

7.2 Scientific assessments of vulnerability

Relatively few rigorous scientific papers were found assessing vulnerability of natural or human systems – those that exist are generally computer models looking at agricultural or economic consequences of different computer generated rainfall/temperature scenarios.

Brooks and Adger (2003) consider that a useful proxy for future vulnerability can be estimated based on the level of impact of climate related natural disasters to date. Using data derived from the Emergency Events Database (EM-DAT) developed by the US Office of Foreign Disaster Assistance (OFDA) and the Centre for Research into the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain in Brussels, Belgium, they ranked countries throughout the world at risk from current climatic shock to show that the majority are least developed countries.

The IPCC's "Assessment of Vulnerability" (IPCC 2000) examines the extent to which climate change might generate adverse weather conditions in different parts of Africa. However, at that time insufficient conclusive data prevented any confident conclusions being reached. The International Institute for Applied Systems Analysis (IIASA) produced a major report on vulnerability of global agriculture to climate change (Fischer 2002). They used the main General Circulation Models linked to a GIS-based framework combining crop modelling and environmental matching procedures to identify crop-specific environmental limitations under various types of management conditions.

In a recent piece of modelling research, McClean et al (2005) study the effect of simulated climate scenarios on the distribution and density of over 5,000 plant species throughout sub-Saharan Africa. Not surprisingly, since ecosystems are defined primarily (although not exclusively) by temperature and rainfall, they record significant changes for a majority of the species. The results of course depend on the climate models used and as already discussed, there is still a lack of adequately reliable Regional models to allow suitable modelling. However, as rainfall scenarios become clearer the approach used to model plant response would seem valid.

It is also worth noting that even with the GCMs used to generate climate scenarios, (McClean) and his colleagues found that species from the Guineo-Congolian rain forests appear to be among the most sensitive to projected climate changes – these rainforest ecosystems would thus be more vulnerable than the dryland woodland. Given the higher natural variability in "normal" climate in the Sahel and Soudanian zones, this makes sense if linked to rainfall change. However, GCM's showing a 1 °C rise in temperature would increase the productivity of rainforests as a whole as long as all other factors are held constant (Biringer 2003).

Van Gemberden et al (2003) on the other hand consider that short term drought alone is unlikely to have significant effect on rain forests in central Africa, where typically weather conditions remain overcast and misty during quick onset drought periods (unlike in

clearly can not be ruled out. However, since such climatic catastrophes would, by definition, overwhelm all other adverse influences they remain more relevant to GHG mitigation lobbyists than adaptation strategies within the scope of TROFCCA.

Amazonia). They speculate that it would be the combination of human activity (especially escape of slash and burn fires) with periods of drought that would cause most damage (van Gemerden 2003).

Bringer et al (in WWF's recently released "User's Manual for Building Reliance to Climate Change in Natural Systems") expect tropical dry forests subject to be more vulnerable to forest fire whether there is an annual increase or decrease in rainfall! They argue that where precipitation is expected to decrease increased desiccation makes the forest system more likely to ignite but which is less vegetated and therefore less able to support the spread of fires. In contrast they expect the increase in plant biomass that will result from greater precipitation will lead to a more continuous source of fuel to support more frequent and intense fires. By concluding that "*a trend of increased fire occurrence tends to lead eventually to a general decrease of fires due to the reduction of fuelbeds over time*" one is left somewhat confused as to what the manual actually recommends (Bringer 2003). Nielsen et al (2003) study the fire regimes of Senegal using remote sensing data. They discuss the potential and limitations of the data available and make recommendations for how best remote images should be used in the future (for identification of fire scarring rather than of active fires). They also conclude that the northern limit of intense fire activity in savannah woodlands can not be adequately explained by variations in rainfall, herbaceous biomass distribution or land cover type.

The launch of the first commercial high-resolution satellite IKONOS in 1999 now permits monitoring of tree density in the Sahel over time independent of the ability of Sahel governments or international donors to fund aerial photo missions (Gonzalez 2004). The use of such data, which can be ground-truthed to detect species composition would help to improve our understanding of ecosystem variability to ascertain to what extent original vegetation types recover or change with interdecadal changes in precipitation.

(Vincent 2004) explores the possibility for adding to assessments of bio-physical vulnerability by creating an index to empirically assess relative levels of social vulnerability to climate change-induced variations in water availability and allow cross-country comparison in Africa. She uses a theoretical aggregate index of social vulnerability based on the weighted average of five composite sub-indices: economic well-being and stability (20%), demographic structure (20%), institutional stability and strength of public infrastructure (40%), global interconnectivity (10%) and dependence on natural resources (10%). On this basis she finds that Niger, Sierra Leone, Burundi, Madagascar, and Burkina Faso are the most socially vulnerable countries in Africa, based on her indices and current data.

Several studies on long-term environmental and agricultural change in the Sahel (in Niger, Nigeria, Burkina Faso and Senegal) have found evidence of significant transitions from degradational land use trajectories to more sustainable and productive production systems. These include increases in cereal yields, higher densities of trees, improved soil fertility management, locally higher groundwater tables, reductions in rural poverty, and decreased out-migration. The researchers (e.g. Mortimore, Reij, Scoones, Turner and others) are obviously keen to make their key point about the adaptability of local farmers and their potential for reversing trends of agro-ecological degradation and make no connection between these positive trends and the apparent improvement of annual rainfall patterns since the mid 1990s. It may be no coincidence that the emergence of many of these success stories also coincides with the establishment of increased precipitation. However, since all the case studies documented relate to changes in land management, any improvement in rainfall would

still only be a secondary contributing factor to the successful land reclamation observed. The conclusion from these researchers is clear, given the right opportunities and preconditions, some West African farmers are not as vulnerable as might be supposed.

As a special report of the Pan Africa START¹³ secretariat on Climate Change and water Issues points out, water demand is likely to double in the Region over the next 20 years, while storage is likely to reduce as siltation reduces the capacity of many existing reservoirs (Odada 2004). The adverse consequences of water shortages on health are reviewed by Epstein and Mills (Epstein 2005) and on local security by Nyong and Fiki (2005). A study on the feedback mechanisms between climate, land-use and hydrology can be found in (Beniston 2002), in relation to Volta basin as part of the GLOWA Volta project, but final results are still awaited¹⁴.

As the one target country with a coast, Ghana is the only country where the issue of climate induced sea level rise is directly relevant. As part of the SURVAS¹⁵ Programme on African Vulnerability and Adaptation to impacts of Accelerated Sea-Level Rise (ASLR), Ghana carried out an initial assessment of the environmental, social and economic vulnerability to anticipated sea level rises over the next century (Osei-Wusuansa 2000). The assessment of the impact of sea-level rise was done by considering a rise of 100 cm by the year 2100 and a socio-economic scenario for 1994. Much of the study was focussed on the loss of land as a result of shoreline recession, flooding and inundation. The report mentions the Mangrove vegetation at risk from flooding and shoreline recession (including *Conocarpus erectus*, *Thespesia populenea*, *Acrosticum eueum*, *Phoenix reclinata* and *Sesuvium portulacastrum*). The coconut palm (*Cocos nucifera*) particularly along the shores of the West Coast is expected to suffer heavy losses.

7.3 Interpreting vulnerability narratives

A great number of publications regarding vulnerability have been produced from the development sector, the environmental conservation organisations, the humanitarian and social development NGOs, the multi-laterals etc – which also receive the highest airing in the press. Invariably these paint worst case scenarios and depict Africa as a whole and often West Africa in particular, as being the most vulnerable of all regions to climate change. Since this paper is looking at the issues of adaptation to climate change, it does not include an extensive review of the literature related to mitigation strategies. It also avoids therefore some of the highly politicised debate on the under-lying causes of climate change (e.g. human induced v. ‘natural’ climate change). For those interested in the current state of the debate, Pielke (in press) offers a recent example of the anti-Kyoto perspective (who argue against anthropogenic green house gas emissions as a primary cause).

However, it is important to point out that the literature reveals some unsurprising trends regarding the political interpretation and representation of climate change vulnerability. The worst case scenario is usually presented: either drought is assumed, or the possibility of increased rainfall is indicated indirectly and only in terms of “increased erosion”, “devastating floods” and “spread of disease” – never in terms of increased agricultural yields or of natural revegetation of desertified areas. Scientific articles may be quoted, but with little variation and

¹³ START - the global change SysTem for Analysis, Research and Training

¹⁴ For more details, visit http://www.geo.vu.nl/users/ivmadapt/downloads/Volta_FinalReport.pdf

¹⁵ Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies (SURVAS) Project (<http://www.survas.mdx.ac.uk>).

often out of context. Hulme's work is probably the most frequently quoted, citing his analysis of the Sahelian drought as being the single biggest rainfall anomaly since (scientific) records began. However, his reflections that this period of drought may well not reflect a longer term trend and may not represent a sustained (greenhouse gas related) climate change are usually never included.

It is of course quite understandable that these pessimistic publications are presenting a one-sided interpretation – this is their job: to try to awaken the general public and the policy makers to the very real dangers of continued levels of green house gas emissions to the health of the planet. They also need to draw attention to the fact that it is the poorest people on the planet who will be the most 'innocent' victims of any adverse impacts of pollution driven climate change. They also need to raise funds. However, they are not a useful basis for developing considered, local adaptation strategies. And at times they may obscure the fact that in Regions like West Africa, sustained attention is still required to deal with the adverse impacts of much more predictable trends: malnutrition, lack of services, inappropriate land policies, bad governance, inequitable global market forces etc.

O'Brien et al (2004) argues that the imprecise use of various terms significantly effects our analysis of both the 'prognosis and the cure' of climate change. They point out that in much of the UNFCCC literature and related research, vulnerability is taken to mean the potential 'net impact' of climate change – i.e. how much damage will still be experienced once the possible adaptation measures have been taken. This has driven research and funding to focus on developing specific adaptive capacity to likely consequences of climate change (e.g. drought resistant seeds, new crops etc). When vulnerability is used in a more holistic way that recognises that for a whole range of reasons (not just climatic) different sections of communities (or eco-systems) are more or less When vulnerability is taken in this sense it is seen more as Addressing climate change means enhancing the ability to cope with present-day climate variability and long-term climate uncertainty.

To understand the thinking of the experts involved in developing IPCC reports and publications it is interesting to read minutes from their recent meetings in preparation of the 4th Assessment Report, which with commendable transparency is available on the web (IPCC 2005). This reveals that many involved consider that because their priority is making politicians and their constituents more aware of climate change and its implications, issues and messages should be simplified as much as possible; As one participant puts it: *"What is needed most is a consistent message (from science) to the outside world to mobilise funding. As long as the scientific community argues over what is real and what not, politicians will not (financially) support the climate change cause. At this moment the message has become too complex, too context specific"* Another points out that *"searching for the "dread factor" remains important."*

Their dilemma is very real and understandable – their intention is to help and to help politicians must be galvanized. The danger of course is that inappropriate policies are generated as a result and that some key underlying issues are overlooked (the unaccountability of the very politicians who the scientists are trying to galvanise, for example!). There is also a strong focus on fund raising for projects, to be undertaken by international organisations etc.....Without being too cynical, is there perhaps a part of this that is not quite as disinterested as it could be?

It is also remarkable how channelled the different interest groups continue to be. For example, a paper produced for the OECD by UNDP/ILO entitled “Risk and Vulnerability in Agricultural Policy: a West African Perspective” clearly advocates for risk management to become more central to regional policy development, but makes no mention of climate change, UNFCCC or the NAPAs (Aubee 2004). Similarly, an in depth description of UNCDF’s strategy to environmental development makes no mention of climate change or how it might be incorporated into development planning (Bonfiglioli 2004).

Given that the Sahel is characterized by some of the most variable climate on the planet (Hulme 2001), it is not surprising that local livelihoods have evolved accordingly. The inherent adaptability of rural communities in the Sahel and much of the northerly Soudanian zones of Burkina, Mali and Ghana is clearly one of their strongest resources. A number of researchers strongly challenge the notion that the Sahel is in some sort of crisis or that local livelihoods are in a state of collapse (Mortimore 2001). Dietz et al (2004) observe when collating the results of over 5 years of research looking at the impacts of climate change in West Africa, “the conclusions [for the future of the Sahel] don’t look very grim, contrary to the much painted picture of doom for Africa”. This is significant in that over 20 scientific research institutions were involved, from Burkina Faso, Ghana, Mali, Niger and the Netherlands. Fuller and Ottke consider that the level of desertification in the Sahel was not as pervasive as some authors had suggested in the 1990s and 80s (Fuller 2002).

For those interested in the epistemology of scientific issues, Norgaard and Baer examine why and how climate change debates become polarised and how different interpretations come to the fore. As they conclude “a greater self-consciousness of the need for plural approaches could improve the basis for learning and decision making (Norgaard 2005). For a detailed examination of the more sinister trends of deliberate manipulation of climate change facts to construct a particular view point (that downplays the role of GHG emissions by man), it is instructive to read a recent article in the journal of Global Environmental Change entitled the ‘Climate of Scepticism’ (Antilla 2005).

7.4 Vulnerability as a result of poverty, inappropriate policies or weak governance

It would be foolishly over-reactionary to suggest that West African communities are not highly vulnerable to climate change and that the biophysical environment is not a primary reason for this. This is undeniable and has already been alluded to many times in this review. However, there is also a growing realisation that frequently the inherent adaptive capacity of local peoples has been, and continues to be, weakened by inappropriate (or non-existent) policies, strategies and interventions from national and international organisations (public and private).

Warren (2005) observes that the surprise with which the news of recent greening in the Sahel is worrying, since it indicates how little policy makers still understand the dynamic nature of the Sahel, its vegetation, climate and local livelihood systems. Even more pointedly he concludes that: “*little, if any, of the recent greening, if and where it has occurred, could be attributed to policy; and that as yet neither models nor interpretations of the satellite imagery yet give firm guidelines for policy*” (Warren 2005). Herrmann and Hutchinson (2005) provide an interesting review on the current debate on desertification, highlighting how points of view and decisions are reached according to the particular interest or background of the different actors involved. They suggest that “*in many ways, we might conclude that we have a non-equilibrium world that is saddled with an overriding equilibrium mindset and policies*

that reflect it.” And “Discussion of desertification from the social science perspective still tends to base its understanding of the dryland environment on outdated ecological models; ecologically motivated assessments of desertification, on the other hand, often fail to incorporate new insights from the social sciences; and, finally, because they may be driven by perverse or parochial interests, policies that affect people on the ground may be formulated largely independent of science that is current and thus may serve to degrade rather than enhance the lives of people most affected.” (Herrmann 2005)

A recent workshop held by the UNDP Drylands Development Centre ("Drought Risk and Development Policy in Africa", Naiorbi UNDP 2005) highlighted the growing acceptance that drought is probably more usefully conceived as social and political issue, rather than just a natural risk. The report looks at discuss how and why drought is as much a consequence of poor governance as of severity of rainfall decrease (UNDP-DDC/BCPR 2005). In an interesting and detailed case study of pastoralists vulnerability to recurrent drought in Iran also stresses that political issues are as important if not more than bio-physical ones (CENESTA 2004). From a wider global perspective Warren reminds us also of the global governance issues driving poverty not least the double standards in trading rules (Warren 2005).

Brooks et al have assessed vulnerability to climate events in terms of mortality. Interestingly, at a national level, they find that issues of Governance, literacy and health services are significantly more important in determining vulnerability than household income per se. The more accountable, transparent and responsive a country's Government, the less vulnerable its population are to death from climatic extremes (Brooks 2005). In their analysis therefore, Burkina Faso is significantly more vulnerable than Mali, while Ghana is not even considered moderately vulnerable.

Geist and Lambin reviewed 132 case studies of dryland degradation to see what underlying patterns might be apparent (Geist 2004). Their results also challenge single-factor explanations that put most of the blame for desertification on the overworking of land by increasing numbers of rural poor and by nomadic populations. While they identify regionally distinct modes of increased aridity, expansion of cropping and grazing activities, infrastructure extension, and, to a lesser degree, wood extraction as *proximate* causes of desertification, the underlying factors emerge as being economic, institutional and political (along with climatic and demographic influences).

Many authors argue convincingly that no standard set of indicators can be used to assess desertification status or the complexity of human-environment interactions inherent to dryland change (Geist 2004). Similarly there is no universal policy for mitigating desertification; rather, as Geist and Lambin put it: *“a detailed understanding of the complex set of proximate causes and underlying driving forces affecting dryland-cover change in a given location is required before any assessment and policy intervention”*.

One of the more worrying examples of recent policy development in the Sahel failing to consider climate change is provided by a 45 page report by the Sahel and West Africa Secretariat (SWAC) of the OECD on the role of cotton in livelihoods in West Africa. It makes no mention what so ever of climate change or its possible impact on cotton production (SWAC 2005). The report defines 10 (very relevant) strategic questions for African cotton sub-sector support initiatives to address, but it fails to ask the question how climate change may affect cotton production and what might be done. This from a report that considers itself

to be “*a lasting resource to inform debate between West African actors and the international community and support the process of developing actions to be taken both in the region and internationally in the months ahead*” (SWAC 2005).

7.5 Concluding remarks on vulnerability

The overall impression left by the literature (at least on this reviewer) therefore is that ecosystems and populations remain highly vulnerable to a range of anthropogenic factors that are driving poverty. Where these factors are lessened, vulnerability to any adverse biophysical factor is also reduced – be it climate variability or change, insect plague, or animal/plant disease. Batterbury and Warren in their introductory essay to the special issue of Global Environmental Change “Human dimensions on the Sahel of West Africa actually conclude with a cautionary warning in the use of research: “...*research has the capacity to mislead and be itself misled*” (Batterbury 2001). We also need to heed the concern of those highlighting the danger of depending on assumptions (what are now increasingly referred to being called “narratives”) to shape policy and practice (Amanor 2002) (Fairhead 2000).

8 ADAPTATION

8.1 What is adaptation? (and adaptation to what?)

There are no shortage of papers in the climate change literature that seek to provide their own definitions for all the terms now being used. One of the less mystifying is provided by the Tyndall centre for Climate Change (ADAPTIVE 2004) which considers adaptation to be: “*the adjustment of a system in order to moderate the impacts of change and to take advantage of, or cope with and recover from, the consequences*”. A range of definitions and theories can also be found in Romero (2005) which provides a useful synopsis of the IPCC Third Assessment Report (TAR). The adaptive capacity is thus the ability (of someone or something) to adapt successfully to the impacts of change. A system has a high level of resilience if it has a good adaptive capacity and/or a low sensitivity to change. Chapters 18 and 19 of the Intergovernmental Panel on Climate Change (IPCC) third assessment report: “Climate Change 2001: Impacts, Adaptation and Vulnerability”¹⁶ provide an overview of the issues. The Tyndall Centre for Climate Change Research is coordinating a research programme known as ADAPTIVE to examine social, economic, political and ecological adaptation to climate change in vulnerable environments (ADAPTIVE 2004).

A common and perhaps surprising feature among the plethora of publications in the developmental literature advocating climate change adaptation is that few if any ask the question: “adaptation to what?” One finds a great deal of national and international reports and initiatives (including the development of the on-going NAPAs¹⁷) all strongly asserting the urgent need to mainstream adaptation into the development process (see for example (Hansen 2003; Huq 2003). The titles, cover-pictures and organisations involved are impressive and suggest that we know what needs to be done and are starting to do it. But often the content fails to provide much rigorous analysis, lacks pragmatic advice or remains too generalised to be of much help. They tend to be limited to broad recommendations that development programmes must internalise climate change issues, support ‘enabling environments’ for communities to adapt, strengthen institutional capacities to respond etc. However, because of

¹⁶ All chapters can be downloaded from http://www.grida.no/climate/ipcc_tar/wg2/

¹⁷ NAPA – National Action Plan for Adaptation to climate change for LDCs through the UNFCCC

the uncertainty regarding local impacts of present and future climate scenarios, there are few concrete proposals in Africa of whether focus should be on responses to droughts or water-logging, floods or fires, wind erosion or mudslides increased malaria or decreased trypanosomiasis, more or less locust plagues.

This ambiguous state of affairs seems especially pronounced in West Africa where, since the 1970s, the institutional (climate-related) attention has overwhelmingly (and quite understandably) focused on drought and desertification. With the poor rainfall of 2004 and the current public focus on malnutrition in Niger, the apparent trend of desiccation is likely to continue to dominate local perceptions and policies. The institutional apparatus related to aridification is already in place: the UN Convention of Desertification, CILSS, AGHRMET and the great number of bilateral, multilateral and NGO initiatives attempting to strengthen rain-fed-based livelihoods.

The 92 page report (UNFCCC 2004) entitled “National Adaptation Programmes of Action-Selection of examples and exercises drawn from regional NAPA workshops” is one of an enormous number of reports being produced by the UNFCCC process (along with all its supporting and subsidiary groups, such as UNITAR¹⁸, LEG¹⁹ etc). On reading it, a growing sense of its disconnect with reality emerges. It is an enormously dense report, packed with all the latest jargon and highly detailed on the process to be followed for developing the NAPAs. However, nowhere does it acknowledge that for many countries (especially in West Africa) we still do not know to what we should be adapting. Nor does it put into context that fact that NAPAs in practice will have nothing new to offer (in terms of concrete development actions on the ground). The countries that have to produce NAPAs are the so-called LDCs (“Least Developed Countries”) – i.e. by most definitions, the poorest in the world - and many are struggling even to maintain current poverty levels from deteriorating under current climatic conditions. In as much as there are no new solutions and in many cases no qualitatively new problems: very many of adverse impacts of climate change will be either an exacerbation of existing problems or a shift in their location. This review does not in any way belittle the need for strengthening adaptation. It just wishes to point out that much of the development literature is not admitting that it is the same need as before – basically that of poverty alleviation and sustainable natural resource management (see also Annex 4 for more details on LDCs, NAPAs and the UNFCCC).

In many cases, the literature reveals that much of what is being couched as ‘adaptation to climate change’ is no different to the existing thinking on sustainable development processes. There is nothing wrong with this; it is just that few organisations seem comfortable to admit it. It is no secret that NGOs have to redress the same initiatives to maintain funding streams – in some cases climate change adaptation appears to have such a function. The IPCC’s Third Assessment Report gives the standard overview of issues related to vulnerability (IPCC 2001). However, apart from providing a useful starting point for understanding vulnerability, the report is unable to offer much beyond advocacy for promoting adaptation as an essential part of on-going policy development. Similarly, Hammill et al (2005) present a list of lessons learnt for interventions promoting adaptation of livelihoods to climate change, based on experiences from ‘adaptation’ projects in different countries. As can be seen however, there are really no *new* lessons that should not already be driving CBNRM interventions be they within a climate change optic or not.

¹⁸ UNITAR – United Nations Institute for Training and Research, Climate Change Programme

¹⁹ Least developed countries Expert Group

Many papers make a strong case for urgently improving our understanding of possible impacts of climate change in Africa (for an overview see (Desanker 2001) with the use of models linked to biophysical and socio-economic parameters. It would be helpful if as many were also more honest when producing large reports on adaptation that little new advice has yet been generated.

From another perspective, several publications from the ‘adaptationist’ school of thinking stimulate relevant reflection on the issue on supporting adaptation interventions. Mortimore et al (2005) (Mortimore 2001) use a broad range of case study material (from Kenya, Nigeria, Niger and Senegal) to argue that many populations living in drylands have been successfully adapting to changing conditions for decades. They also critique the over-simplistic use and interpretation of Land Cover Change (LCC) as proxy indicators for “good” or “bad” land use change (LUC), pointing out that the reality on the ground can sometimes show a qualitatively different picture emerging from broad scale LCC analysis. Similarly, that most examinations of land use change do not reveal crucial changes linked to ecological or economic sustainability (such as farm capitalisation, agricultural intensification etc). They recommend therefore that “*representative analyses of process at micro-scale need to be linked* be good advice if we are to start to understand what type of adaptation is needed and on what scale.

Linked to this issue is the growing acceptance of the disequilibrium nature of semi-arid/sub-humid systems (natural and human). In the past, conservation management has been associated with preventing change. It was assumed that vegetation structure (tree density) in savannas was stable, and was in equilibrium, since changes in vegetation were perceived as a disruption of equilibrium conditions, and therefore as undesirable. But now some of the basic assumptions are being challenged so it becomes less simple to determine when spatial and temporal variation in tree abundance and species should be considered acceptable or an alarming sign of serious degradation.

8.2 Success stories to date -progress in Developing Climate Change Adaptation Strategies

In 1987 and 1988 CILSS, in cooperation with GTZ (Programme Allemand CILSS) and Rochette & al studied 21 cases of agriculture and NRM in the Sahel, which were considered in those days to be at least partially successful. They included a wide range of experiences in soil and water conservation, irrigation, agroforestry, windbreaks, livestock marketing, soil fertility management, village land use management, etc. The 21 case studies from 5 countries were published in 1989 by CILSS and GTZ and the book reflected the effort of the Sahelian peoples and their partners’ to combat desertification in the Sahel. By focusing on new techniques and new approaches, the book provided evidence that in the 1980s progress was made in combating desertification (CILSS 2005).

Much has happened since this study “Le Sahel en Lutte contre la désertification”. Other case studies and assessments indicated increased investments in NRM across the sub-region over the last fifteen years. Over the same period, most countries made reforms in the laws and policies that influenced decisions about investing in NRM (e.g., Decentralization Laws, Forestry Codes, the roles of National Technical Services, etc.). Other assessments brought attention to the impacts of NRM initiatives on spurring rural economic growth, reducing poverty, mitigating conflicts, reducing degradation rates and empowering rural populations. But, while we have evidence that local investments in NRM grew, we have little information on the scale, the reasons, or the impacts.

(Faye 2001) also point to success stories in the (predominantly Sahelian) Diourbel Region of Senegal, where farmers have selectively adopted new soil and water conservation practices to maintain or increase yields per unit of rainfall (even wheel rainfall was still depressed in the 1980s).

Collection of information about successful projects is now being conducted by a number of organisations (WOCAT 2005). As already mentioned, the literature on the evolution of West African (and especially Sahel/Soudian) agro-ecosystems is characterized by a polarized debate between those that consider that desertification and land degradation continue to dominate and those that challenge this assumption. The latter group is dominated by the publications of Mortimore and Tiffen e.g. (Mortimore 2001) (Mortimore 2001) and of Reij and colleagues (Reij 2005). They argue that farmers have responded to the “crisis” of the 1980s by adapting to the challenges *and opportunities* generated by increasing population, continued drought and declining yields, access to new agricultural technologies (mainly SWC practices and drought resistant varieties).

A report on successful case studies supported by UNEP (UNEP 2002) illustrates a range of technical interventions that have demonstrated their potential for combating desertification.

(Winslow 2004) focus on the success stories of African drylands – showing how small holder agricultural intensification and reversal of environmental degradation is possible. Much of the literature that aims to counter previous “doom and gloom” depictions of African drylands is based on the study carried out by Reij and Steeds for the Global Mechanism of the UNCCD (see (Winslow 2004). This review considers it is important to avoid polarisation.....

(Reij 2003) review the rehabilitation of the soils and productive capacity of degraded lands in Burkina Faso’s central plateau between 1980 and 2001. They also find that with improved soil and water management techniques and more intensive agriculture, small holder farmers have managed to increase cereal yields and production.

In Niger, the pilot study led by Yamba and al²⁰, in collaboration with IRG, has highlighted the positive impact of NRM projects on the ecological, economic and social environment of the target populations (Boubacar 2005). Thus, non exhaustive sampling has revealed an important thickening of the vegetation cover, an increase in the ground water level, a decrease in poverty even the realization of food self-sufficiency, the creation of associated movements and the reinforcing of the organizational capacities of the rural populations. The study highlights an increase in the fodder production, which is favorable for breeding and milk production. It has also reported a diversification and an increase in agricultural productions due to rainfall or on the lands arranged for irrigation. Galvin et al (2003) (Galvin 2004) also show how farmers in East and southern Africa have been adapting to increased climate variability for many years and discuss options for culling and changed range management. Rinaudo also presents evidence of the measurable success of farmer assisted natural regeneration in the Sahel (Rinaudo 2005).

The former or current NRM projects are also recognized as governance improvement strategies in the management of natural resources with the local rural management organizations and in the management of the supply in food products and inputs with the multitude crop banks and inputs banks. These projects have made it possible to anticipate the

²⁰ Sahel Study, Niger Pilot Study Report, April 2005 – www.frame.org

missions of local authorities in particular the collective natural stock management and the local development planning (Boubacar 2005).

The fragile evolution of adaptive land management in the Department of Samorogouan in Burkina Faso provides a useful on-going case-study deserving of further monitoring. Nelen et al (2004) describe how village led processes of negotiation and initiative led to an initial situation in which multiple land users (pastoralists, subsistence and cash-crop farmers, landless migrants) developed the institutional potential for sustainable NRM. The importance of the case-study is that is largely an indigenous process but illustrates how sensitive and appropriate outside assistance (in this case from an SNV project) can help processes along. It is a good example of building adaptive capacity. As Toulmin (2005) point out that the considerable adaptation already demonstrated by small holder farmers in the Sahel (to the climate change of the 1970s and 80s) has been autonomous by local communities with little role by governments in making adaptation possible.

8.3 Emerging conclusions and recommendations for adaptation

8.3.1 General recommendations

As discussed above, there is no shortage of publications concerning adaptation to climate change. However, disappointingly few of them would have many new ideas to offer. Without being too cynical, it would seem that at times a lot of effort has gone into repackaging existing ideas concerning poverty and drought related vulnerability in the new wrappings of climate change, but with no new inputs. Having said that, there is of course still useful and relevant material being produced. This review attempts to present key messages according to the main different components for increasing adaptive capacity being recommended. We will first look at some of the key, generalist papers coming out that appear to reflect mainstream thinking and then examine some of the sectoral issues that are most frequent in the literature

The most extensive recent publications on climate change adaptation include the United Nations Development Programme – Global Environment Facility’s “Adaptation Policy Framework” (APF), developed with support from the Swiss, Canadian and Dutch governments. This APF as “*an innovative set of guidance tools for the development and implementation of adaptation strategies. The APF aims to help countries as they integrate adaptation concerns into the broader goals of national development. Ultimately, the purpose of the APF is to support adaptation processes to protect and, when possible, enhance human well-being in the face of climate change, including variability*” (Burton, Lim et al. 2005). The authors structure their APF around four principles, which generally would reflect the emerging consensus among practitioners regarding climate adaptation (see Box 2 below).

Box 2 The four major principles of UNDP-GEF's 'APF' for climate change²¹

- 1) *Adaptation to short-term climate variability and extreme events is included as a basis for reducing vulnerability to longer-term climate change.* As users seek to prepare for near-, medium- and longer-term adaptation, the APF helps them to firmly ground their decisions in the priorities of the present.
- 2) *Adaptation policy and measures are assessed in a developmental context.* By making policy the centrepiece of adaptation, the APF shifts the focus away from individual adaptation projects as a response to climate change and toward a fundamental integration of adaptation into key policy and planning processes.
- 3) *Adaptation occurs at different levels in society, including the local level.* The APF combines national policymaking with a proactive “bottom-up” risk management approach. It enables the user to hone in on and respond to key adaptation priorities, whether at the national or village scale.
- 4) *Both the strategy and the process by which adaptation is implemented are equally important.* The APF places a strong emphasis on the broad engagement of stakeholders. Stakeholders are seen as instrumental in driving each stage of the adaptation process.

Quoted from (Burton, Lim et al. 2005)

(Toulmin 2005) makes more succinct and practical recommendations as to what support for climate change adaptation should prioritise in Africa:

- *Build on what local people are already doing by strengthening their own capacities to do what they want*
- *Strengthen local land rights, including support for collective management of common resources*
- *Support development and spread of local technologies for soil and water conservation*
- *Support south-south learning*
- *Ensure that new projects of any sector are designed so as to increase their contribution to climate change adaptation*
- *Invest in new and better energy systems in Africa, through decentralised power generation; use of biofuels, solar technology*

Recommendations generated by AIACC²² (Elhassan 2005) for strengthening adaptation to climate change are as follows:

- *Adaptations to current climate risks are generally consistent with adapting to future climate change*
- *Immediate actions on adaptive capacity building and enhancement of current coping capacity are necessary to reduce vulnerability to current climate-related risks and climate change.*
- *Adaptive capacity can improve where people have better access to resource, market, technology, information, social service, high level of awareness, skills, security, strong institutions and effective organizations*
- *National policy processes and sustainable development planning need to integrate adaptive capacity building and adaptation strategies at the community level*
- *Adaptation concept and practice will evolve overtime when more information on practical experience become available (but we need to start learning by doing now)*

²¹ The APF is supported by a further nine Technical Papers providing detailed guidance for : 1. Scoping and Designing an Adaptation Project. 2. Engaging Stakeholders in the Adaptation Process. 3. Assessing Vulnerability for Climate Adaptation 4. Assessing Current Climate Risks. 5. Assessing Future Climate Risks 6. Assessing Current and Changing Socio-economic Conditions 7. Assessing and Enhancing Adaptive Capacity 8. Formulating an Adaptation Strategy 9. Continuing the Adaptation Process

²² Assessment of Impacts and Adaptations to Climate Change – international programme facilitated by START

- *Effective mechanisms for information exchange and sharing of experiences are highly needed to advance knowledge and actions on adaptation*
- *Need to identify and share lessons from successful community-based adaptive capacity - building experience – both autonomous and project-based (AF-14 project goal).*
- *Need to understanding the processes , priorities and dynamics of local communities before formulating practical adaptation strategies*

The recent Millennium Ecosystem Assessment provides a broad overview of experiences to date in responding to desertification that also clearly directly relevant to climate change adaptation and reducing vulnerability (MEA 2005). It highlights:

- Poverty-ecosystem linkages (not just economic)
- Strengthening institutional and technological capacity, access to markets, and financial capital of local communities for improved soil and water management practices
- Security of tenure – recognising that traditional communal systems may often be more relevant than new private statutory systems
- Increased integration of pastoral and agricultural land uses provides an environmentally sustainable way to avoid desertification. However, policies to replace pastoralism with sedentary cultivation in rangelands can contribute to desertification
- Enabling policies that involve local participation and community institutions, improve access to transport and market infrastructures, inform local land managers, and allow land users to innovate are essential to the success of these practices.

There would be several examples from the literature that suggest that so called climate adaptation projects are in effect no different from existing development projects that are trying to produce sustainable livelihoods. One of many examples is the AIACC²³ Climate Change Adaptation project promoting “*adaptive capacity building*” for climate change, whose recommendations are listed above (Elhassan 2005). The project appears to have been well designed, implemented and has generated positive results, but one has to ask whether it was in any way different from standard sustainable livelihood, NRM focused, community-based development projects. Its two main development objectives were: i) to create locally sustainable NRM system to rehabilitate overexploited lands, and ii) to reduce the risk of production failure by increasing the number of livelihood alternatives; while the core project interventions promoted were:

Institution Building; Training and capacity building; Rangeland Rehabilitation (replanting, stabilization of sand dunes, creation of windbreaks, livestock restocking and management); Community Development (water development, rural energy management, introduction of revolving credit, drought contingency planning).

All the contributions to the 2004 IDS Bulletin ‘Climate Change and Development’ (Volume 35, no 3) in one way or another allude to the importance of responding to climate change issues in a holistic manner, with a wider development framework. A very different interest group, the OECD, come up with similar conclusions. In a report for OECD strategy development in West Africa, Aubee stress the need for policy coherence between climate and development however remains a major concern. The report suggests that there is a need to *downscale* the discourse on adaptation from a multilateral negotiations context, to a more substantive dialogue between sectoral planners, relevant stakeholders and climate experts on how best to operationalise adaptation as part of ongoing development activity. (Aubee 2004).

²³ Assessment of Impacts and Adaptations to Climate Change – international programme facilitated by START

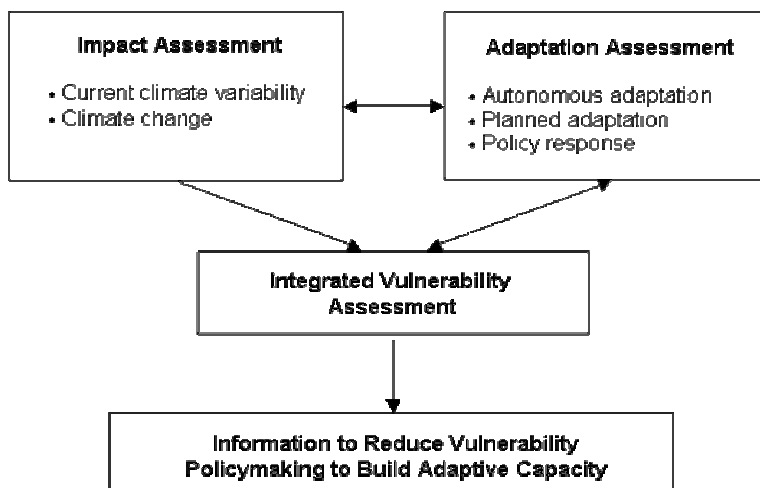
In discussing desertification processes, Geist (2004) stresses the need for generating local solutions based on knowledge of local causal factors and their interactions.

Huq and Burton emphasise the importance of mainstreaming adaptation interventions into all development interventions and funding mechanisms (Huq 2003). They therefore recommend that:

1. *Development funding agencies* need to include the potential impacts of climate change in all their assistance work. This should be applied both to country development strategies and specific projects, if development benefits are to be fully realised and their own investments are not to be exposed to unacceptable risk.
2. *Developing country governments* need to work with the funding agencies and their own sub-national and local communities in assessing the potential impacts of climate change in all sectors and to take appropriate action to adapt to climate change.
3. *Development NGOs* need to jointly assess the impacts of climate change with their target communities and to incorporate adaptation to climate change into their activities wherever necessary.
4. *Climate change policy-makers* need to find ways of relaxing the rules of the UNFCCC process and the GEF if the funds available are to be effectively used for the benefits of developing countries.
5. The *Research Community* needs to advance the theory and practice of ‘adaptation science’ and to identify clearly the elements of enhancing adaptive capacity as well as improving the assessments of potential climate change impacts.

A number of donors and agencies have been advocating adaptation to climate change as an important part of their portfolios for several years. See for example Klein (2001) on Germany’s assistance to Africa concerning climate change adaptation.

The fourth and final regional workshop on National Adaptation Programs of Action (NAPAs) was held in Burkina-Faso October 2003 with the assistance of the government of Burkina Faso, the UNFCCC secretariat, the implementing agencies from Global Environment Fund (GEF), United Nations Institute for Training and Research (UNITAR), United Nations Environment Program (UNEP) and the Least Developed Countries Expert Group (LEG). The main objective of the NAPA is to identify the urgent and immediate needs of the Least Developed Countries (LDCs). The process seeks to raise awareness of adaptation and its link to poverty reduction and sustainable development and to develop national capacity for LDC-NAPA preparation and implementation and is represented as follows by the NAPA facilitators:



The recently released “Surviving Climate Change in Small Islands: A Guide Book” by the UK Tyndall Centre for Climate Change Research (Tompkins et al 2005) is worth reading. Not only does it provide a useful synthesis of all the key issues related to assessing vulnerability and developing practical and realistic adaptation plans, it is also a rare example of a scientific-based advice presented in a user-friendly way that would be accessible to people for whom English is not their first language (Tompkins 2005).

8.3.2 Holistic approaches to adaptation based on poverty alleviation

Most reports highlight the need to look at increasing adaptability and reducing vulnerability through holistic or integrated strategies that explicitly promote multiple objectives linked to alleviating poverty: improving services, strengthening livelihoods and sustainable natural resource management (Burton, Lim et al. 2005); MEA 2005(FOE 2005). Their key point is that vulnerability is basically a consequence of poverty and that increased adaptability can only be achieved through the successful alleviation of poverty.

The conclusions of a special task forces of agencies (IUCN, IISD, SEI)²⁴ convened in 2001 to develop appropriate adaptation strategies also highlight the need for a holistic view point which “*places the goal of poverty reduction at the centre of adaptation*” (IUCN 2003). Eriksen (2001) also stresses the relevance of an integrated approach that strengthens coping mechanisms at the household level. He points out that such approaches of reducing vulnerability, especially through income diversification, are supported for under the Convention for desertification control but much less for climate change. As Orindi puts it: “*the problems impeding socio-economic development in African countries are often the same as those that increase vulnerability to climate change*” (Orindi 2005).

The recent Millennium Ecosystem Assessment provides a broad overview of experiences to date in responding to desertification that also highlight the link between strengthened livelihoods and improved vulnerability (MEA 2005), stressing as it does poverty-ecosystem linkages and the need to strengthen access to markets, and financial capital of local communities

Faye et al, based on extensive studies in Senegal, make the following recommendations for developing adaptive capacity, clearly highlighting the need for integrated, livelihood security approaches (Faye 2001):

- Management of tariffs in relation to imported food stuffs
- Development of markets and the free flow of accurate market information
- Encouraging private sector investment in rural farm and of farm business
- Strengthen animal health services
- Strengthen appropriate applied research for diversification of crops and technologies
- Soil fertility management and SWC
- Improve access to credit
- Develop education curricula that are relevant to rural needs (including for self-employment in the non-farm sector) and strengthen basic numeracy and literacy
- Public investment in small rural towns (water, health, telecommunications, transport etc)
- Appropriate land tenure and usufruct policies (that recognise working customary systems)

²⁴ The World Conservation Union, the International Institute for Sustainable Development and the Stockholm Environment Institute

A critique of the prevailing sectoral approach of climate change adaptation from Eastern Africa is given by Orindi and Murray. Part is worth quoting in full as it puts openly what few others are elucidating so clearly: *“Most of the options suggested in the National Communications are reactive, technical and expensive. Moreover, they have been treated in a sectoral manner which could make their implementation difficult. Considering the limited resources available, it is highly unlikely that all will be carried out or address the fundamental social vulnerabilities to climate change. Real, long-term solutions can be found in existing livelihood strategies used by communities”* (Orindi 2005).

It is also worth quoting direct from Brooks (2005) on this subject: *“Given the uncertain nature of future changes in climate in semi-arid regions such as the Sahel, the building of flexible and resilient livelihoods is a priority. The creation of “enabling environments” for adaptation and the building of “adaptive capacity” are prioritised; support for traditional livelihoods that have evolved to cope with climatic variability is one way of achieving this. Any measures to enhance resilience and promote adaptation must take account of local contexts and recognise that imported developmental models may be inappropriate; indigenous livelihood strategies have often emerged from centuries or even millennia of linked environmental and social change”*. Sperling et al (Sperling 2003) also discuss the relevance of livelihoods to reduce the vulnerability of the poor to climate change through holistic adaptation strategies.

Mamadou Honadia, the UNFCCC focal point for Burkina Faso also stresses the importance of integrating adaptation to climate change with other processes such as poverty alleviation, biodiversity management and desertification control (Honadia 2001). Papa Cham, the UNFCCC Focal point for the Gambia highlights the need for more effective collaboration between climate change Focal Points and other in-country stake-holders, including the private sector and research/NGO sector (Cham 2001). He sees the need for support to allow better communication and experience sharing between neighbouring countries sharing similar problems and in general to promote a much broader level of awareness raising.

Based on a series of research projects in dryland Africa over the last 25 years, the Drylands Research Group would argue that the interpretation of the Sahelian farmer as being dependent on external variables is inherently flawed. Led by Mike Mortimore and Mary Tiffen, one of the key conclusions of this research is that a new paradigm is needed to replace the misconception of dependency and shift it to recognise the inherent adaptability of dryland farmers. They argue that markets, adoption of new technologies, agricultural intensification and income diversification are already defining characteristics of farmers in these areas of naturally high climatic variability. Policies are needed that support this inherent adaptability.

(Heerink 2005) looks at World Bank statistics to show that overall, food production per capita in much of SSA is getting worse, despite improvements in yields and areas under cultivation. He explores the different options for stimulating improved integrated soil fertility management and concludes that there is an urgent need to consider the social costs and benefits of short-term price policies that supplement medium to long-term structural policies. Rational price policies should try to minimise these negative effects. Direct price control is therefore not a realistic option. Two major options stand out for supporting agricultural prices, namely reduced taxation of agricultural exports and levying import taxes on food imports.

The need to ensure that conflict resolution mechanisms are considered within holistic adaptation strategies is highlighted by Nyong and Fiki (2005). Focusing on conditions in the

Sahel they provide a convincing evidence of how droughts have increased local conflict in the Region and present recommendations on how appropriate support to strengthen local conflict resolution capacities can be developed. This is not always easy and will definitely require more effort and time. As a facilitator for the workshop held in Nairobi to discuss with East African legislators strategies linked to climate change (Africa 2004) candidly admits “*It was not an easy workshop to put together. The discussions did not necessarily focus on climate change. One felt that the Members of Parliament had yearned for such a forum, and therefore took advantage of the occasion to discuss other problems facing the East African region. The organizers did not deny them this heartfelt need to network.*”

8.3.3 Community-level²⁵ natural resource management

This report will not attempt to review the huge number of experiences for improving soil and water conservation practices and agricultural technologies developed to cope with increased aridity and desertification over the last 30 years. Reij et al (1996) provide an earlier review covering Mali, Burkina Faso and Ghana. See also (Fox 2000) for a specific water harvesting approach to cope with variability and changing distribution of rainfall.

However, what is significant from the literature is the clear conclusion that adaptive and flexible community-based NRM is an essential adaptation strategy to cope with climate change and increasing climate variability. Decentralised locally accountable Governance, with local ownership and management of natural resources by local communities is accepted by almost all analysts as an integral part of any strategy looking to protect livelihoods and the environment. The key issue here is that the priority is not a technical issue but an institutional one – to all local end-users take control of NRM management with appropriate rules and support. “*Given the dynamic of transition in land use systems, the strongest evidence of sustainability (whether environmental, economic or social/institutional) is a continuing adaptive capacity on the part of the land users. Furthermore, sustainability may hold different meanings at different scales (from individual holdings through the village, terroir, district or department to the region). Some degradation at local level may be considered tolerable within a district that has achieved a degree of sustainability in natural resource management at an aggregate level.*” (Mortimore 2005)

Fairhead and Leach give good advice regarding possible interventions in the tropical forest zones of West Africa (Fairhead 2002). Their starting point is to recognise that “*West African people in the forest-savanna transition zone may have influenced ecological processes far more effectively than has been imagined. Rather than seek to condemn and amend their practices, conservation may have much to learn from them*”. They go onto to identify four prerequisites for promoting landscape enrichment:

- i) Understand and build on local people’s existing NRM practices that encourage tree cover.
- ii) Reformulate inappropriate, colonially-derived statutory law on land and tree tenure systems to strengthen customary procedures that have proved themselves more effective at accommodating ambiguous and complex local realities
- iii) Develop wider management strategies that focus on supporting relevant social and economic investment that allow local people to maximise the landscape enrichment contribution of their livelihoods
- iv) Ensure that any attempt at ‘people-led’ conservation is based on a thorough understanding of historical legacy and contexts.

²⁵ This paper recognises the inadequacy of using the term ‘community’ generically, but still adopts the short hand. Thus community-level does not necessarily mean communal management or ownership.

Wily (2002) gives a good overview of participatory forest management (PFM) lessons throughout Africa (including Burkina Faso, Ghana and Mali). She concludes that “*PFM is sufficiently widespread and effective in Africa today to be recognised as a significant route towards securing and sustaining forests*”. She stresses the importance of ownership and legal mechanisms to safe-guard local community rights and responsibilities for PFM to fulfil its potential.

From the perspective of natural forest management in Burkina Faso, a useful and recent assessment of dryland forest management practices and research needs is given by Sawadaogo (2005). He points out the current lack of political willingness (both from the Government and from the donors) to focus on NRM is a major drawback and is the result of previous poorly conceived (and thus unsuccessful) forestry management projects. He also highlights the fact that any sort of serious strategic planning for forest management is weakened by the lack of the necessary baseline data against which to measure change. The need for a forest inventory is crucial.

A collaborative alliance, calling themselves the Global Drylands Imperative (GDI)²⁶, make the following recommendations related to land tenure reform in the drylands (UNDP 2003):

- i) Commit to transparency and public participation in land tenure
- ii) Where appropriate, intervene in land markets and ensure that the redistribution of lands is fair while supporting the development of effective and accessible land information systems
- iii) Commit to developing systems of land tenure that respect the local and customary traditions
- iv) Officially recognize that land and its resources in drylands typically have multiple users.
- v) Ensure marginalized groups are benefiting from land distribution programs where the legal means are accompanied by awareness-raising
- vi) Promote collaboration amongst all actors to ensure that any land tenure reform processes take a holistic, comprehensive and co-ordinated view of institutional and physical environments

However, GDI do not allude in their document to climate change or to the issue of changing usage and value of land (and its vegetation cover and water resources) with changing precipitation.

The importance of common property resources in west Africa is also highlighted in other studies (Beck 2001) and illustrates the care that is needed in land reform programmes to avoid a swing toward over-privatisation. However, without support to allow the local institutions to remain effective (which will involve a degree of reinventing themselves) traditional common property management will inevitably be weakened as older systems lose their traditional authority. “*Recognition of traditional land rights and systems of management in the formal land laws (for example in Tanzania) is therefore a significant step towards reducing vulnerability of communities. Natural resource management should build on this to allow communities to continue using resources on a sustainable basis by bringing innovative ideas from both research and development fields. We need to explore how progressive policies that support community involvement in natural resource*” (Orindi 2005).

²⁶ African Centre for Technology Studies (ACTS); Centre for International Sustainable Development Law (CISDL); United Nations Development Programme (UNDP)

While the priority for promoting effective community NRM may be institutional, certain key technical issues are also being prioritised. In the semi-arid sub-humid zones, where most trees have strong regenerative capacities (coppicing, suckering, layering etc), farmer-assisted natural regeneration is especially relevant. Several authors point out that farmers and herders in the region have traditionally adapted to arid and semi-arid conditions by promoting *natural regeneration* of trees and shrubs. Gonzales (2001) points out that since natural seedlings (less than 40 cm high) of drought tolerant Sahel species account for 37% of small trees, natural regeneration could potential reconstitute the vegetation cover *under current climatic conditions*. Of course this would require adequate protection from livestock at the right time during the young trees growth. That this is possible is demonstrated by the fact that stands of locally protected, naturally regenerated *Faidherbia albida* over 3 m high can be found at densities of and 20 trees/ha in densely populated (and grazed) areas.

Verchot et al describe a series of relevant research results and case studies relate to agroforestry techniques and systems that could help to strengthen the adaptive capacity of farmers facing new challenges from both increases and decreases in rainfall (Verchot 2005). These include approaches for improving water harvesting and soil moisture, reducing erosion from run-off, increasing soil nutrients and expanding income generating opportunities from tree (timber and non-timber) cash crops. This paper is another good example of the wealth of important and relevant land-use practices that remain relevant regardless of climate change and which are being researched and promoted as part of on-going sustainable development strategies rather than for climate adaptation per se.

Recommendations generated by a recent review by FORNESSA and IUFRO²⁷ (see Box 3 below) of selected case studies of rehabilitation of degraded lands in Africa are practical and relevant to strengthening adaptive capacity of rural populations (Blay 2004), despite the fact that the authors only fleetingly mention climate change and then only as an *impact* of land degradation, not as a cause.

Box 3 Recommendations arising from FORNESSA-IUFRO review (adapted from (Blay 2004))

Policy Aspects

1. Adopt appropriate policies that, among others, allow a paradigm shift in forest governance from centralised to decentralised management involving local communities (community based forest management or joint forest management) and other stakeholders.
2. Pay particular attention to the role of range management for livestock in the dry zones especially, adopting a multi-sectoral approach as needed.
3. Review and if necessary change land policies to ensure secure and clear tenure rights for different communities. The review should be based on national land use priorities taking into account biophysical as well as socio-economic conditions.

Management Aspects

4. Ensuring the collection of baseline data to allow future impact assessment
5. Development of integrated and holistic approaches, including industrial and other off-farm livelihood opportunities to reduce pressure on forest and range resources.
6. Sustainable agroforestry production systems must be affordable by the resource-poor.
7. The value of traditional and local knowledge especially that held by the stakeholders.

²⁷ Forestry Research Network for Sub-Saharan Africa (FORNESSA); International Union of Forest research organizations, Special Programme for developing Countries (IUFRO-SPDC)

8. The importance of developing the skills of individuals and communities in planning, organisation, management and accounting.
9. The need for diversification of income generating activities and adding value through developing markets and marketing;
10. Finally the necessity for planning to ensure sustainability of the benefits of rehabilitation when project activity comes to an end.

A recent report on NRM case studies from Niger suggests the important contribution of assisted natural regeneration to local livelihoods and soil and water conservation (Boubacar 2005). Rinaudou also presents first hand evidence from successful NRM projects in Niger to show the economic reasons why farmers will sustain more trees on their land, given the opportunity (Rinaudo 2005). He argues that farmer assisted natural regeneration “is very cheap, very rapid and returns on investment begin from the first year”. His experience assumes that a realistic wood harvest for farmers is based on pruning 5 stems on each of 40 stumps per hectare but harvesting only one stem per stump per year, always encouraging a replacement:

Year 1	40 stems x 0.10 cents	\$ 4.00	
Year 2	40 stems x 0.70 cents	\$ 28.00	
Year 3	40 stems x \$1.50 ²⁸	\$ 60.00	
Year 4	40 stems x \$ 3.50	\$ 140.00	
Year 5	40 stems x \$ 3.50	\$ 140.00	
Year 6	40 stems x \$ 3.50	\$ 140.00	
Total		\$ 512.00	[\$1.00 = 500 CFA]

The benefit to the soil, crops, livestock and environment in general could also be calculated. Soil fertility is increased and erosion decreased; mulch from leaf litter retains moisture and adds nutrients to the top soil, increasing crop yields; animals eat pods and leaves - when there is very little grass available and leave manure on the soil, benefiting crops; the wind break effect of trees protects crops and helps to settle nutrient rich dust from further a field. These benefits are tangible and begin from year one (Rinaudo 2005).

Bellefontaine et al (2003) review the unrealised potential for use of suckering and layering as management techniques for woodland regeneration in semi-arid areas. In West Africa, they observe that the *Daniellia oliveri*, *Detarium microcarpu* and *Isobertinia doka* woodlands seem to be to a large extent the result of regeneration from suckering, and identify 115 indigenous or naturalised woody plant species that produce suckers. They also point out that although very few appear to produce air-layering *naturally*, most seem to have the capacity if managed accordingly. They also suggest that some species (especially in the Miombo of eastern and central Africa) will start to show greater suckering with decreases in rainfall or increased browsing pressure as (e.g. *Colophospermum mopane*). At Atlit in Israel, from a *Faidherbia albida* planted in 1913, in 1961 25 suckers were counted within a 22 m radius around the tree. In the sixties, these suckers and the mother tree were cut out to establish an apricot orchard. The mother tree and the most vigorous sucker vigorously re-sprouted and produced many individual suckers within a 20m radius. In the seventies, the apricot trees were replaced by a banana plantation after mechanical preparation of the soil. This resulted in a temporary reduction of the number of the *F. albida*

²⁸ The price of \$1.50 for a 3 year old stem is probably an under-estimate, so that total revenues could be much higher

suckers. However, the clone has continued expanding around the outside and in 1974, 37 plants were recorded.

The success of farmer assisted natural regeneration of trees in West Africa is cited by many authors (Rinaudo 2005). It is interesting to note that from one case study in Niger in the 80s how food for work was used to encourage the practice and the pros and cons of the experience (Rinaudo 2005).

Practical field trials with green manure crops in the forest-savannah transition zone of Ghana show that over 100 kg of atmospheric N per year can be fixed with *Macuna* and weed control (Anthofer 2005) an example of a technology adopted by farmers in response to weed encroachment (*Chromolaena odorata*) and removal of fertiliser subsidises. This is important it allows much better soil structure development and water holding capacity than use of inorganic fertilisers.

Under the umbrella of the Forestry Research Network of Sub-Saharan Africa (FORNESSA) and with financial resources provided by the European Commission through the Global Forest Information Service - GFIS Africa Project, a group of African scientists compiled case studies of land rehabilitation from all major ecological regions in Western- Eastern and Southern Africa covering “dry”, “humid” and “sub-humid” forests and woodlands. The results of these case studies served to formulate general lessons learned for the rehabilitation of degraded forests lands (Blay 2004). WWF’s “A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems” gives an overview of key climate change threats to different forest types and suggests a 15 point framework for adaption action plans (Biringer 2003; WWF 2003). These are of course focused on habitat protection and maintenance of biodiversity so are more relevant to the national parks and reserves than to woodland already significantly transformed by systematic human use (see Annex 4 for a summarised version of their recommendations for strengthen forest resilience to climate change impacts).

Butt et al (2005) used Global Circulation models predicting reductions in rainfall to estimate the level which cereal and animal production would decrease and the percentage of the population at risk from hunger would double from current estimations. They then showed that by using improved and heat resistant cultivars and changed cropping patterns the risk of hunger could be significantly reduced. An interesting application of GIS was used by Freeman to map potential areas in Burkina Faso and Niger where specific proven soil and water conservation practices could be replicated (Freeman 1999). Using soil type, topography and agro-climatic data, the methodology demonstrated its potential for strengthening strategic land-use management planning.

Recent studies confirm the strong influence of fire and grazing management on the biodiversity and dynamics of vegetation semi-arid savannahs. Archer’s work on grazing regimes in the Karoo suggests that rangeland management systems can be found that cope better with falling rainfall (Archer 2004); The fallows of northern Soudanian agro-climatic systems in Mali (Dembele 1996) – concludes that early fire and protection from livestock is the best management for maximizing biodiversity. Trollope et al provide insights on fire management from southern African grasslands (Trollope 2004).

An examination of how introduction of appropriate agricultural technologies can both strengthen local (economic) livelihoods and lead to more sustainable forest management is offered by (Angelsen 2001). One conclusion they reach is that the increased use of tree crops

can provide (if managed correctly) win-win situations. While their review was not considering the influences of climate change, tree crops are clearly an important means of adaptation to changing climate as they provide a complementary source of income that is less climate sensitive than annual cereal crops. Similarly, Sunderland and Ndoye's review of the potential for non-timber forest products to contribute both to livelihoods and to sustainable NRM (Sunderland 2004) is relevant to the development of adaptation strategies for climate change. In both cases, two key aspects of institutional development are highlighted: local (end-user) property rights and market development. Leaky points out however, that where tree crops become so successful they start to become domesticated by commercial businesses, with both losses and gains for different types of household among local communities (Leakey 2005).

This review was unable to locate much in the scientific literature regarding climate change and cocoa, surprising given its enormous importance to the Ghanaian economy (similarly for shea butter in Burkina Faso). Farmer field schools on cocoa management, with a focus on management practices needed to adapt to changing climatic conditions would be appropriate. For example, the sustainable Tree crops Programme of the International Institute for Tropical Agriculture has recently produced a manual intended for use by Farmer field school facilitators on sustainable cocoa production. (IITA 2005). ICRAF's *ProKarité* Project however is interested in considering the effect of climate change on oil production and biochemical composition (Masters and , per com.). Note also that the PRSP for Burkina Faso is beginning to push for greater support for shea butter production and export: *“shea is once again in demand as an input in the food processing industry and in the para-pharmaceutical industry (beauty products). It therefore offers interesting export opportunities for Burkina Faso to exploit. Nevertheless, for this to happen, Burkina Faso must first solve the organizational and quality problems that have so far restricted the country's ability to compete. More incentives are needed to encourage private sector participation. In order to get round the constraint imposed by the regulations for cocoa farmers, Burkina Faso's economic agents should arrange, in their contracts, for the product to be picked up at the edge of their fields, and they should investigate which ports are best suited to ship their products”*.

8.3.4 Sequestration and Clean Development Mechanisms (CDM)

The Clean Development Mechanism (CDM) was established by Article 12 of the Kyoto Protocol and is intended to attract private sector involvement, either through investment aimed at generating saleable certified emission reductions (CERs), or through the purchase of these CERs by companies who have their own emissions obligations. It is also intended to provide specific benefits for developing countries, including transfer of clean technology, foreign direct investment, localised environmental improvement and an income stream from the sale of CERs. The recent inclusion of small-scale projects in the final decision on LULUCF under Article 12 (Decision 19/CP.9) is meant to assure that low-income communities also benefit from projects under the CDM. Under the Kyoto Protocol, forestry is permitted as a sink measure under the Clean Development Mechanism (CDM), but only in the form of 'afforestation' and 'reforestation'. These tend to involve large-scale plantation systems, which although cost effective in terms of carbon sequestered, in most cases have only limited benefits to local populations. Many communities in developing countries however transform unsustainable management of existing natural forest, to sustainable management, under a variety of programmes such as JFM and CBFM, which are unrelated to climate change. This type of management does result in additional carbon sequestration, but credit for this cannot be claimed under CDM (see also (Skutsch 2003).

There has been much debate as to what extent the CDM can or should be used to promote carbon sequestration not only as a mitigation approach (through establishment of forests as carbon sinks) but also as means of increasing adaptation. Forner gives a brief up-date on the issues mitigation-adaptation as they relate to forestry, highlighting the development of the LULUCF (land use, land use change and forestry) guidelines by the IPCC (Forner 2005).

A review of 16 projects devoted to carbon sequestration (CS) throughout the developing world covering what the authors describe as “the most representative CS projects financed by GEF (FAO 2004). They found that the approach, impact and CS potential varied considerably between projects. Ranging from 7 mt C/ha to 129 mt C/ha; coverage from less than 5,000 ha up to one million ha; with cost efficiencies from US\$3 mt C to US\$12 mt C. In the case of the community based rangeland project in Sudan, the un-discounted cost was US\$3.5 t C, and including the project costs, US\$3.75 t C.

Many authors point out that using CDMs to promote community natural resource management (as a means of carbon sequestration) may face significant problems. The high transaction costs of the projects (compared to the value of the carbon sequestered) is the most commonly cited and the problems associated with ensuring net carbon accumulation (i.e that any benefits from a new carbon sink and not offset by a related but geographically distant new source. Other problems include deciding who benefits and how benefits are shared (Jindal 2004). (Kim 2003) uses a CDM case study from South Africa (rural solar energy) to illustrate some of the practical difficulties that exist in allowing both investors and beneficiaries to meet their needs through the Clean Development Mechanism. The danger, as others have observed, is that CDM becomes primarily a tool for investors to obtain cheap carbon credits, while sustainable development opportunities (for adaptation to climate change) remain much more limited. (Touré 2003) look at the potential for increased storage of carbon in two degraded forests in the north-Soudanian central Senegal. They showed relatively low rates of carbon storage in degraded woodland (an average carbon stock of between 1.8 mt/ha and 4.4 mt/ha), significantly lower than undisturbed forest in a similar environment.

Many environmental groups have already alluded to the potentially wider harmful effect of the CDM, arguing that it somehow legitimises over-emissions of GHGs and lets countries off the hook in terms of addressing the root problem of unsustainable energy and industry sectors. The debate is healthy and continues (see for example (Leach 2004). However, what is less often raised as a concern is that the increasing level for resources and effort that are being put into efforts to fit community based sustainable land use into CDM financed carbon forestry may be something of a diversion. Expectations to use the CDM to provide the incentive for sub-Saharan farmers to plant trees must be put into perspective. Generally it is probably more useful to think in terms of helping farmers to plant trees autonomously rather than on the basis of additional cash handouts from outside. Climate change may provide opportunities for African forests but it seems more likely that these will come from the areas where positive climate changes are experienced rather than from the CDM “*providing new incentives to plant trees*” (CIFOR 2005)

(Boyd 2005) are more optimistic. They argue that a review of experiences to date shows that while most of the small-scale pilot sink projects have not shown strong results, the reasons are more related to a lack of attention to social issues and local reality than to an inherent flaw in the viability of the small CDM concept itself. Similarly Murdiyarsa, who assesses lessons learnt to date from CDM projects. While also recognising the high transaction costs, he

recommends that projects must remain sufficiently small-scale to allow genuine local participation and ownership while ensuring strong integration with broader policy issues, donor priorities and the private sector (Murdiyarso 2005). He argues that the higher transaction costs and risks associated with working with multiple stakeholders, can be avoided by integrating them with other rural development projects and by working with local, representative community-based organizations, it is possible to make sinks projects work for both people and the climate. This would be in agreement with (Skutsch 2003).

Gerald and Melissa Leach also conclude that while many pitfalls do exist, not least with the CDM's limited capacity to strengthen rural livelihoods, the approach should not be ruled out, rather it should be improved so as the negative effects are minimised (Leach 2004). They challenge the several high profile environmental lobbying groups that highlight the potential negative effects of detracting from cutting emissions and of inappropriate forestation activities as "throwing out the baby with bath water".

(Skutsch 2005) provides a useful overview of the practicalities of carbon forestry in West Africa and some practical suggestions as to how to reduce transaction costs. She considers the potential for community based forest management (of existing forests) in developing countries, as a future CDM strategy, to sequester carbon and claim credits in future commitment periods. This kind of forestry is cost effective, and should bring many more benefits to local populations than do afforestation and reforestation, contributing more strongly to sustainable development. However community forest management projects are small scale, and the transaction costs associated with justifying them as climate projects are likely to be high. A research project being carried out in six developing countries is testing carbon measurement and monitoring methods which can be carried out by community members with very little formal education, which should greatly reduce these transaction costs. Using hand-held computers with GIS capability and attached GPS, villagers with four years of primary education are able to accurately map their forest resource and input data from sample plots into a programme which calculates carbon values.

One of the reasons for not recognising the sink capacity of community based management initiatives is undoubtedly the difficulty of measuring the carbon saved, and various uncertainties such as leakage and permanence. There are strict rules about how carbon can be measured and rigorous data will be a prerequisite if such projects are to be accepted under the climate convention. However the cost of employing professional scientific methods to gather and process such data (the so called 'transaction costs') are likely to be prohibitive, meaning that any financial gains by the community as a result of 'selling' their carbon, will be wiped out. The trick is then to find techniques which can at least partially be carried out by the communities themselves, at a much lower cost, and to demonstrate that these are as reliable as 'expert' methods.

A research project carried out by the University of Twente, ITC and three regional research institutes (in Nepal, Tanzania and Senegal) is testing carbon assessment methods involving the use of handheld GPS/GIS devices by local communities who are already engaged in community forest management activities. The purpose of the research is to demonstrate that such communities can make reliable assessments of the increased sink values of their forest and monitor this over an extended time period. If this objective can be realised, it may begin to open the way for these communities to supplement their forest based livelihoods through the 'sale' of their carbon as a non-timber forest product in the future

(Dijk 2004) studied the biomass and carbon dynamics of plantations of albezia (*Paraserianthes falcataria*) established on degraded, bench-terraced cropland (previously under maize and cassava) in upland Java. They found that the trees recycled carbon (lost during agricultural cultivation) back into soils at high rates and concluded that along with the beneficial effects on erosion and soil nitrogen content, albezia plantation forestry may offer considerable potential for soil improvement and carbon sequestration. Verchot et al (2005) describe the trade-offs between profitability of given agro-forestry systems (in Cameroon) and their respective potentials for carbon sequestration potential.

Grünzweig et al have use eddy flux, physiological and inventory measurements to provide quantitative evidence for the potential of carbon sequestration potential in arid-land forests. They show that a 35-year old, 2800 ha afforestation system at the edge of the Negev desert. contains $6.5 \pm 1.2 \text{ kg C m}^{-2}$, and continues to accumulate $0.13\text{--}0.24 \text{ kg C m}^{-2} \text{ yr}^{-1}$. The CO_2 uptake is highest during the winter, out of phase with most northern hemispheric forest activity. This seasonal offset offers low latitude forests ~ 10 ppm higher CO_2 concentrations than that available to higher latitude forests during the productive season, in addition to the 30% increase in mean atmospheric CO_2 concentrations since the 1850s (Grunzweig 2003).

CDM has been used in Ghana to fund a range of small-scale emission reduction projects in the energy and industrial sectors in Tanzania, Ghana and Kenya. IED carried out an assessment for DFID (the funder) and concluded that in many cases it was difficult to achieve all objectives (Begg 2003). A report by UNEP outlines several case studies linked to improving livelihoods, but all related to renewable or clean energy and not to trees as such (UNDP/GEF 2004).

Olsson and Ardo (2002) consider the possibilities for restoring degraded agro-ecosystems in Africa as part of carbon sequestration programmes. They investigated the potential for increasing soil carbon content in semiarid agro-ecosystems in the Sudan and showed that increasing fallow periods will result in increased soil carbon content and converting marginal agricultural areas to rangeland will restore the carbon levels to 80% of the natural savannah carbon levels in 100 years. The economic gain from a future carbon sequestration programme has the potential of a significant contribution to the household economy in these agro-ecosystems. Justice et al give an overview of the Central African Rain Forests of the Congo basin and their carbon stocks (Justice 2001). They also suggest that a range of carbon trading projects are feasible and would contribute both to biodiversity objectives and to local livelihood security. They also stress the essential nature of effective forest monitoring and management as components for the economic development of this region.

(Ponce-Hernandez 2004) describes in detail a highly sophisticated integrated modelling approach for assessing carbon stocks and modelling win-win scenarios of carbon sequestration through land-use changes. While the model has been used in practice in the Caribbean and Latin America to design optimal land use for multiple objectives combining carbon sequestration and livelihood security, the sophistication of the soft ware puts it outside of the reach of any but the most elaborate of research projects.

It is now known that soil carbon sequestration, both in forest and agricultural systems, is probably more significant than above ground sequestration. Lal (2005) studies the sequestration rates of carbon soils and practical ways for maximising carbon uptake. Working in Australia, Turner at al suggest that the reality is more complex and that short rotation forest plantations may even reduce soil carbon relative to some other land uses (Turner 2005).

Robert (Robert 2001) gives a useful review of Soil Carbon Sequestration for improved land management. *“In many farmers’ fields, in humid and subhumid climates as well as under irrigation, organic matter contents have been increasing rapidly after a change in land management procedures to conservation agriculture, including zero- or minimum-tillage and retention of residues on the soil surface. Carbon sequestration in agricultural soils from conservation tillage and other methods of improved land management can be permanent as long as the farmers continue to use these practices. Conservation agriculture has spread where farmers have been convinced by experience of its benefits. However, the transition to conservation agriculture is neither spontaneous nor free of cost. Conventional wisdom on the benefits of ploughing, such as stimulating nitrogen release from soil organic matter, and a lack of knowledge on the resulting damage to the soil system, tend to maintain plough-based agriculture. During the two or three transition years to conservation agriculture, there may be extra costs for some tools or equipment. The weed incidence, albeit rapidly diminishing with time, may need herbicide applications in the first two years or so, and the yields and the resilience against drought will improve gradually, becoming evident after the first one or two years.”*

A report by the Institute of Energy and Sustainable Development (Begg 2003) looks at a wide range of practical lessons learnt from CDM assisted small-scale energy projects over a range of sectors in three host countries in Africa, Tanzania, Ghana and Kenya. The range of projects studied were Biogas, SHS, Charcoal production, sustainable wood source, power factor capacitor improvement, Solar, MHP, Pico HP, cement production efficiency improvement, Improved Cook Stoves (ICS) and bagasse cogeneration for sugar production.

8.3.5 Seasonal weather forecasting

A recent report by the UK Government highlights the deterioration of climate services generally in Africa and presents a range of interventions for strengthening local forecasting capacities over a range of time scales (Washington 2004). They argue convincingly that investment in raising the capacity of African climate services represents an important opportunity “to increase the resilience and reduce the vulnerability of the continent to climate variability and change on all time scales”. They suggest a range of practical interventions in this regard, with a focus on activities that may provide policy benefits over a few years. Throughout the paper they stress that activities designed to address climate variability in the short term will inevitably strengthen adaptive capacity for longer term climate changes.

Roncoli studied traditional rainfall forecasting methods by farmers in Burkina Faso and explored the potential for synergy between indigenous approaches and scientific meteorological forecasting, showing the interesting complementarities between the two systems – in terms both of content and delivery (Roncoli 2003). Tarhule and Lamb look in detail at the practicalities of improving forecasting services in West Africa and argue convincingly that this should be a priority for increasing adaptive capacity of rural populations in the region (Tarhule 2003). They highlight the need not only to improve forecasting capacities but also the means of communications and the quality of interpretation and use.

(Boone 2004) Livestock production in South Africa is limited by frequent droughts. The South African Weather Service produces climate forecasts estimating the probability of low rainfall three and six months into the future. Boone et al used the ecosystem model SAVANNA applied to commercial farms communal areas to assess the utility of a climate

forecast in refining drought coping strategies to demonstrate the ecological and economic benefits of timely selling of animals in times of drought. They also suggest that a real-time farm model linked with climate forecasting would be a valuable management tool.

Environmental education has already been identified as important in Burkina Faso for example and the Ministry of Environment has prepared a strategy for its development and introduction (SP/CONAGESE 2001). However, due to financial short falls it still remains to be implemented. There would clearly be room to include in any final national curricula relevant material related to global climate change and especially the inter-dependency of local climate and vegetation.

Sultan et al (2005) have used simulations to demonstrate that millet yields (close to Niamey, Niger) can be consistently improved if sowing date is governed not by the usual practice of onset of local rains, but by using the date of the Regional onset of the Summer monsoon as determined by the northward shift of the ITCZ from 5°N up to 10°N (about 22-24 June). This did not protect yields from prolonged intra-seasonal dry periods, the impact of which depends on the development stage of the millet at the time. They show that (i) the onset of the summer monsoon over West Africa is linked to an abrupt latitudinal shift of the ITCZ around 24 June from a quasi-stationary location at 5°N in May–June to another quasi-stationary location at 10°N in July–August, and (ii) intra-seasonal variability of convection over the Sahel is dominated by two main time-scales, around 15 and 40 days (Sultan 2005).

(Skees 2001) Skees and colleagues assess the feasibility of rainfall-based index insurance to provide effective, low-cost drought insurance for Moroccan farmers and rural dwellers. They argue that a rainfall-indexed insurance product is feasible in Morocco, where the statistical correlation between rainfall and cereal revenues. Proportional rainfall insurance contracts would pay the insured an amount based on the shortfall in actual rainfall during a set period compared with the trigger rainfall. The contracts could be purchased in any amount, allowing farmers to insure the full amount of their expected revenue if they wish.

Mama Konate (the UNFCCC focal person for Mali and Director General of the Mali National Meteorological Service) and Youba Sokona (Konate 2003) present a review of Mali's vulnerability to climate change and identify what they see as the main adaptation options. They report on the success of Mali's agro-meteorological programme in increasing agricultural yields by provision of relevant information, regular forecasts etc. On the basis of an assumed deterioration in rainfall and the existing success of the meteorological services, they recommend a range of technical adaptation strategies. That aimed at assisting the agricultural sector to adapt is based on improved forecasting, genetic modification of crops to strengthen drought resistance and introduction of improved for soil and water management practice (KONATE, Director General et al. 2000). He gives the following results from Mali:

- 40 to 50% reduction of replanting
- Yield increases of 20% or more
- In 1998 use of meteorological and agro-meteorological information prevented the agricultural season from failure
- In January 2002, forecast of out of season rains allowed the national cotton company to save millions of euros
- The national meteorological office is now a member of the National Council for Agricultural Advice and works closely within the early warning system for food security
- Reduction in application of pesticides and more efficient utilisation based on agro-meteorological information

The advice of several analysts (see Hulme et al (Hulme 2001)) seems sound: while waiting for more confident long term models to be developed, our analysis of African sensitivity to climate change should also be linked to short-term seasonal *variability*. Similarly, “*initial steps to reduce vulnerability should focus on improved adaptation to existing climate variability*”. By strengthening capacity to adapt to seasonal variability not only will vulnerability to short term adverse climate events be strengthened, but relevant lessons will be generated to respond to longer term changes as they become evident. The institutional development is needed both to produce and disseminate such short term forecasts, but also to allow them to be used by local communities. Archer (2003) gives a useful review of community oriented seasonal forecast experiences in Africa (including case studies from Burkina Faso). She points how care is needed to ensure that systems are designed to meet the requirements of the end-user and to avoid exclusion of marginalised groups (such as women and nomads). She also discusses the role of incorporating traditional weather forecasting practices with modern scientific ones.

The relevance of working with forecasting to better adapt to seasonal climatic variability is also beginning to emerge as a strategic approach in the health sector. A partnership pilot by the University of Bamako and Columbia University is piloting the “Season Smart” approach in Segou Region of Mali. This will map the spatial and temporal variability in common climate-susceptible childhood illnesses, to identify seasonal regularities in disease incidence and intra-annual correlations between illness and climate variability. They then develop the climate-health early warning system on these recognized seasonal patterns (Sally Findley, pers.com)²⁹.

A French NGO, “Action Contre La Faim”, has been exploring the possibility of using remote sensing in Mali to help pastoralists better track changes in range distribution and biomass (Portier 2003). Using cheaply available images from the internet, an initial study has shown that with realistic procedures it is possible not only to track changes in range supply at broad scales, but also at much higher scales to locate particular species. Such approaches could be relevant in the development of protocols for local monitoring of vegetation change.

8.3.6 Artificial precipitation enhancement

For several years, Burkina Faso has been deploying cloud seeding technologies (from aeroplanes and ground based mortar flares) as a high profile part of its adaptation strategy for climate. The project, known as ‘Saaga’ is actually included in the PRSP. A quote from a Government’s report illustrates the official position: “*To combat drought, and more specifically to reduce the vagaries of rainfall, the government has opted for a program to increase rain artificially through cloud seeding. The necessary high-tech equipment was installed in 2001, and technicians have been trained in using it. It was put into use for the first time in 2002, and succeeded in extending the rainy season until September. Agricultural output was thereby increased by 547,000 tons. Financing for the program was planned at CFAF 600 million, of which 530 million, or 88.33 percent, has been spent*”. (STC-PDES 2003).

The National Centre for Atmospheric Research reports on its limited work with precipitation enhancement, but with markedly ambivalent conclusions (NCAR 2004) The WMO gives an

²⁹ Sally Findley, Professor of Family Health, Columbia University, Mailman School of Health, sef5@columbia.edu; www.mailman.hs.columbia.edu

overview of its related cloud seeding work (Terblanche 2005). A workshop was held by CILSS to evaluate the impact of cloud seeding project SAAGA but again with no clear results (CILSS 2004). Continued international support for these cloud seeding activities appears to be approved by the WMO itself (WMO 2005) although no evaluation or scientific study on the efficacy of SAAGA has been found by this literature review. Despite this “, *two co-operation agreements were signed between the Economic and Monetary Community of Central Africa (CEMAC) and WMO as well as between the Government of Burkina Faso and WMO under Burkina Faso’s cloud-seeding project, SAAGA*”.

Since the efficacy of this technology is still so questionable, it is perhaps worrying that not only is Burkina planning to invest more in its application, but also is provoking neighbouring countries to adopt it as an adaptation strategy.

8.3.7 Institutional Development for Climate Change Adaptation.

Introducing the IDS Bulletin issue on Climate Change and Development, (Yamin 2004) identifies policy coherence and institutional coordination as presenting the greatest challenge for climate change and development agendas. (Eriksen 2000), on the basis of a detailed study of vulnerability and management of local agro-ecosystems in Kenya and Tanzania, also concludes that the key is to support policy development to improve the enabling environment for local people’s inherently dynamic and integrated adaptation strategies. He also reminds us that policy change alone is insufficient – support for implementation of policy is just as necessary.

This focus on institutional development is echoed in almost all papers discussing adaptation, especially the need to make institutions flexible, responsive to people and more adept at dealing with complexity and uncertainty. As Lovell correctly points out, without institutional reform, adaptation to climate variability and change will remain ineffective since the “*current top-down (predominantly technical) approaches to integrated natural resource management, and bottom-up (predominantly social/institutional) approaches, will remain de-linked, and we will continue with the ineffectual structures and stratagems of “big government” and the well-meaning, but piecemeal, attempts of “non-government.”*” (Lovell 2002). A look at Burkina Faso’s State of the Environment Report for 2002 would also reveal institutional communication problems exist between sectors – the report makes critical environmental observations and recommendations that are not necessarily reflected in policies and trends of the agricultural sector for example (SP/CONAGESE 2002).

Pelling and High (2005) examine the role of social capital (“*features of social life - networks, norms and trust - that enable participants to act together more effectively to pursue shared objectives*”) in strengthening adaptation to climate change. While calling for more research to help better understand the opportunities and limitations of social capital’s contribution to resilience, they suggest (cautiously) that the multi-layered and multi-faceted social ties of everyday social interaction may be a community’s best resource in maintaining a capacity to change collective direction. As they point out, if this is true, the implications for development policy under climate change would be radical, demanding a reassessment of the current norms that favour investment in economic growth over social development.

Noppen et al (2004) provide very relevant and practical recommendations drawn from lessons learnt between 1989 and 2003 by the (Danish supported) Niger Household Energy Strategy. Again the key lesson is on developing institutional mechanisms to transfer management of

forests to local communities, to improve ecological sustainability and livelihood security. Similarly, all the contributions to IIED's publications within its 'Securing the Common' series³⁰ (including case studies from Mali and Burkina Faso) stress the need for adaptive and decentralised NRM through institutional change. They also provide a useful collection of practical recommendations drawn from the experiences of several focused and well documented interventions.

A report by the International Council for Science explores what has to be done to promote the necessary institutional shift and to take into account such "soft" issues such as culture, history and psychology into policy development (ICSU 2005) related to adaptation. (Folke 2002) et al stress the need to develop adaptive, flexible and learning institutions at all levels to respond to the non-linear dynamics of natural resource and human systems. management that accepts they stress. (Adger 2004) argue that building social resilience has to be part of any successful strategy that seeks to sustain ecological management in the face of climate change. A key component they argue is any opportunity to strengthen communication within and between social groups and local networks.

Lovell identifies five prerequisites for integrated natural resource management to be achieved successfully at the sort of scale relevant for adapting to global and Regional challenges such as climate change (Lovell 2002). Significantly they are all institutional issues:

- the political will to democratize and genuinely empower local communities;
- shared visions across all institutional levels, based on careful problem analyses;
- effective coordination of civil and professional science;
- commitment to a continuous and iterative learning process; and
- long-term (10-20 year) funding for research in tandem with organizational development.

Hulme (2003) reflects on a number of institutional issues arising from the Sahelian droughts of the 1970s and 80s which should inform ongoing development of adaptation strategies:

- The lack of climate foresight (based largely on a lack of knowledge and data at the time) resulted in all stake-holders being unprepared for such a dramatic and protracted change in rainfall regimes
- Weak infrastructure and a rigid institutional framework, at least in the government sector, probably contributed to the severity of the initial impacts of the droughts (in which hundreds of thousands people probably died).
- The more flexible informal institutions of traditional society probably allowed a more strategic adaptive behaviour which allowed local communities to recover relatively quickly and develop into the twenty-first century.

Another publication from the Global Drylands Imperative looks at institutional reform as a means of reducing vulnerability in the drylands (de Oliveira 2003). They identify a range of pre-requisites for promoting the appropriate institutional change needed to strengthen adaptive capacity of dryland societies (see Box 3 below).

³⁰ These can be downloaded from www.iied.org/drylands/pubs/pastoralres.html#securingthecommons or contact iied@earthprint.com

Box 3 Prerequisites for strengthening institutional opportunities for adaptation in dryland societies (summarised from (de Oliveira 2003))

- Move away from a “one size fits all” strategy or approach toward a more complex and adaptive dryland ecosystem management strategy that embraces the heterogeneity of drylands as well as its interaction with the variety of human beings that live in these ecosystems.
- Management strategies need to work within the dynamics of drylands and not go against the fluctuations and changes in these ecosystems (e.g. don’t try to increase drylands productivity through the use of technologies that are not suitable for drylands ecosystems).
- Management strategies need to recognize that droughts are not abnormal events in drylands.
- Management strategies need to take into account the temporal dynamics underlying dryland ecosystems. Mobility of people and flexibility of tenure systems are necessary.
- Management strategies must be designed that respect the different degrees, and types of use, of ecosystem services to ensure that no stakeholder groups are marginalized in the process.
- The focus must not only be on improving human well-being in terms of material wealth as this will only have limited success.
- Combined with the above described efforts, attempts should be made to ensure policy coherence among and between policies at all levels.

In examining changes needed for successful climate change adaptation, (Ogunseye 2001) concludes that “*more than any other challenge, African countries must look inward and re-examine the quality and effectiveness of their politics, policy and development strategies*”. He does not however suggest how this might best be done. Lovell does however discuss the issue on how to create the necessary political will for appropriate institutional development, how to facilitate shared visions across all institutional levels, and who should set research agendas (Lovell 2002). It should also be noted that most papers fail to draw attention to the role of the private sector, which may be an important oversight given that commerce probably has more influence on the lives of many people in Africa than the development community does.

A surprising number of large scale programmes focused on environmental development in the Region are still not acknowledging the issue of climate change, including the UNCDF (United Nations Capital Development Fund) strategy for Africa (Bonfiglioli 2004). Similarly, despite the calls for coordination, there are very examples of interaction between the three main UN Conventions (Desertification, Biodiversity and Climate Change) or within the PRSP process. Interestingly, the PRSP for Bukina Faso mentions drought and desertification but not global climate change (STC-PDES 2003). At the same time, a number of bilateral donors have been looking to integrate climate change into their development portfolios as a cross cutting issue for some years. By 2001, German overseas aid was aiming to mainstream adaptation to climate change as a core part of its approach (Klein 2001) “Adapting to climate change is, first and foremost, a development-policy issue”. Similarly USAID is embracing climate change (USAID 2005).

Many analysts are stressing the importance that the basis for policy development must change from the traditional land degradation, equilibrium-based models of the 1990s and before, to emerging paradigm of inherent adaptability and multi-state human-vegetation dynamics (Hutchinson 2005). This however calls for promotion of a change in institutional attitude and culture (since it further threatens the ‘official’ and the ‘expert’), the realisation of which in practice is discussed by few.

In terms of institutional change at a global level, perhaps the final word should go to those advocating a reassessment of the unsustainability of fossil fuel business-as-usual growth trajectories. Multilateral banks and other international economic institutions have an enormous emissions footprint. Their role in supporting conventional development strategies: funding large-scale coal, oil and gas plants, instead of small- scale solar and other renewables, demonstrates how vested interests continue to dominate economic institutions that are supposed to serve the needs of the poor (Yamin 2004). In an interesting review of historical³¹, examples of adaptation to climate change, Orlove examines what lessons can be learnt for the future. Depressingly he notes that a common pattern is for human societies to exacerbate the problem even when they know the long term consequences of their actions (Orlove 2005 in press).

³¹ The Mayans, the Vikings and the USA Dust Bowl farmers of the 1930s

Annex 1 Fact Sheets for the three target countries of TROFCCA (World Bank 2005)

Burkina Faso

Environmental strategy/action plan prepared in **1993**

	Group data		
	Country data	Sub-Saharan Africa	Low income
Population (millions)	12.1	705	2,312
Urban population (% of total)	17.6	36.5	30.4
GDP (\$ billions)	4.2	439	1,103
GNI per capita, <i>Atlas</i> method (\$)	300	500	440
Agriculture and fisheries			
Land area (1,000 sq. km)	274	23,596	30,456
Agricultural land (% of land area)	37	43	43
Irrigated land (% of crop land)	0.6	4.2	26.7
Fertilizer consumption (100 grams/ha arable land)	4	145	654
Population density, rural (people/sq. km arable land)	225	352	509
Fish catch, total (1,000 metric tons)	9	5,191	16,410
Forests			
Forest area (1,000 sq. km)	71	6,435	7,939
Forest area share of total land area (%)	25.9	27.3	26.1
Annual deforestation (% change, 1990–2000)	0.2	0.8	0.7
Biodiversity			
Mammal species, total known	147		
Mammal species, threatened	7		
Bird species, total breeding	138		
Bird species, threatened	2		
Nationally protected area (% of land area)	11.5	8.7	7.7
Energy			
GDP per unit of energy use (2000 PPP\$/kg oil equiv)	..	2.8	4.1
Energy use per capita (kg oil equiv)	..	667	493
Energy from biomass products and waste (% of total)	..	57.5	49.4
Energy imports, net (% of energy use)	..	-56	-6
Electric power consumption per capita (kWh)	..	457	312
Electricity generated by coal (% of total)	..	68.2	47.4
Emissions and pollution			
CO ₂ emissions per unit of GDP (kg/2000 PPP\$ GDP)	0.1	0.4	0.4
CO ₂ emissions per capita (metric tons)	0.1	0.7	0.8
Particulate matter (pop. weighted average, µg/cu. m)	108	54	63
Passenger cars (per 1,000 people)
Water and sanitation			
Internal freshwater resources per capita (cu. m)	1,074	5,546	3,583
Freshwater withdrawal			
Total (% of internal resources)	3.1	1.8	11.5
Agriculture (% of total freshwater withdrawal)	81	85	92
Access to improved water source (% of total population)	51	58	75
Rural (% of rural population)	44	46	70
Urban (% of urban population)	82	82	89
Access to sanitation (% of total population)	12	36	36
Rural (% of rural population)	5	26	24
Urban (% of urban population)	45	55	61
Under-five mortality rate (per 1,000)	207	171	123
National accounting aggregates, 2003			
Gross national savings (% of GNI)	6.6	16.9	23.1
Consumption of fixed capital (% of GNI)	7.6	10.6	8.9
Education expenditure (% of GNI)	2.4	4.7	3.4
Energy depletion (% of GNI)	0.0	8.0	5.8
Mineral depletion (% of GNI)	0.0	0.5	0.3
Net forest depletion (% of GNI)	1.0	0.7	0.8
CO ₂ damage (% of GNI)	0.2	0.9	1.2
Particulate emission damage (% of GNI)	0.5	0.4	0.6
Adjusted net savings (% of GNI)	-0.2	0.6	8.9

Ghana

Environmental strategy/action plan prepared in 1992

	Group data		
	Country data	Sub-Saharan Africa	Low income
Population (millions)	20.7	705	2,312
Urban population (% of total)	37.1	36.5	30.4
GDP (\$ billions)	7.6	439	1,103
GNI per capita, <i>Atlas</i> method (\$)	320	500	440
Agriculture and fisheries			
Land area (1,000 sq. km)	228	23,596	30,456
Agricultural land (% of land area)	63	43	43
Irrigated land (% of crop land)	0.2	4.2	26.7
Fertilizer consumption (100 grams/ha arable land)	74	145	654
Population density, rural (people/sq. km arable land)	307	352	509
Fish catch, total (1,000 metric tons)	451	5,191	16,410
Forests			
Forest area (1,000 sq. km)	63	6,435	7,939
Forest area share of total land area (%)	27.8	27.3	26.1
Annual deforestation (% change, 1990–2000)	1.7	0.8	0.7
Biodiversity			
Mammal species, total known	222		
Mammal species, threatened	14		
Bird species, total breeding	206		
Bird species, threatened	8		
Nationally protected area (% of land area)	5.6	8.7	7.7
Energy			
GDP per unit of energy use (2000 PPP\$/kg oil equiv)	5.0	2.8	4.1
Energy use per capita (kg oil equiv)	411	667	493
Energy from biomass products and waste (% of total)	66.4	57.5	49.4
Energy imports, net (% of energy use)	28	-56	-6
Electric power consumption per capita (kWh)	297	457	312
Electricity generated by coal (% of total)	..	68.2	47.4
Emissions and pollution			
CO ₂ emissions per unit of GDP (kg/2000 PPP\$ GDP)	0.2	0.4	0.4
CO ₂ emissions per capita (metric tons)	0.3	0.7	0.8
Particulate matter (pop. weighted average, µg/cu. m)	33	54	63
Passenger cars (per 1,000 people)
Water and sanitation			
Internal freshwater resources per capita (cu. m)	1,451	5,546	3,583
Freshwater withdrawal			
Total (% of internal resources)	1.0	1.8	11.5
Agriculture (% of total freshwater withdrawal)	52	85	92
Access to improved water source (% of total population)	79	58	75
Rural (% of rural population)	68	46	70
Urban (% of urban population)	93	82	89
Access to sanitation (% of total population)	58	36	36
Rural (% of rural population)	46	26	24
Urban (% of urban population)	74	55	61
Under-five mortality rate (per 1,000)	95	171	123
National accounting aggregates, 2003			
Gross national savings (% of GNI)	28.1	16.9	23.1
Consumption of fixed capital (% of GNI)	7.2	10.6	8.9
Education expenditure (% of GNI)	2.8	4.7	3.4
Energy depletion (% of GNI)	0.0	8.0	5.8
Mineral depletion (% of GNI)	1.1	0.5	0.3
Net forest depletion (% of GNI)	2.5	0.7	0.8
CO ₂ damage (% of GNI)	0.7	0.9	1.2
Particulate emission damage (% of GNI)	0.2	0.4	0.6
Adjusted net savings (% of GNI)	19.3	0.6	8.9

Mali

Environmental strategy/action plan prepared in ..

	Group data		
	Country data	Sub-Saharan Africa	Low income
Population (millions)	11.7	705	2,312
Urban population (% of total)	32.3	36.5	30.4
GDP (\$ billions)	4.3	439	1,103
GNI per capita, <i>Atlas</i> method (\$)	290	500	440
Agriculture and fisheries			
Land area (1,000 sq. km)	1,220	23,596	30,456
Agricultural land (% of land area)	28	43	43
Irrigated land (% of crop land)	2.9	4.2	26.7
Fertilizer consumption (100 grams/ha arable land)	90	145	654
Population density, rural (people/sq. km arable land)	167	352	509
Fish catch, total (1,000 metric tons)	100	5,191	16,410
Forests			
Forest area (1,000 sq. km)	132	6,435	7,939
Forest area share of total land area (%)	10.8	27.3	26.1
Annual deforestation (% change, 1990–2000)	0.7	0.8	0.7
Biodiversity			
Mammal species, total known	137		
Mammal species, threatened	13		
Bird species, total breeding	191		
Bird species, threatened	4		
Nationally protected area (% of land area)	3.7	8.7	7.7
Energy			
GDP per unit of energy use (2000 PPP\$/kg oil equiv)	..	2.8	4.1
Energy use per capita (kg oil equiv)	..	667	493
Energy from biomass products and waste (% of total)	..	57.5	49.4
Energy imports, net (% of energy use)	..	-56	-6
Electric power consumption per capita (kWh)	..	457	312
Electricity generated by coal (% of total)	..	68.2	47.4
Emissions and pollution			
CO ₂ emissions per unit of GDP (kg/2000 PPP\$ GDP)	0.1	0.4	0.4
CO ₂ emissions per capita (metric tons)	0.1	0.7	0.8
Particulate matter (pop. weighted average, µg/cu. m)	194	54	63
Passenger cars (per 1,000 people)
Water and sanitation			
Internal freshwater resources per capita (cu. m)	5,150	5,546	3,583
Freshwater withdrawal			
Total (% of internal resources)	2.3	1.8	11.5
Agriculture (% of total freshwater withdrawal)	97	85	92
Access to improved water source (% of total population)	48	58	75
Rural (% of rural population)	35	46	70
Urban (% of urban population)	76	82	89
Access to sanitation (% of total population)	45	36	36
Rural (% of rural population)	38	26	24
Urban (% of urban population)	59	55	61
Under-five mortality rate (per 1,000)	220	171	123
National accounting aggregates, 2003			
Gross national savings (% of GNI)	15.6	16.9	23.1
Consumption of fixed capital (% of GNI)	8.0	10.6	8.9
Education expenditure (% of GNI)	2.1	4.7	3.4
Energy depletion (% of GNI)	0.0	8.0	5.8
Mineral depletion (% of GNI)	0.0	0.5	0.3
Net forest depletion (% of GNI)	0.0	0.7	0.8
CO ₂ damage (% of GNI)	0.1	0.9	1.2
Particulate emission damage (% of GNI)	0.5	0.4	0.6
Adjusted net savings (% of GNI)	9.2	0.6	8.9

Annex 2 Range decrease of the ten species experiencing the greatest relative decline from ca. 1945 to 1993 in sites in northern Senegal (taken from Gonzalez 2001).

The range decrease is expressed as a percentage of a species' range ca. 1945.

Ranked species	vegetation zone	decrease (% of range ca. 1945)
1. <i>Ficus ingens</i>	Sahel	100
2. <i>Cordyla pinnata</i>	Guinea	96
3. <i>Nauclea latifolia</i>	Guinea	94
4. <i>Swartzia madagascarienss</i>	Guinea	90
5. <i>Afraegle paniculata</i>	Guinea	87
6. <i>Detarium senegalensis</i>	Guinea	86
6. <i>Ekebergia senegalensis</i>	Guinea	86
8. <i>Morus mesozygia</i>	Guinea	83
9. <i>Ekebergia capensis</i>	Guinea	83
10. <i>Macrosphyra longistyla</i>	Guinea	80

Annex 4 Summarised from the WWF publication “BUYING TIME: A USER'S MANUAL” taken from (Biringer 2003)

1. Reduce present threats

The most apparent strategy for improving forest resilience to climate change is to promote overall ecosystem health. A variety of present non-climate threats to forest systems exist, namely conversion, fragmentation, and degradation. Identifying and targeting for action the reduction of priority threats in a particular forest system will go far in ensuring that forest structure, composition, and function that increase a forest's resilience are maintained.

2. Avoid fragmentation and provide connectivity

“Edge effects” threaten the microclimate and stability of a forest as the ratio of edge to interior habitat increases. Eventually, the ability of a forest to withstand debilitating impacts is broken. Fragmentation of forest ecosystems also contributes to a loss of biodiversity as exotic, weedy species with high dispersal capacities are favored and many native species are inhibited by isolation. The importance of minimizing road networks deserves special consideration. Roads exacerbate the effect of a warmer climate to increase the incidence and rate of invasions of forests by pest and disease by encouraging the dispersal of invasive exotic species. They also restrict the dispersal of less mobile native species.

3. Maximise size of management units

The fossil record provides evidence that species have adapted to changing climates by shifting their ranges. Protected areas established to conserve a particular species may not contain appropriate habitat in the next few decades. Overlaying a climate change scenario upon existing protected areas and other management units will give managers an indication of where a given habitat will occur to enable revision of management boundaries. However, given the rather crude estimation of climate change impacts within particular locales as well as the largely unknown change in ecosystem dynamics that will occur, it is prudent to give forest systems the maximum allowance of habitat in which to migrate. Attention should be given in the design of protected area networks to the need for north-south as well as altitudinal migration opportunities. The solution in this case does not rely solely on a reorientation of protected area boundaries, but also to a paradigm shift where decision-making regarding land uses takes place on a large, bio-geographic scale to include potential habitat outside reserves.

4. Provide buffer zones and flexibility of uses

The fixed boundaries of protected areas are not well suited to a dynamic environment unless individual areas are extremely large. With changing climate, buffer zones might provide suitable conditions for shifting of populations to lands bordering reserves as conditions inside reserves become unsuitable (Noss, 2000). Buffer zones increase the patch size of the interior of the protected area and overlapping buffers provide migratory possibilities for some species. Buffer zones must be large, and managers of protected areas and surrounding lands must demonstrate considerable flexibility by adjusting land management activities across the landscape in response to changing habitat suitability.

5. REPRESENT FOREST TYPES ACROSS ENVIRONMENTAL GRADIENTS

Representing the full range of habitat types is a traditional conservation method, to set aside areas for scientific study, as a node of comparison against disturbed areas, and as a means of conserving species that may be too difficult to manage separately. The uncertainty about the precise type and distribution of impacts necessitates maintaining a full spectrum of forest types within protected areas to enable some resistant and resilient types to persist.

6. PROTECT MATURE FOREST STANDS

Primary forests have been shown to be particularly resilient to climate change. Mature trees are better able to weather large-scale disturbances than recently established forests, thereby providing a refuge for species reproduction once favorable climatic conditions return. While shifts in composition along environmental gradients are still expected in established forests the effects are expected to be much slower, thereby giving species more time to adapt.

7. PROTECT FUNCTIONAL GROUPS AND KEYSTONE SPECIES

Maintaining the natural diversity of species and functional groups in forest is a sound overall strategy for enhancing both resistance and resilience to climate change. Several recent studies have demonstrated increased tolerance to environmental extremes and recovery potential as species richness increases. Species diversity in turn promotes the “redundancy” or number of species present in critical functional groups.. Efforts to identify keystone species and functional groups will help forest managers maintain natural patterns of abundance and distribution.

8. PROTECT CLIMATIC REFUGIA

“Across continents, at both temperate and tropical latitudes, topographically diverse areas allowed habitats and lineages to persist through altitudinal shifts and, in many cases, to diverge during periods of climate change.

9. MAINTAIN NATURAL FIRE REGIMES

The frequency and intensity of fires are known to correlate with changing climatic conditions. “Regional differences in fire ecology imply that fire policies established in response to concerns about climate change should not be uniform; rather, they should be established based on what is known of the fire ecology of each region and forest type...A mixed strategy in which managers let many natural fires burn, protect old growth from stand-replacing fires, and manage other stands through prescribed burning and understory thinning, is probably the optimal approach.

10. ACTIVELY MANAGE PESTS

Climate change has been associated with increased infestations of insects, disease, and exotic species. Nonchemical pesticides have been proposed as means to reduce leaf mortality from insects. Other nonchemical options such as baculoviruses are being investigated for their potential use in attacking pest species such as spruce budworm while leaving other species and the environment relatively unharmed (NRC, 2001).

11. SILVICULTURAL TECHNIQUES TO PROMOTE FOREST PRODUCTIVITY

Because climate change will likely have differential impacts upon different species and age classes of trees, a straightforward, ‘no regrets’ strategy is to apply silvicultural techniques that maintain a diversity of age stands and mix of species.

12. PREVENT CONVERSION TO PLANTATIONS AND PRACTICE LOW-INTENSITY FORESTRY

Forestry operations that minimize soil disturbance and utilize less clearcutting and chemical pollutants help reduce the invasion of exotic species, loss of carbon from soil, and the potential loss of mycorrhizae. The size of canopy openings and removal of biomass from sites should both be reduced. These methods are more likely to promote the resistance and resilience of forests to climate change than intensive forestry operations.

13. MAINTAIN GENETIC DIVERSITY AND PROMOTE ECOSYSTEM HEALTH VIA RESTORATION

Adaptation to climate change via selection of resilient species depends upon genetic variation. Efforts to maintain genetic diversity should be applied, particularly in degraded landscapes or within populations of commercially important trees (where genetic diversity is often low due to selective harvesting).

14. ASSIST MIGRATION WITH SPECIES INTRODUCTIONS TO NEW AREAS

Management programs specially designed for tree species that will be especially impacted by climate change may be necessary in some areas. The primary method of ensuring the species’ survival will be to consider introducing the species that are ‘climatologically trapped’ to more suitable or safe habitats

15. PROTECT MOST HIGHLY THREATENED SPECIES *EX SITU*

For some forest ecosystems, such as the cloud forests of tropical mountains, climate change is already (or will soon become) the dominant threat to an extent that mitigation efforts will not prevent some loss of species.

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