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Preparing for Climate Change in Agricultural Drylands with a Focus on West Africa

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Abstract: Climate change will have impacts all over the world, positive and negative, but these impacts are not evenly spread over the world. It can be expected that many of the world's drylands will experience severe livelihood shocks as a result of climate change in the coming decades, and the agricultural drylands in West Africa are often mentioned as the ones that will be hit most by increased rainfall volatility (droughts, but also floods). This paper uses the approach and the results of a major Dutch-West African research project (the Impact of Climate Change in Drylands, with a focus on West Africa; 1998-2004), and puts these results in perspective of other, and more recent research findings.

Key words: Agricultural drylands, climate change, vulnerability, drought, floods, livelihood shocks, West Africa.

The Prospects of Climate Change in Agricultural Drylands

During the last sixty years the average temperature on Earth increased by 0.5°C, and CO_2 levels increased by at least 70 ppm (or almost 25%) (IPCC, 2007). Not many climatologists deny these facts, and their at least partial relationship, anymore. The current worldwide attention for the causes and effects of climate change are a result of those facts, but certainly also a result of the successful alliance of scientists, the media, and politicians, sometimes too close for comfort. It has now reached a level of global mobilization, sometimes with the characteristics of a media-hype, and often with quite some semi-religious zeal added. Framing of the changes as a 'problem' for humanity has done much to give it its current urgency. The fact that the 'problem' is 'caused by humanity's greed' (and some would add: short-sightedness) did and does add to a feeling of collective guilt, and of a collective task of global proportions. Ronald Emmerich's film The Day After Tomorrow, released in 2004, shows alarming prospects of dramatic climate change, leading to the paradoxical effect of a new Ice Age in the northern hemisphere as a result of global warming, of course with the Hollywood-inspired scenes of droves of environmental refugees from the United States scrambling into Mexico (and turning down the fence that was meant to keep Mexicans out of the USA). In 2006 Al Gore's *An* Inconvenient Truth uses what basically is a power-point presentation as a tool to influence a truly global audience, although - during the Bush era - not with the necessary political impact in his own country, that waited for a political turn-around to leave its *laager*. Documentaries shown by National Geographic Television show what

would happen if the world's temperatures would rise with 1, 2, 3, 4, 5 or even 6 degrees Celsius during this Century. An influential book by Jared Diamond, Collapse (2004) adds historical parallels to feed a millenarian feeling of apocalypse.

In policy and scientific circles solutions are formulated both to mitigate the on-going changes, and to better adapt to these changes (IPCC, 1995; 2007), but between 'mitigators' and 'adaptors' uneasy tensions exist, as the mitigators think that as many efforts as possible should be directed to lower the greenhouse gas (GHG) emissions (or avoid their rise to dangerous levels), and the adaptors feel that massive funds are needed to protect Mankind - and particularly its more vulnerable groups – and Nature - and particularly its most endangered species - against inevitable changes, even if mitigators would succeed after some time. Despite this uneasiness, both mitigators and adaptors are fighting sceptics, who – either funded by oil and car industry lobbies, or not – do not believe in human-induced climate change, or in the severity of its consequences, or regard it as one among many challenges for humankind, of which some deserve far more attention than climate change.

Earth's ecospace consists of a large number of ecozones, in which some have proven to be very attractive as humanspace, and others can be regarded as harsh lands for human occupation and usage. Basic geography tells us that some of it has to do with intrinsic 'site' values of the ecozone as a habitation and livelihood basis for human occupation, given the technologies at people's disposal, and given the cultural valuation of what is regarded as 'useful', 'beautiful', and 'safe' (or for that matter: 'useless', 'ugly' or 'dangerous'). Other reasons to make ecozones attractive (or not) have to do with situational aspects, their location vis-à-vis other places. Hence, they have to do with aspects of centrality and isolation (or relative costs to deal with those situational aspects). The world's agricultural drylands in the tropics and subtropics are typically in-between areas: not as harsh as the real deserts, and not as attractive as (some of) the more humid areas. Their contributions to greenhouse gas emissions have been relatively modest, but the predicted impact of climate change is often suggested to be particularly severe in these drylands, because of the fragility of human (agricultural) activities in this ecozone. In the latest flagship publication of UNEP, the Global Environmental Outlook 4 (UNEP, 2008) the world's drylands are one of the 'archetypes' of vulnerability (also see: van der Geest and Dietz, 2004; Benson and Clay, 1998). Droughts there are seen to be the highest risk in these "highest risk hot spots" (UNEP, 2008). Combining (high) water stress, (low) agropotential, (high) soil degradation, (low) road density and (high) infant mortality as markers of vulnerability the authors differentiate eight forms of the dryland risk archetype. Dryland Africa, and dryland West Africa in particular, show high combinations of risk factors (Id.: 323). Although average population densities in the world's drylands are highest in dryland India, parts of dryland West Africa are densely populated as well, and many of these people belong to the world's ultra poor. Drought-related economic loss is relatively high there (when drought strikes), but the chapter on vulnerability also shows

that progress towards reaching the MDG target on food security is generally good (from 'strong' to 'modest') in most of Africa's dryland countries (Id.: 325). Baseline year for the MDGs is 1990 and, as we will see, particularly dryland West Africa was blessed with relatively good rains since then (unlike the drylands in southern Africa, where indeed food security has deteriorated).

It is interesting to note that the dryland section in the vulnerability chapter does not mention 'climate change' as such, but talks about desertification, land degradation, diminishing freshwater availability, risks of conflicts over scarce resources, and movement of dryland refugees. Elsewhere in the GEO4 book, risks of climate change are being discussed, though, and with interesting regional detail for the various drylands in Africa. For (the drylands in) 'Western and Central Africa' the text is pretty vague: "impacts on crops, under a range of conditions", and "possible agricultural GDP losses ranging from 2 to 4% with some model estimations". For Northern Africa, most of it agricultural dryland or arid, the prediction is that "climate change could decrease mixed rain-fed and semi-arid systems, particularly the length of the growing period, such as on the margins of the Sahel (and) increased water stress and possible run-off decreases in parts of Northern Africa by 2050". For Eastern Africa the impacts and vulnerabilities associated with climate variability and change are that "rainfall is likely to increase ...according to some projections (which would mean that) previously malaria-free highland areas... could experience modest changes to stable malaria by the 2050s, with conditions for transmission becoming highly suitable by the 2080s...". For Southern Africa there is "possible heightened water stress... southward expansion of the transmission zone of malaria may likely occur; by 2099 dune fields may become highly dynamic... (and) food security is likely to be further aggravated by climate variability and change" (Id.: 207). In that sense, the impacts of climate change on livelihoods and on human health are interconnected (Martens *et al.*, 1999; Patz *et al.*, 2005).

According to UNEP (2008) and many others "some impacts of climate change are inevitable in the coming decades, due to the inertia of the climate system" (supposing that mitigation measures, or a major economic depression, will have some impact on lowering worldwide greenhouse gas emissions). UNEP continues by pointing out that "adaptation is necessary, even if major mitigation measures are rapidly implemented...developing new varieties of crops that resist droughts and floods, and climate proofing infrastructure to cope with future impacts of climate change are a few examples". And they very rightly add: "adaptation is often site-specific, and must be designed on the basis of local circumstances" (Id.: 67). On the other hand, climate change is only one of the many global-level influences on drylands: "globally driven processes, including climate change, have direct impacts on well-being in drylands" (Id.: 322-323).

Most of the drylands of the world are inland areas, and are more or less immune for some of the most threatening aspects of climate change: sea level rise, and violent

storms. The biggest threat in drylands is the growing unpredictability, and probably growing volatility of rainfall, with more droughts, more floods, unclear starting dates of planting seasons, and mid-season disturbances of the agricultural cycle as the most likely disturbances (Vörösmarty *et al.*, 2000). Irrigated agriculture, and livestock-based farming systems, will experience periods of increased water stress, but excessive river water and rainfall may also pose problems. These are more likely, as it may be expected that in general the world's rainfall will increase with rising temperatures, particularly in the world's tropical and subtropical drylands. Temperature rises as such - although already considerable in dryland Africa (see Hulme *et al.*, 2001), will probably not have major impacts (although combined with sand storms in the hot, dry seasons it might) while it is likely that higher CO_2 levels will improve the productivity of a large number of useful plants.

It is the combination of the impacts of climate change with other adversities that may make climate change a threat to future potentials of people's livelihoods in the drylands. Severe droughts and floods triggered by climate change may undermine the existing institutions to deal with adversity, and may cause the collapse of government structures, market infrastructure, and peace. It is the combination of vulnerable environmental conditions, with vulnerable governance structures, massive poverty and adverse world market conditions that may create turmoil and disaster, not just 'climate change' (Vogel, 1998; Dobie, 2001; Wisner *et al.*, 2004; Ruben *et al.*, 2007).

Preparing for climate change demands improving governance structures and people's buffer capacity. We can learn from what happened during one of the epic droughts, the Sahelian droughts in the 1970s and 1980s. To do that we will use the results of a major research project on the impact of climate change in drylands, focusing on West Africa (Dietz *et al.*,2004; the ICCD project) and add updates. But first we will look at some classifications that might assist the attention for site specificity (or better: type specificity) that is asked for by UNEP.

Classification of Agricultural Drylands in the Tropics and Subtropics

The world's agricultural drylands can be characterized as semi-arid and sub-humid areas, with average annual P/ETP between 0.20 and 0.75 (UNESCO, 1977). Arid lands, with P/ETP below 0.20 are not included in this definition, as without irrigation crop production is a very marginal activity, or not possible at all. Average rainfall conditions in the agricultural drylands restrict rain-dependent agriculture to mainly sorghum, millet and (marginal) maize cultivation as food crops and groundnuts and cotton as crops for agro-industry and for export. Recently, the cultivation of jatropha (an oil-rich agro-fuel plant) is seen as a promising possibility for the agricultural drylands, and with expanding acreages. Animal husbandry based on mainly cattle, goats and sheep can and often does add to food supply and cash income. In general, rainfed agriculture in these drylands gives relatively low crop yields. Yearly rainfall variation can be considerable. Rainfall

unreliability results in relatively high risks of crop failure due to drought (and occasionally excessive rainfall). Yet, the world's drylands support a considerable part of the world's population. According to the World Atlas of Desertification (UNEP, 1997), in Africa 40% of the population lives in areas prone to drought and susceptible to desertification. In Asia it is almost as high (39%), while in South America it is 30%.

In West Africa, UNESCO's map of the world distribution of arid regions (UNESCO, 1977) shows a band of semi-arid conditions from Dakar in Senegal, via Ouagadougou in Burkina Faso to Niamey in Niger and further to Kano in Nigeria, the Sahel proper. South of this zone there is a band of sub-humid conditions.

Other tropical and subtropical agricultural drylands in the world can be found in the Americas (Mexico and the southern United States, northern Venezuela, north-eastern Brazil, western Ecuador, Peru, parts of Chile, southern Bolivia, western Paraguay and northern Argentina), in northern Africa, and in major parts of eastern and southern Africa, in West Asia (Israel, Jordan, Syria, Lebanon, south-western Arabia and Yemen, major parts of Iran, and Afghanistan) and in the Indian subcontinent (major parts of Pakistan, western and southern India), in minor parts of China, and in major parts of Australia.

UNESCO's aridity assessment (UNESCO, 1977) was based on rainfall (P) and evapotranspiration (ETP) conditions for mostly 1930-1960. Semi-arid conditions are defined between P/ETP of 0.20 and 0.50, as for sub-humid conditions the boundaries are set at a P/ETP between 0.50 and 0.75. Combined with assessments of land degradation and population density it formed the basis for the typology of all agricultural drylands in the tropics and subtropics in the research project 'Impact of Climate Change in Drylands' (Dietz and Veldhuizen, 2004a). Land degradation assessments were based on the so-called GLASOD map (Oldeman *et al.*, 1991). Population density was first assessed by using data for the situation in the 1960s, mainly based on the World Atlas of Agriculture (IGDA, 1971) and differentiating between 'high density areas' (with more than 50 inhabitants per square kilometer) and 'low density areas' (<50 inh. km^{-2}). Later, it was possible to update these population density data for the situation of the mid-1990s (Global Demography Project, CIESIN, ESRA, NCGIA, see UNEP/GRID, 1998). Urbanization assessments were added for the situation around 1960 and around 1990, based on the United Nations Demographic Yearbooks, 1997 and using the existence of urban administrative areas of more than 100,000 inhabitants as a threshold for differentiating 'urban' from 'rural' areas. All data were mapped by using a grid system of 1°x1°, roughly covering 110x110 km.

In total the world has 1902 1°x1° 'cells' of agricultural drylands in the tropics or subtropics, which were completely or mainly semi-arid and/or sub-humid, occupying an area of 23 million square km, or 17% of the world's land mass. Table 1 gives an overview for the world's major regions, showing that the West African agricultural drylands, the focus of our study, had the

Table 1. Number of tropical/subtropical semi-arid and sub-humid cells per major world region (one cell = 1°x1°)

Region	Semi-arid	Sub-humid	Total	Total as % of region
West Africa	86	53	139	20
Eastern and Southern Africa	272	328	600	57
North Africa	40	3	43	9
West Asia	45	13	58	12
Indian subcontinent	85	101	186	55
China	44	46	90	12
South and Central America	197	212	409	25
USA	52	32	84	11
Australia	211	82	293	46
Total	1032	870	1902	17

fifth largest expanse, after eastern and southern Africa, south and central America, Australia and the Indian sub-continent. The West-African agricultural drylands cover 20% of the total West African land area. Most of the remainder is arid, like in North Africa, West Asia, and Australia, unlike all other world regions, where most of the non-drylands are humid. Further details can be found in Dietz *et al.*, 2004; Dietz and Veldhuizen (2004a).

West Africa's agricultural dryland profile, compared to the world's tropical and subtropical agricultural dryland profile as a whole, is given in Table 2. West Africa's agricultural drylands are only 7% of the world's total. The most problematic areas, semi-arid areas with relatively high degradation and a relatively high population density, are considerably over represented in West Africa: they consist of 20% of the world's total in that type of agricultural drylands.

In Table 3 information is presented about the dryland types per Sahelian country.

Four categories of drylands are most prominent in West Africa

- The semi-arid areas with high degradation, but relatively low population density have 38 cells, many of them in Niger.
- The least problematic type in terms of probable resource stress (sub-humid, with low degradation and low population density), is represented by 34 cells, many of those in Mali.
- The category of least problematic semi-arid areas (those with low degradation and low population densities) consists of 22 cells, many of those in Mali and none of them urban.
- The category of most problematic semi-arid areas comes fourth, with 19 cases: three cells, two of them urban, in Senegal (urban: Dakar and Thiès/ Kaolack), three in Burkina Faso, at the Mossi plateau, including Burkina Faso's capital city Ouagadougou, four in Niger (including the urban cells of Niamey and Maradi in Niger), and nine in

Table 2. West Africa's agricultural dryland profile, compared to the World's agricultural dryland profile (tropics and subtropics): number of 1°x1° cells and percentage

Type of agricultural dryland	West Africa, number of cells	World, number of cells	West Africa as % of world
Total agricultural drylands	139	1902	7
Semi-arid	86	1032	8
High degradation	57	353	16
High density	19	97	20
Urban	7	41	17
Rural	12	56	21
Low density	38	256	15
Urban	1	14	14
Rural	37	242	15
Low degradation	29	679	4
High density	7	71	10
Urban	0	32	0
Rural	7	39	18
Low density	22	608	4
Sub-humid	53	870	6
High degradation	9	266	3
High density	5	102	5
Urban	1	50	2
Rural	4	52	8
Low density	4	164	0
Urban	0	15	0
Rural	4	149	3
Low degradation	44	604	7
High density	10	117	9
Urban	2	63	3
Rural	8	54	15
Low density	34	487	7
Urban	1	30	3
Rural	33	457	7

northern Nigeria, including the urban areas Kano and Sokoto.

Four other types of dryland areas are less prominent in West Africa

- The category of sub-humid areas with low degradation, but high densities is represented by 10 cells, including two urban ones: Bamako, capital city of Mali, and Maroua, administrative headquarters of Cameroon's Extreme North Province.
- The category of semi-arid areas with low degradation, but high densities has seven cases, almost all of those in Nigeria and none of them urban.

Table 3. Types of agricultural drylands in West Africa, country details, number of 1°x1° cells

Country	Total drylands	SAHDHP	SAHDLP	SALDHP	SALDLP	SALDLP	SHHDLP	SHLDHP	SHLDLP
Mauritania	4		4						
Senegal R	13	1	3		5				2
Senegal U		2							
Gambia	3							2	1
Guin. Biss	1								1
Guinea	1								1
Mali R	27		4		12		1		9
Mali U								1	
B. Faso R	20	2	7		2	1	1	1	4
B. Faso U		1							1
C'd'Ivoire	1								1
Ghana	6					1			5
Togo	1						1		
Benin	5								5
Niger R	18	2	13		1				
Niger U		2							
Nigeria R	32	7	4	6	2	1		5	3
Nigeria U		2	1			1			
Camer. R	5		2	1		1	1		1
Camer. U								1	
Rural		12	37	7	22	4	4	8	33
Urban		7	1			1		2	1
Total	139	19	38	7	22	5	4	10	34

SA = Semi-arid SH = Sub-humid (according to UNESCO map),
HD = High degradation LD = Low degradation (according to GLASOD map),
HP = High population density LP = Low population density (around 1994),
R = Rural (no cities with at least 100,000 inhabitants in 1990),
U = Urban (at least one city of more than 100,000 inhabitants in 1990).

- The category of most problematic sub-humid areas, with high degradation and high population densities, has five cases, including one urban cell: Katsina in Nigeria.

- Finally the category of sub-humid areas with high degradation and low densities has four cells, none of those urban.

The dynamics of aridity, 1930-60 and 1960-90: The UNESCO classification is rather outdated, and as part of the ICCD project an update was made for the years 1960-1990, enabling a comparison between the UNESCO map with the more recent situation (Dietz, 2004).

If we compare the 1960-1990 aridity situation with the 1930-1960 situation, that formed the basis for the UNESCO aridity classification for all agricultural dry-land areas in tropics and sub-tropics, the number

of dry-land 1°x1° cells which experienced a deterioration of the average rainfall situation to a lower level (so: from sub-humid to semi-arid or from semi-arid to arid) was far higher than the number of cells experiencing an improvement (from semi-arid to sub-humid, or from sub-humid to humid). Its global distribution is as given in Table 4 (Dietz, 2004).

It is clear from this overview that UNESCO's well-known and much-used aridity classification was made with rainfall data, which give a rather 'rosy' picture of the world's aridity situation. Out of 1902 dryland 'cells' (semi-arid and sub-humid combined), 542 cells, or 28% experienced a change to a dryer class, and only 125, or 7% a change to a more humid class.

West Africa-disasters in the 1970s and 1980s: West Africa belongs to the areas, which only experienced deterioration if we compare the 1930-1960 period with the 1960-1990 period. However, it happened at levels, which were almost the same as the average for the world's agricultural drylands. West Asia and the Indian subcontinent even experienced a much more severe deterioration in relative terms. The drylands in China are a big exception. They experienced a major improvement. For all West African agricultural drylands, rainfall data for the period 1960-1990 show a rather dramatic decline in average rainfall conditions (Put *et al.*, 2004). In the northern zone, with semi-arid conditions in 1930-60, some regions have clearly become arid (on average) during the 1960-1990 period, with in most years unsuitable conditions for millet or sorghum production. A considerable part of the sub-humid zone of the period 1930-1960 has become semi-arid in 1960-1990, with considerable drought risks, and certainly for crops, which are less adapted to drought stress (like maize and cotton). Everywhere in dryland West Africa the risks of agro-climatological droughts had increased; and the onset of the monsoon season had become less predictable and generally later. The northern regions had experienced a number of years with extreme risks of agro-climatological droughts, and these created the most persistent images of 'Sahelian drought'.

Data at national levels show a rather high, but by no means complete, correlation

Table 4. Changes in aridity classification: 1960-1990 compared to UNESCO's (ca 1930-1960) classification, world's agricultural drylands, number of 1°x1° cells

World region	Deterioration	Improvement
USA	14 (17%)	0 (0%)
South and Central America	97 (24%)	32 (8%)
North Africa	11 (25%)	0 (0%)
West Africa	37 (27%)	0 (0%)
Southern and Eastern Africa	192 (33%)	44 (8%)
West Asia	35 (58%)	0 (0%)
Indian Subcontinent	85 (47%)	8 (4%)
China	0 (0%)	39 (46%)
Australia	71 (26%)	2 (1%)
Total	542 (29%)	125 (7%)

between average annual rainfall situations and average annual production figures for grains during these years. At local levels, though, (and in the sub-humid zones in particular - Northern Ghana was studied in depth) only a very minor, and sometimes even a negative correlation was found between rainfall and crop yields. For all regions we got lots of doubts about the reliability of both rainfall and crop yield data, and about the usefulness of the 'agro-climatological drought risk indicator' that was developed for this research project, as sometimes the annual rainfall figure gave a better correlation with recorded crop yields than the much more sophisticated drought-risk indicator.

West Africa's agricultural dryland experiences (a negative trend, droughts, a more variable, and less predictable climate) in the years between 1960 and 1990 were shared with many of the world's agricultural drylands. The severity of its impact (in particular during the drought of the 1970s) was a result of West Africa's relatively weak economic structure and its reliance on local subsistence-oriented agriculture (also see Hulme *et al.*, 2001). Both the transport network and the trade structure was weak, fall-back possibilities on other, non-agricultural livelihood resources were very meager, and the state structure and performance was rather dismal. Added to these negative characteristics is the fact that West Africa's agricultural drylands have a uni-modal dry-land climate (with only one major harvest in a year; unlike the bi-modal climate situations in e.g., most of dryland India and parts of dry-land Eastern and Southern Africa). West Africa's irrigation infrastructure were also very weak, with the exception of the areas next to the Niger River in Mali.

Drought risk assessment, and application in dryland West Africa: In the past, several techniques have been developed to assess the risk of crop failure in relation to rainfall variability (e.g., Wilhite, 1993). One approach is the drought index, which provides a composite picture based on time series analysis of the effect of water deficiency on crop performance. It is a static approach often linked to a given region and crop. In this study a drought risk index for sorghum and millet is used to assess chances of crop failure. For dryland West Africa this seems to be the appropriate approach. The index as an indicator for increasing drought stress facilitates communication between scientists of different disciplines, managers and policy makers. Such indicators are quantitative and provide insight in the expected success rate for crop production in a given region and may trigger counteractive measures by policy makers.

The drought index used in the ICCD study (Verhagen *et al.*, 2004) is based on indices made by Bailey (1979) and the FAO (1980). Bailey uses monthly precipitation and mean monthly temperatures to define a moisture index, in which 'wet', 'neutral' and 'dry' months are differentiated.

It is constructed as follows $S=0.18P/(1.045) \times T$, where S in the dimensionless drought index, P is the precipitation in cm and T is the temperature in ^{o}C. Months are 'wet' when $S > 0.81$ and 'dry' when $S < 0.53$. In between 0.53 and 0.81, months are called 'neutral'. The FAO approach, developed to define Agro-

Table 5. Drought Index after Bailey (1979) and FAO (1980)

Index	Classification	Method	Criteria
0	No drought	Bailey	At least four consecutive 'very wet' months
1	Very light drought	Bailey	At least four consecutive 'moderately wet' months
2	Light drought	Bailey	Three consecutive 'moderately wet' months
3	Moderate drought	FAO	Three consecutive 'slightly wet' months
4	Severe drought	FAO	Two consecutive 'slightly wet' months and a 'dry' month which is sufficiently compensated by storage of rain of the previous month (storage: P-ETP; available rain = $Pm + P_{m-1} - ETP_{m-1}$).
5	Extreme drought	FAO	Two consecutive 'slightly wet' months without moisture storage in the third month or less than two consecutive 'slightly wet' months

Ecological Zones, uses monthly precipitation (P) and monthly potential evapotranspiration (ETP) data and allows soil moisture storage of a 'rain' month for a following 'dry' month. For the FAO, a month was regarded as sufficiently wet for a crop that is adapted to dry conditions (like sorghum and millets) when P>0.5 ETP. Also when P>ETP, the surplus rainfall can be accumulated for the next month as soil moisture storage with a maximum storage period of one month. In Table 5 the full range of the six values of the drought risk index is given.

Using average monthly precipitation, temperature and potential evapotranspiration the index distinguishes between 'very wet' (Bailey's 'wet'), 'moderately wet' (Bailey's 'neutral'), 'slightly wet' (FAO's 'rain'), and 'dry' months. For dryland West Africa we will focus on the rainy season, starting in May and extending to October. As the method uses average monthly data, high-resolution or daily climate variability is eliminated from the equation. Using recorded climate data the drought index can be calculated for a number of years and provide insight in how the drought risk index behaves over time. Changes in precipitation, are used to calculate the drought risk. Put *et al.*, 2004 gives a geographical presentation of drought risks in the difficult decade between 1975 and 1985.

West Africa-recovery after about 1987: However, recent rainfall data show a remarkable recovery for many rainfall stations in West Africa's Sahel region. Often the recovery period started around 1987. Many rainfall graphs with five-year averages show a rapid deterioration between 1965 and 1987, often with 30% less average rainfall in latter years. But often the recovery is also swift, with improvements in the 1990s and 2000s back to levels that are not far from (although still below) the period of the 1950s and 1960s, which can be seen as periods with relatively abundant rainfall. It is not at all true that the Sahel, so often used as an archetype of disaster and drought, only experienced rainfall deterioration since the 1960s. We may even go one step further. The 1950s and 1960s can be regarded as relatively good periods, in which the process of decolonization was supported by good rains, and hence a benign climate for expanding (commercial) agriculture, and a supportive situation for expanding governments, with steep

development ambitions at the time. The rainfall crisis in the 1970s and 1980s created a major agricultural crisis, and a severe societal crisis, in which the young democracies one after the other collapsed and became crisis- and violence-ridden dictatorships. This often made things worse for people who were desperately looking for survival. When the rains improved again after the late 1980s this supported conditions for re-democratization and for economic recovery, the last few years assisted by improving prices for many of their export commodities (partly as a result of rising demand from Asia). Farmers, who had survived the onslaught on their livelihoods, had become very creative in diversifying their options (see later) and had also begun to invest in many improved land management practices, often assisted by NGOs from abroad (and sometimes by government agencies, supported by multi-lateral and bi-lateral aid agencies; cf Reij *et al.*, 1996; Batterbury and Warren, 2001).

Another classification of the world regions and another look at dynamics: 1990-2005: The geographer John Cole (Cole, 1996) developed a classification of the world's macro-regions, based on 'natural resource wealth', which he then compared with wealth assessments for these macro-regions based on gross regional product (GRP) data. His 'natural resource wealth' assessments were based on land surface, agricultural land, freshwater availability, fossil fuels and minerals, all for the situation around 1990. For all variables he looked at per capita values. He used this analysis to prove that natural resource wealth was not at all related to economic wealth: there are as many nature- rich world regions in the economically wealthy group as in the economically poor group, and the other way around. For our purpose in this paper it is interesting to look at Cole's assessment of freshwater availability, for which he looked at total average rainfall volumes in specific world regions (per capita), and compared that with the total rainfall volumes for all world regions combined. His findings are not surprising, but worth repeating. Indeed, as for all variables used to assess natural wealth, it is obvious that (per capita) relatively abundant water availability does not automatically result in higher economic wealth, and relatively high water stress does not automatically result in lower economic wealth (see Table 6). Cole used this 'mantra' as a strong didactic reminder of the importance of 'fighting geographical determinism', and of the relevance of one of the most basic approaches in the 20th century academic geography: that of 'possibilism'. With adequate societal institutions to stimulate creativity (or what Homer-Dixon would call: ingenuity; Homer-Dixon, 1995) and avoid violent conflicts even poorly endowed areas can manage to develop considerable economic wealth.

What is revealing, though, is connecting this water-based classification with a comparison of the changes in the relative position of the world's macro regions in terms of the distribution of economic wealth over time (measured as GRP/capita). We have used Cole's data for 1990, and compared those with country data for 2005, as given in another geographical textbook, Rowntree *et al.* (2008), constructing exactly the same world regions as used by Cole.

Table 6. Cole's assessment of freshwater 'wealth' per capita for his twelve world regions, situation around 1990 (world average = 1)

Water-rich world regions	Water abundance	Water-poor world regions	Water stress
Oceania	4.0	Western Europe	0.7
Latin America	3.3	China	0.4
North America	2.3	Japan and South Korea	0.4
Russia/C. Asia	2.0	*South Asia*	0.3
Sub-Sahara Africa	1.5	Central Europe	0.3
South East Asia	1.2	*North Africa/SW Asia*	0.2

Italics: Economically poor macro regions in 1990.

As with all other variables indicating 'natural wealth' it can be concluded that almost all water stressed regions did improve their relative position in the world's distribution of economic wealth during these fifteen years (the exception is North Africa and South-West Asia, the most water-stressed macro region of all). All water-abundant world regions either experienced a relative deterioration of their position in the world's distribution of economic wealth or - for two regions - a stabilization. Unfortunately the data do not allow a more detailed analysis, for instance comparing dryland countries in Africa, with relatively well-watered countries. What is clear, though, is that the data about the recent period (1990-2005; see Table 7) does not allow any general statements about a negative relationship between water availability and economic dynamics; to the contrary: it suggests that world regions with water stress have generally improved their relative position in world economics during the most recent decades. This may suggest that indeed Ian Bannon and Paul Collier might be right in suggesting that natural resource abundance and not natural resource scarcity creates conditions for adversity (through war and violence, as they prove; calling it the 'resource curse'), although their variables for natural resource abundance mainly look at sources of energy and mineral wealth, and not at water (Bannon and Collier, 2003; also see: De Soysa, 2005; Kahl, 2006).

Our analysis for West Africa's agricultural drylands indeed does suggest that the adverse periods during the 1970s and 1980s had made (surviving) farmers much more flexible, and better prepared to deal with adversities. The ecologically fragile situation most farmers found (and find) themselves in did create conditions for creative (adaptive) land and farm management on the one hand, and for avoidance strategies with regard to violent conflicts. As very well studied in another context, the Northern Kenyan drylands, Adano and Witsenburg (2008), proved that farmers/pastoralists in fragile situations will try to avoid conflicts during periods of climatic adversity, as many of them are very well aware that conflicts would then be suicidal. 'Playing with conflict' (and violence) is much more rewarding during periods of relative abundance, when there is more to gain by using violence, and when there are better fall-back options in case of loss. This indeed contrasts heavily with Thomas Homer- Dixon's widely cited belief

Table 7. Comparing Cole's water abundant and water stress world regions with their relative economic position 1990-2005 (world average = 1)

Water-rich world regions	Econ. position 1990	Econ. position 2005	Water-poor world regions	Econ. position 1990	Econ. position 2005
Oceania	2.6	2.4	Western Europe	2.8	3.2
Latin America	1.0	1.0	*China*	0.6	0.7
North America	4.5	4.3	Japan and South Korea	2.6	3.0
Russia/C. Asia	1.4	0.8	*South Asia*	0.2	0.3
Sub-Sahara Africa	0.3	0.2	Central Europe	1.1	1.7
South East Asia	0.5	0.5	*North Africa/SW Asia*	0.8	0.7

Italics: Economically poor macro regions in 1990.

that scarcity breeds violence (Homer-Dixon, 1999). It is of course not true that scarcity never breeds conflict (Homer-Dixon gives many case study examples); it is only likely that during periods of relative scarcity people in general try to avoid conflict, as it may prove disastrous for their sheer survival, as individuals and as groups. What we need is unbiased empirical, comparative studies about the conditions that create 'cascades to violence and war' (Noorduyn, 2005).

Climate Change Predictions and Options for the World's Drylands

As part of the ICCD project various climate change scenarios were tested to predict the rainfall situation in West Africa in 2050 (van der Born *et al.*, 2004). These were then compared with existing scenarios, which used other models (van Boxel, 2004). The scenario analysis, using different global circulation models, showed a wide variety of outcomes for 2050, but with rather strong suggestions that most of dryland West Africa is expected to become a lot dryer (by higher temperatures and lower rainfall levels). However, rainfall increases for the Sahel have also been predicted; see Watson *et al.* (1998). The consequences of negative P/ETP projections would be an increase in high-risk environments for agriculture, and a further southward shift of the arid and semi-arid zones. Changes in rainfall distribution could mean an additional stress on agricultural production in these areas. Simulation studies reveal a shift of the onset of the growing season and lower yield levels. But scenarios also predict more volatility and hence also a higher chance of occasional storms and floods. This could have life and livelihood threatening consequences, as some of the recent major floods in the region show. In a daring attempt to measure the likely damage costs of climate change for major macro-regions in the world, Tol (2002) comes to rather alarming conclusions for Africa as a whole, on a variety of damage variables. Also Andrew Challinor and his colleagues are not at ease with the impact of climate change on African crop systems (Challinor *et al.*, 2007). They state that Africa is thought to be the region most vulnerable to the impacts of climate variability and change. They put a lot of emphasis on the availability of knowledge and information (for farmers and governance agencies at various levels of scale).

If the average rainfall situation in West Africa will deteriorate, from a global perspective, West Africa is probably one

of the exceptions, with most of the world's tropical and sub-tropical drylands becoming wetter (increasing temperatures more than compensated by increasing rainfall levels; see Watson *et al.*, 1998). Hence, extrapolation of the rather unique situation of West Africa to other drylands may not be very useful. In addition, the driving forces of Africa's agricultural production performance are so much more influenced by a problematic macro-economic and macro-political context and by failure to catch up with the positive side of globalization that this is another reason to be very cautious with extrapolating findings for Africa to the world's drylands as a whole. But in general, the world's drylands will definitely experience periods of adverse climatic conditions, even if the overall rainfall trend in most of them may be positive, with increasing impacts of climate change as a result of higher levels of greenhouse gasses (and acknowledging the fact that higher CO_2 levels in the atmosphere also create better conditions for some vegetation, including important crops).

Climate change doesn't come alone; demography is important too

Between 1960 and 2000 population increase in the West-African drylands belonged to the world's highest, close to 3% per annum, and in addition a considerable part of the population has migrated towards the southern coastal states while inter-continental migration, mainly to Europe, has started to become considerable. Between 2000 and 2008 annual population growth figures were still between 2.5% and 3%. Deteriorating situations in the arid and agricultural dryland areas of Senegal, Mali, Burkina Faso and Niger (due to decreasing rainfall, land degradation, and violence) have resulted in a rapid intra-country migration southward, and in a swelling of the big cities like Dakar, Bamako, Ouagadougou, Niamey and Kano. We have made a comparison for Sub-Sahara Africa as a whole between 1960 and 1994 (based on data in UNEP/GRID, 1998).

West Africa shows a mixed picture. For the arid frontier zones in Mauritania, Mali and Niger the data actually show a population decline. On the other hand, almost everywhere along the West African coasts the population increased more than four-fold in those 35 years. Increases between 250 and 400% are also visible in eastern Senegal, in a large area around Bamako, in Niamey and in mid-western Nigeria. However, major areas in Burkina Faso and northern and eastern Nigeria did not grow so fast: here the population less than doubled, a result of massive out-migration towards the south and to countries abroad. Estimates for Burkina Faso suggest that close to half of the adult population born there has moved, at least for part of the year, to coastal states like Ivory Coast and Ghana (although the recent turmoil in Ivory Coast, and economic recovery in Burkina Faso has resulted in some return migration).

For the 1°x1° agricultural dryland areas ('cells') in West Africa a typology was made of population density and urbanization for both 1960 and 1990/1994 (1990 for urbanization; 1994 for population density). In 1960 there were 21 cells, which had a high population density (>50 inh. km^{-2}); in the early 1990s this had grown to 41

cells. In 1960 there were 3 cells, which had a high population density and included an urban centre with more than 100,000 inhabitants; in the early 1990s there were 10 of those, seven in the semi-arid zone and three in the sub-humid zone (Fig. 1; Dietz and Veldhuizen, 2004b). Further rapid population growth can be expected. For West African countries as a whole, the World Bank predicts an annual population growth of between 2.5% and 2.8% for 2000-2025 (World Bank, 1995), although recently long-term growth is thought to be lower, because of increasing urbanization and the impact of HIV/AIDS. The West African Long Term Perspective Study, a multi-donor endeavour to look into West Africa's near future, predicted that "West Africa's population will almost certainly double over the next thirty years" (see: Club du Sahel, 1995). It was also predicted that there would be a major (further) redistribution of the population. In the year 2020, the urban population in West Africa will most likely be over 60% of the total population, compared with 40% today. The urban population will be more than three times greater than in 1990. However, the rural population will also have increased by 40% (Ibid.). Population growth and urbanization will require massive investments in infrastructure and social services (water being a particularly problematic challenge) and a major intensification and commoditization of food production. If world market perspectives for the area's current major export crops, cotton and groundnuts, are not improving, this will also lead to a shift in favor of food crops, and a further increase in the shortage of foreign exchange.

In many areas of dryland West Africa, the current actual land use for crop production purposes is less than 20% and the current yield per cultivated hectare less than 600 kg of sorghum or millet per hectare, and in drought years considerably less. Optimal harvests during good rainfall years are beyond 3000 kg ha^{-1} though. Theoretically, local grain production could be sufficient to feed the predicted population numbers in 2050 all over the agricultural drylands of West Africa. In practice, however, cropland expansion, yield intensification, higher cash-value agriculture in exchange for grains from elsewhere, and non-agricultural income-earning activities in exchange for food from elsewhere, will all be needed to prepare for a major challenge.

Malthusian doom or Boserupian transitions?

The predicted on-going population explosion in some of the world's agricultural drylands, including those in West Africa, coupled with deteriorating climatic conditions for agricultural production, looks quite alarming, particularly for dryland West Africa. The expected rapid land use changes can add a threat as a result of land degradation, which threatens to give lower crop yields and lower possibilities to cover fuelwood energy needs, especially near urban centers of energy demand. Growing water shortages may add to the gloomy picture. On the other hand, very negative scenarios predicted during the big Sahel drought of the early 1970s did not come true. Many observers point to great efforts to improve land and water management and agricultural production and they have pictured a resilient population in the region (e.g. Hilhorst and Reij, 2004). And it is also possible to refer to areas with equally

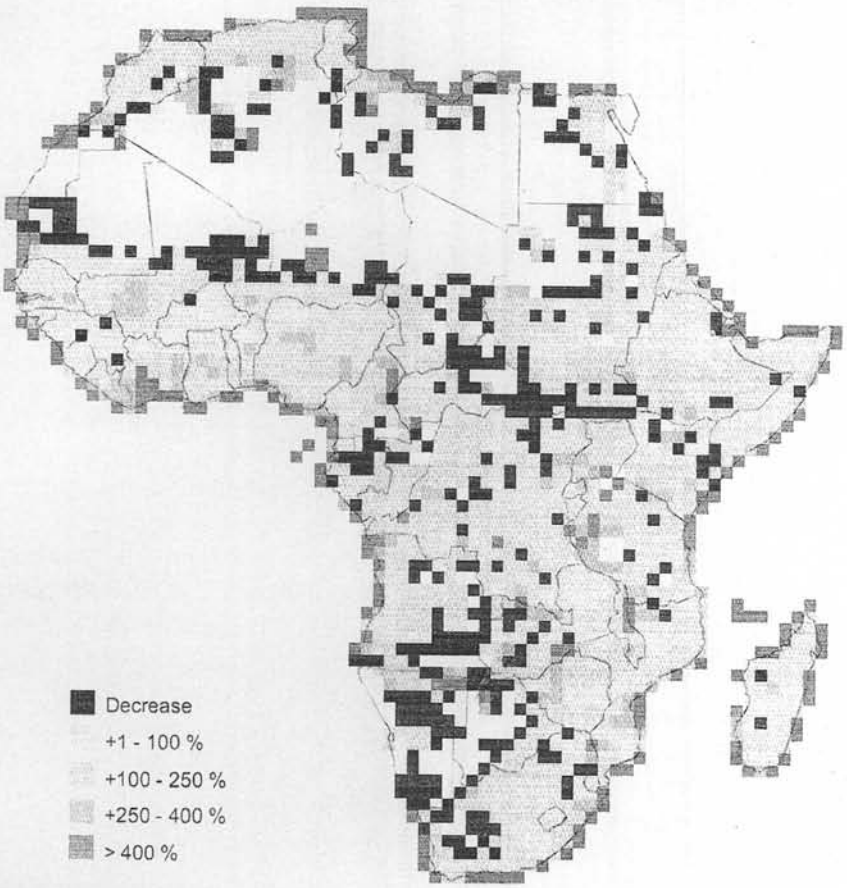

Fig. 1. Demographic change in Sub-Sahara Africa between 1960 and 1994 (Dietz and Veldhuizen, 2004b).

problematic agricultural production circumstances (e.g. most of dryland India) which have much higher population densities and a much more intensive use of natural resources, without necessarily moving towards Malthusian doom (cf Walker and Ryan, 1990; Put and van Dijk, 2000). Stress can also force a transition to more intensive resource use, and even to higher sustainability of that resource. There is room for 'Boserupian optimism' (Boserup, 1965; Mortimore, 1998 and see Tiffen *et al.*, 1994, for an introduction with an East African emphasis). For parts of dryland West Africa recent observers indeed report numerous examples of 'transitions to a more sustainable land use' and better land and water management technology, resulting in higher yields and more profitable agriculture. They also show a major diversification of the economy and a rapid impact of urbanization and of a more urban-based economy. However, part of that recent optimism may be based on the slightly

improving rainfall situation during the 1990s, rebuilding strength during 'relatively fat years'. If the upward short-term trend is only part of a normal cyclical movement, but in a long-term dynamic trend that is tilted downwards, there is reason for caution.

'Normal' intensification theory, which does only look at population, land and other resources and technology, and which neglects the impact of climate change or even climate variability, differentiates a number of options, which can all assist in solving problems related to increasing population densities in a situation with scarce resources.

Decision making units (individuals, households, business units and organizations at higher levels of scale) can make use of a portfolio of relevant options to obtain food or to increase the possibilities to obtain food (or energy or water). During periods of relative rainfall abundance the portfolio looks different compared to periods of relative drought. Assuming that future scenarios for dryland West Africa should be based on lower rainfall and higher temperatures, for the ICCD research it has been particularly relevant to study past portfolios of options, which were chosen during relatively dry years during adverse periods, like those of the 1970s and 1980s (Dietz and Verhagen, 2004).

For all decision-making units in a particular research area together, the total portfolio of experienced options can be seen as the 'portfolio of theoretical options'. Possibilities to use parts of this portfolio of theoretical options depend on characteristics and type of the individual decision making unit (based on particular typologies; e.g. 'household types based on assets', or 'ethnic groups'). For a particular type of decision- making unit a particular selection of options can be regarded as 'the portfolio of relevant options'. So, 'relevant options' are a subset of all theoretical options that are experienced by the combination of all decision-making units in a particular area. What a portfolio of relevant options is, will depend on the type of decision making unit like many assets or hardly any assets; many entitlements or few entitlements; crop habitus or livestock habitus; pathway experiences that are traumatic or not, etc. (De Bruijn and van Dijk, 2004).

Each decision-making unit at each particular time (or period) has selected a particular 'portfolio of experienced or chosen options'. For each decision-making unit we can reconstruct the history of these portfolios of chosen options. This we call 'a pathway of chosen options'. It is likely that decision-making units, which look alike (or which are in the same class of a typology), all have pathways, which look alike as well.

Portfolios of theoretical, relevant and chosen options, as well as pathways, can be studied at the level of individual decision-making units (individual men and women, households, functionaries in organizations). However, if all information relevant to individual decision-making units in a certain region is put together a region (grid cell, micro watershed or administrative unit) can also be seen as a (spatial) unit of analysis, and all options which are 'internal' can be treated as a 'black box', focusing only on the relationships with the outside world: all options which (partly) depend on exchange relationships with decision-making units outside the region.

We have made a list of nine major elements of 'livelihood strategies', which are all part of the portfolio of theoretical options. We will briefly look at each of these nine major elements of the portfolio of options for the acquisition of food (although the same approach can also be followed if we would focus on energy or drinking water resources).

Thinking in terms of (combinations of) options

The basic research question is: what can people do if livelihood stress increases;

Option 1: Food acquisition by using stored food or selling other stored assets and buy/barter food in return

Storage of food, which has been produced in years with relatively abundant harvests, can be an age-old practice, but it can also be a new or reinvented strategy, either at the level of individuals/households or at the level of communities or even as a result of national policies. Better storage technology and lowering food losses during the harvests, during food preparation and during consumption can also result in a major improvement, because of the rather large losses that occur. Many 'coping strategies' during problematic times can also be based on investing in various assets and selling those in dire times. Assets can be in the form of accumulated wealth (gold, or other jewellery; animals; bank savings; land; house; household utensils) or in the form of productive capital (e.g. agricultural inputs, agricultural and non-agricultural machinery). The sale of small ruminants (goats, sheep) is a widespread 'first aid' strategy in case of trouble.

Option 2: Direct food intensification: increasing the total food production is a possibility

- by extending the area under food crops to 'wastelands', forest areas, game- or bio-reserves or pasture and range-lands; of course this may depend on the positions of relative strengths of competing land users: cultivators versus charcoal burners, game wardens, forest departments, pastoralists, etc., as well as 'pioneer' cultivators competing among themselves, often with an ethnic element in claims and counter-claims;
- by more efficiently using a variety of geographical niches, and by more efficiently distributing crops and crop varieties over seasons;
- by limiting the fallow period and - if that is done in a sustainable way - maintaining or improving soil fertility by adding manure, fertilizer, compost, etc.;
- by improving soil and water management; partly this depends on long-term security of access to these improved lands; and this often depends on indigenous, religious and/or state-defined rights over land, water and other natural resources;
- by adopting crops and crop varieties with higher or more assured yields per hectare; and by improving access to 'improved' seeds of these crops and crop varieties;
- by developing irrigation, either using river, canal or piped water or groundwater reserves; this may also increase the number of crop growing seasons in a year;

- by intensifying animal husbandry practices (e.g. better veterinary care, higher-yielding breeds, stall feeding, better husbandry); or by shifting part of the animals to places better endowed with feed and water;
- by investing more labor and care in food crop cultivation, and in animal husbandry practices;
- by investing more labor and care in gathering 'wild food', and by accepting a diet that in 'normal' circumstances is regarded as inferior ('poor men's food', or 'hunger food') or taboo for 'normal people'.

Land use models, which include differences in soil resources, technology/ management, and farming systems approaches, can be used to predict various food production scenarios, and its requirements in terms of inputs. National economic modelling can also shed light on the driving forces of changes in land use from a market and state intervention perspective (Brons *et al.*, 2004a).

Option 3: Investing in indirect food intensification

It could also be a possibility to invest in indirect food intensification, by producing crops, raising livestock or collecting tree products for an external market and buying or bartering food in return. Possibilities depend on net terms of trade for the actual producers. Such products, include cotton (for the sub-humid zone), groundnuts (for the semi-arid zone), charcoal (for both) and meat (for both, but with higher 'caloric terms of trade' in the semi-arid zone). Zaal (1998) shows surprisingly high and even improving caloric terms of trade for a region in the north of Burkina Faso. This possibility depends both on the price trend at the world and regional markets for export products, on the price trends of food on these external markets, and on the marketing infrastructure, and transaction costs (including taxes, bribes, monopoly profits, etc.) in the areas of demand. This option 'works' only, when for the producers/ consumers the net impact of producing for the market gives a higher return in terms of food than if they would have produced the food themselves. A country like Senegal, already for quite some time, has clearly chosen for a ground-nuts-for-cereals exchange, importing one-third of its food requirements during the 1990s. International and national market dynamics and government policy all play a role in determining likely outcomes, with after early 1990s a shift away from policy-driven adjustments to market-driven adjustments (de Haan *et al.*, 1995). It may be expected that the role of agro-fuel production will increase throughout the drylands (and elsewhere) as some of the more rewarding options. This may threaten long-term sustainability of livelihood, biodiversity and food security, but it may also improve the portfolio of options. Monitoring where this leads to is an important challenge for policy-oriented development and environmental scholars.

Option 4: Food acquisition by marketing non-agricultural products and buying/bartering food

By changing a basically agricultural economy to one in which production of mining products, handicrafts and/or industrial products becomes more important and where non-agricultural producers get higher net rewards for their labor time than if they

would have produced their own food. This option very much depends on niches on the world market (e.g. 'ethnic art'), or on making use of comparative advantages of the region, e.g. low wages, low environmental sink costs, or non- existence of effective anti-pollution policy. In most of the world's agricultural drylands a breakthrough of 'tiger'-type industrialization is far away, though, especially in West Africa, given the extremely low education level in the area (with primary school net attendance percentages of below 60% in Senegal to below 40% in Mali (UNICEF, 2008), and secondary school enrolment percentages below 10% for men and below 5% for women in most areas (World Bank, 1995).

Option 5: Food acquisition by selling services and buying/bartering food

This can be done by attracting tourists and other visitors, either to enjoy nature and landscape adventurism, culture (either in its 'ethnic' form or as a hybrid popular culture e.g., west-African popular music), or sexual services and the 'image of care'.

Option 6: Food acquisition by selling labor and buying/bartering food

If the scale of analysis is the individual decision-making unit all income acquired by selling labor for wages (permanent, seasonal, casual; for government agencies, Non Governmental Organizations or the private sector; near home or far away) is relevant. If the scale of analysis is the region, the relevant option is the acquisition of remittance money, sent by people who come from the region, but who work elsewhere, either on 'hunger trips', on seasonal trips or for long periods, and who send food, money or material goods, either regularly or irregularly. Remittance networks may link the area to many parts of the globe, although mostly the links are rather bilateral. In dryland West Africa the links with the (urban) coastal zone, although fluctuating in destination, have become extensive, but also many Sahelians have now taken up residence in less densely populated humid and sub-humid areas towards the south, but still far from the coast. A growing number of Sahelians has migrated to Europe, and send back considerable sums of money. Figures for 1990 show a total remittance sum (net transfers at the national level) of Burkina Faso and Mali together of 557 m$, while total export income was 769 m$ and total official development aid 800 m$ (World Bank, 1992). In recent years, the net transfers have become less important, though, because of a deepening crisis in Ivory Coast, which was the major receiver of migrants from the north. In 1998 total net transfers of remittances for these two countries were 313 m$, while total export income was 1036 m$ and total official development aid 754 m$ (World Bank, 2000). Recent data for Mali show that 1.2 million Malian migrants abroad remitted 177 m. US$ in 2005 (World Bank, 2008). For Sub-Sahara Africa as a whole total remittances grew from 3.2 billion US$ in 1995 to 10.3 billion US$ in 2006 (Ratha *et al.,* 2008).

Option 7: Food acquisition by social security arrangements

This can be done either directly (in the form of social care or in the form of food aid by local governments or non-governmental agencies or by foreign donors of development assistance or by international non-governmental organizations), or indirectly (in the form

of income support, for which food can be bought: pensions, social security payments, bank or trader's/ moneylender's credit).

Food aid (mostly cereals) has been a structural phenomenon in Sahelian countries since the famine of 1973-74. Part of cereal imports comes through food aid (in 1993 40% in Mali, 25% in Burkina Faso, 20% in Ghana and 12% in Senegal), but in most years it only covers a minor part of all food needs (in 1993 less than 5%; World Bank, 1995). It is possible that food aid could become a more structural phenomenon, as development assistance has already become so in most study areas, with official development aid between 8 and 25% of Gross National Income and a major element of government budgets (World Bank, 1997). When recently the food prices all over the world exploded, areas with fragile local food supply became very vulnerable and started to experience collapsing food markets. In July 2008 The World Food Programme (WFP) of the United Nations announced it is expanding operations in West Africa to feed an additional 1.4 million people who are struggling due to high food prices in dryland countries like Mauritania, Burkina Faso and Senegal (in addition to Guinea, Sierra Leone, and Liberia). These six countries had been severely affected by high food and fuel prices coupled with poor harvests owing to floods and droughts. WFP notes that between July 2007 and July 2008, food costs for its operations in the region have increased by almost 60% and overall operational costs are now 30% higher. Increased fuel prices have also pushed up transportation costs as many regions in need of assistance are landlocked (http://allafrica.com/stories/200807290855.html).

Option 8: Food acquisition by stealing

This can either be done directly (stealing food from other people's fields or storage places, or by stealing/raiding animals) or indirectly by stealing material goods, and exchange those for food, or by demanding bribes, contributions, etc. On a regional scale waging a war or raiding neighbors and transport the 'booty' back home is a possibility as well.

Option 9: Lowering food demand

It can also be a 'solution' to a pressing or threatening food problem to lower the demand for food, temporarily, or even structurally. At the level of individual decision-making units it can be a strategy to accept lower food intake; eating less meals a day or eating food of lower quality. At the level of households it can be a strategy to send members (children mostly) away, e.g. bring them under the care of relatively well-to-do families or to 'marry daughters away'; it can also be a strategy to break up (joint) families and accept responsibility for a lower number of household members.

At the level of scale of regions lowering food demand can be acquired by:

- *Out-migration*: Out-migration not necessarily results in remittances and should not only be judged by its capacity to generate remittance income. Out-migration can also lower the burden on those staying behind, and lower the overall food needs. In West Africa, there is a considerable spatial mobility and not only by people who traditionally are mobile, like the Fulani (or Peulh). (cf. de Bruijn and van Dijk, 1995; Breusers, 1998). Many research areas experience a volatile population, 'in

flux', with large numbers of people moving out (in the Sahel towards the south mostly), large numbers of people moving in (in the Sahel from the north generally) and quite a number of people moving through. This considerably changes entitlements to make use of land and other natural resources, with 'identity' being an important attribute to claim rights and 'identification' an important means to gain negotiated access.

- *Diminishing natural population growth by lower birth rates*: Family planning is regarded in some circles as the most obvious thing, to bring down the high birth rates, which are a result of very high total fertility rates (close to 6 in Mali and Burkina Faso) and better health conditions. Birth rates can also diminish as a result of severe body stress due to malnutrition, resulting in higher abortions and infertility.
- *Diminishing natural population growth by higher death rates*: The death rates are still high by world standards in many of the world's drylands particularly in West Africa, but much lower than it was in the 1960s and expected to further go down, despite the diseases like HIV/AIDS. What is possible, is a chaotic explosion of violence that could have a major impact on food demand. Violent disruption of livelihoods will also result in a disruption of agricultural production, land management and distribution channels and in a destruction of food and capital stocks (including existing investments in natural resources and infrastructure). It also has a negative impact on local food supply, with long-term effects that may completely undermine what can be cynically called 'gains' of lower food demand.

Merging intensification theory with climate change theory

If intensification theory would be merged with ideas about deteriorating climatic conditions (that is: dryer conditions and more droughts), it should deal with the likely changes in the 'portfolio of options' and the more severe restrictions in 'room to manoeuvre' (see Feenstra *et al.*, 1998). For the West African drylands it will be evident that the possibilities to store food for 'lean years' may become lower when there will be less 'years of abundance', if nothing else changes (option 1). On the other hand, individual and collective attempts to save more food and store it for bad times may become far better organized than it had become during recent droughts. Direct food intensification (option 2) may be endangered, as a result of extreme weather and severe drought risks, and generally lower yields of 'normal' food crops and livestock. There will also be a shift of land use to more marginal types of land use (in yield terms), e.g. from maize back to sorghum, with lower average yields, or from crops to livestock (with lower average caloric production per ha) (see Ribot *et al.*, 1996). As far as the indirect food intensification option is concerned (option 3) it will be clear that in the northern zones of groundnut or cotton growing areas this may no longer be possible; with the groundnut and cotton zones potentially moving southward (although for cotton this geographical shift is not so clear, yet; Ton, 2004). Its economic impact depends on relative price developments between groundnut, cotton,

and other export crops on the one hand and imported food on the other. The same is true for livestock. If the caloric terms of trade for livestock against grains remain as good as they currently are, it might well result in a situation that is far less intensive land use in direct food acquisition terms (e.g. cattle instead of groundnuts) that can result in higher indirect food acquisition. In case of climate change in the direction of dryer conditions for agriculture it is likely that all other options (options 4 to 9) will become more important, probably resulting in a tendency of 'de-agrarianization' of livelihood portfolios. As this will also result in a change of settlement patterns, with urban settlements becoming far more important (Harts-Broekhuis and De Jong, 1993; Club du Sahel, 1995), it will probably strongly increase the demand and price of charcoal. In the short run charcoal-based income could increase its share in livelihood portfolios; in the long run, if not properly managed, it could contribute to a damaged environment, with further negative impact on micro-climates and land qualities and even to diminishing rainfall. All this could partly be counter-balanced by improved agro-biological conditions as a result of higher CO_2 concentrations in the atmosphere.

Patterns of responses to climate change: The evidence from dryland West Africa during the 1970-1987 drought era

Individual people and households (or other types of micro-decision making units of individuals) who are confronted with these elements of resource stress in dryland areas have developed 'coping strategies', both to overcome difficult resource conditions during 'average years' and to survive during drought years (Dietz and van Haastrecht, 1997). The word 'coping' in fact stands for three different elements of behavior to improve the security of life and livelihood in a situation of high climatic risks: insurance (prepare for bad times), coping (actually deal with the crisis when it happens) and adaptation/recovery (trying to rebuild after a crisis) (see van der Geest, 2004). A household's, or region's, vulnerability to drought stress or to deteriorating climatic conditions depends on its ability to manage the insurance, coping and adaptation variables, in short: its adaptive capacity (Kasperson *et al.*, 2005). In drylands households have adapted to seasonal fluctuations, which result in relatively good months (for pastoralists during the rainy season, for cultivators after the harvests) followed by bad months (the 'hunger season', the *'soudure'*, for pastoralists towards the end of the dry season, for cultivators during the rainy cultivation season). Each household has a variety of 'normal' responses (in terms of insurance, coping, and recovery/ adaptation) to the adverse months in each year. In drought years the relatively good months are just not there or become shorter, the bad months last longer and the 'usual' problems become more severe (there is a host of literature about 'coping strategies in dryland environments', see Reitsma *et al.*, 1992 for a summary of the relevant literature until the early 1990s; important later additions are Watts and Bohle, 1993; Blaikie *et al.*, 1994; Bohle *et al.*, 1994; Ribot, 1995; Davies, 1996; Ribot *et al.*, 1996; Scoones, 1996; Davies and Hussain, 1997, Ellis, 1998; Reenberg, 1998; Meze-Hausken, 2000; Wisner *et al.*, 2004; Eriksen *et al.*, 2005).

At the level of micro-units we often find a mixture of options being utilized, a broad and diverse portfolio, that is often flexible and 'adaptive' (Millar, 1996). The combination of elements can be changing continuously; and portfolios of chosen options in 'bad years' can look completely different from those in good years. Understanding people's behavior necessitates a long-term perspective, looking at production and consumption behavior, but also at people's social security networks. Local elements then mingle with a variety of extra-local elements, and agricultural ones with non-agricultural ones. Individuals make use of a variety of fallback mechanisms, which include the 'household' and the 'family', but which also contain other linkages. Women make use of different sets of actors than men, and older people of different sets compared to younger people. Investments in social and symbolic capital ('networks' and 'identity') can bear fruit soon, or only after many years (de Bruijn and Van Dijk, 1995). In the ICCD research we focused on people's long-term 'pathways', particular portfolio histories, with particular time-space combinations. Where long-term household data exist (see Brons *et al.*, 2004a and 2004b) we tried to reconstruct 'patterned responses'. We think we can predict behavior in future years with more livelihood stress by zooming in on 'past performance' during years with extreme to moderate drought risks. The likely importance of intra-family networks during difficult times and over time necessitates an approach that goes beyond household surveys. It is useful to reconstruct family genealogies and to understand diverse responses to drought risks, and diverse pathways, by members of the same lineage. We also try to find out how internal social security arrangements within a lineage link up with external social security behavior via the market, the state and non-governmental organizations, and to look at collective action (Brons *et al.*, 2007). We agree with critical observers like Turner (1999) that there are limits to community resource management approaches, and that higher-level governance arrangements are often necessary. And it is useful to find out how drought risk buffers operate via assets (at various levels of scale; and as combinations of more public and more private arrangements) and how entitlements to assets are handed over from one generation to the next in the various cultural groups who live in the various west African case study areas that were studied (e.g. Hesseling and Ba, 1994; Breusers, 1998). Results can be compared with existing policy-oriented frameworks, like Ribot *et al.* (1996); Kok and Heij (1998); Reenberg (1998).

We expect that the following variables will influence the pathways of chosen portfolios of options at the level of individuals, households and networks of (clan-) families. At the level of specific areas (e.g. the regional cells of the ICCD research, or an administrative district) a historical-geographical analysis of these variables for all current inhabitants is useful, as long as it is acknowledged that many people in these types of areas are very mobile and the geography of their 'insurance, coping and adaptation mechanisms' does in fact often entail a much larger geographical space than the regional cell or administrative region alone.

These variables do play a role at both social and geographical levels of analysis:

- the existing natural capital, and in particular the availability of high-quality niches of agricultural production, and of risk-aversive fall-back niches in times of drought;
- access to this natural capital: entitlements to natural resources;
- the endowment of physical and financial-economic capital and actual entitlements to these endowments in times of need; this includes existing mechanisms to insure against hardship and risks, and to borrow money and/or goods; especially important are entitlements to (formal and informal) insurance payments and access to (formal and informal) banking institutions during and after periods of crisis;
- the quality of human capital, like health, fertility, knowledge and labor power that can be mobilized at places and times where and when it is needed;
- cultural capital: the use of identity; the existence of behavioral taboos, and its flexibility in times of crisis; psychological 'stamina' to endure hardship; codes for the payment of labor and codes for 'sharing';
- social and political capital: existing networks of support and of support possibilities in times of need; its social and geographical extent;
- the possibilities to mobilize this social and political capital: entitlements to social resources;
- the availability of markets and the transaction costs to reach these markets; the quality of the organization of these markets, in particular during times of (drought) crisis;
- existing mechanisms of taxation, tribute, rent, interest, gifts and 'gifts' and possibilities to evade these mechanisms, in particular during periods of stress, like droughts.

To understand farmers' behavior in West African drylands in preparing ('insuring') for possibly dryer conditions in the next few decades, and for agro-climatic droughts, in coping with droughts and adverse production conditions, and in adapting to changed conditions afterwards, it is wise to look at their performance before, during and after drought years in the past. For West African drylands really dry years were experienced in the early 1970s and early 1980s and those experiences live on in people's memories. However, also just before the field research started, farmers in many areas had experienced rather bad years (1996-1997) which could also give some insights in their behavior. The method that was developed to study people's 'pathways' and relating those to life cycles and external shocks (droughts, but also economic and political turmoil) looks promising (De Bruiijn and van Dijk, 2004). It also proved very valuable to approach people's behavior by realising that they use a combination of many options, and many of those outside agriculture, to secure livelihood. This was studied with an eye for contextual differences at village/area level (as in Southern Mali, the Koutiala- Sikasso area; Brons *et al.*, 2004a), aridity levels (as in comparisons between the semi-arid north-Douentza in Mali and Kaya and Gorom-Gorom in Burkina Faso - and the sub-humid south - as in

Koutiala and Northern Ghana – van Dijk *et al.*, 2004; Breusers, 2004; Dietz *et al.*, 2004; Zaal and Diallo, 2004), growing importance of major urban centers (as research around Bamako and Ouagadougou shows; Broekhuis *et al.*, 2004) and differences in endowments at household level, and resulting classifications of vulnerability (as household and plot-level research in Burkina Faso shows, Brons *et al.*, 2004b). However, a major problem of doing research on long-term changes in regions, such as West Africa, is the lack of reliable statistics and the lack of long-term panel data, despite decades of foreign-funded regional development projects and programmes (Zaal *et al.*, 2004). Original optimism to be able to use some long-term data sets almost always turned into a deception. Any attempt to get a better grip on changes to come and a better understanding of farmer's/people's behavior needs to be supported by genuine attempts to build up monitoring data in a variety of chosen areas and with enough attention for regional and social detail. Reconstructing climate, agricultural and socio-economic histories now became a puzzle and it was rather difficult to interpret the multitude of existing studies from this perspective.

However, some tentative conclusions can be formulated and they don't look very grim, contrary to the much-painted 'picture of doom' for Africa. West Africa's shock experience in the 1970s and 1980s did have the result that people became much better prepared for possible new drought shocks, and that its agricultural production performance in the 1990s (when rainfall became considerably better) improved:

- there was a major increase in the importance of non-agricultural resources of livelihood, both locally, and (mainly) as remittances from places of work elsewhere;
- there was also a major increase in urbanization and in urban demand for food, water and energy; improving the livelihood options not only for farmers around cities, but also for farmers at rather far off places (charcoal and non-perishable food coming from areas hundreds of kilometers away) (Broekhuis *et al.*, 2004);
- in the countryside there was a major increase in the importance of cash income from high priced agricultural produce like cotton, vegetables, livestock, milk and charcoal;
- the development of physical infrastructure and credit availability played a major role in increasing the yields and area under cotton. Farmers managed to increase cotton income by lowering input costs through adopting better crop management practices (Brons *et al.*, 2004b);
- cereal and groundnut production benefited from the expanding availability of animal traction, fertilizers, and improved market outlets (Id.);
- the price policies particularly enhance the income of the rich farmers, but have a negative effect on soil nutrient states. Subsidies on input bring about a more sustainable land use. Structural policies that reduce transaction costs generate the largest income improvements while, particularly during dry years, poor farmers benefit relatively more than wealthy farmers. Market reform programmes therefore continue to be important for reducing poverty and

enhancing food security (Ruben *et al.*, 2004),

- major farm management decisions are based on conditions prevailing during dry years, which result in surprisingly modest farm yield impacts of agricultural drought in relatively dry years (Idem) even resulting in under-utilization and 'over-compensation in terms of labor input and care' during dry years (Dietz, Millar *et al.*, 2004);
- in a number of places (e.g. most of Burkina Faso) there has been a major investment in soil and water conservation, which not only slowed down erosion, but also improved the water retention capacity of the soils;
- at a number of places there were considerable investments in irrigation, and a movement to hitherto hardly-used riverine and marshy areas partly due to the adoption of the animal-drawn plough;
- all over dryland West Africa, there was a strategic attempt by many farmers to develop a multi-locational, and multi-sectoral household economy, through both on-farm and off-farm activities;
- in some areas there was an increasing importance of livestock as a drought-risk buffer, and of grains-for-livestock trade, making use of (very) positive caloric terms of trade for farmers who sell livestock;
- in areas with high population densities livestock management became more intensive, with better manure management and integration of livestock in farming;
- old socio-cultural dichotomies in livelihoods e.g., between the agricultural ethnic groups like Bambara and Mossi, and the livestock groups, like the Fulbe are gradually disappearing, but cultural identities and identification processes are still important, and have political significance at the national and local levels; the decentralization processes of government power and the growing importance of non-governmental agencies can be expected to have a major impact on the culturally diverse ways of coping with adverse situations and on access to natural resources and to livelihood options in general.

Our encouraging findings and those of others (e.g. Reij and Waters-Bayer, 2001; Mortimore, 2005) may well be based on the positive rainfall situation of the 1990s and on the lessons that people have learnt from the droughts of the 1970s and 1980s (individually and collectively, and assisted by foreign donor agencies which have been quite important in West Africa). If the 1990s prove to be a temporary upswing in a climate cycle (see Hulme, 1995; Hulme *et al.*, 2000), government and donors are advised to be more cautious and to prepare for more difficult periods to come. Research efforts are needed to support this caution.

Suggestions for Better Preparedness for Future Climatic Adversities

In April 2000, the ICCD team organized a final workshop to discuss the major research findings. The workshop participants agreed that the following policy options should get the highest priority, more or less in order of importance (Dietz *et al.*, 2004).

Put a lot of energy in the development of early warning systems

In all Sahelian countries adequate early warning systems should be strengthened and

operational assistance should be given to governments to enable them to develop effective indicators and to faster communicate early warning messages to the relevant institutions and to the farmers and pastoralists in the region (Hazell, 2004). These early warning data should also guide those involved in famine relief operations. The experiences gained in Mali since 1983 could be used as a guideline (Konaté, 2004). The explosion of communication technology all over the area in recent years may help to develop strategies to reach as many people as possible. Mobile phones (and sms services) are particularly promising.

Support integrated knowledge development

Knowledge of climate change and climate variability and of adaptations should be better developed in the Sahel region and other drylands and should enable the integration of scientific disciplines dealing with the issue (agro-biological sciences, geography, anthropology and economics in particular), partly by a better operationalization of relevant concepts, and partly by joint empirical field work. Scientific models should be improved to better understand adaptations over time and responses to droughts.

Develop adaptive technologies

Adaptive technologies should be developed and tested, for agriculture, pastoralism, silviculture and horticulture. In the Sahelian context the adequacy of 'northern' technologies should be tested in 'southern' areas, supposing that the semi-arid zone will move southward. More research is needed on drought-resistant, early-maturing crops and varieties and on drought and disease resistant animals (Allen-Diaz, 1996). Exchange of information within the region and with other agricultural drylands, which lead in technology development, is important. Improved co-operation is needed between research centers within the region and those abroad, for efficient and more rapid dissemination of results.

Improve social security and (micro) insurance

Existing social security mechanisms should be maintained and new ones developed. More knowledge is needed about the functioning of social security networks and mechanisms during and after catastrophic events like droughts, floods and locust invasions. Micro-credit and micro-insurance systems should be strengthened to enable people to better cope with drought shocks. Income insurance based on local rainfall conditions is relatively easy to administer and can be implemented by the private sector (Hazell, 2004). It is widely acknowledged that climate change adaptation in the drylands and elsewhere should be linked to risk reduction and to human security (e.g. O'Brien, 2008).

Acknowledge the importance of migration and remittances

More attention should be given to migration and its role for both rural and urban economies should be redefined. Agricultural policy in the region should be better aware of the role of geographical mobility, not only in pastoral systems, but in arable systems as well. Instead of blindly focusing on the issue of 'environmental refugees', it is much more realistic to see migration as inevitable and as an opportunity.

Acknowledge the important role of urban centers as hubs of demand and innovation

Agricultural policy should also take growing urban demand as a point of departure, and in assessing urban demand the growing importance of non-local resources of this demand should get more attention.

Improve legal security of access to land and water

The governments in the Sahel region should develop policy on land and water issues: ownership, access, control, investments and benefits, with specific attention for aspects of equity and for the livelihood of nomads. It is important to map areas that are still relatively under-utilized in the sub-humid zone and to develop policy guidelines for sustainable land and water utilization in these hitherto relatively 'empty' zones. It is also important to specifically look at the land and water 'entitlement' changes in the peri-urban areas in the region. In looking at the possibilities for policy interventions, careful attention is needed for implications for inter-ethnic relations and potential violence. And of course there will be zones, which should remain hubs of biodiversity, and hence deserve to get status as nature conservation area, preferably managed at community level (Hulme and Murphee, 2001; Ros-Tonen and Dietz, 2005)

Support decentralization

Attempts to decentralize policy formulation should be strengthened and implemented. The financial strength of the local government system needs to be built up, along with the capacity to monitor land use changes and to implement regulatory arrangements for local-level situations.

Increase public investment in water and education

Public investments in two types of infrastructure should be given priority: education and water. Education is partly needed to make people less dependent on agriculture. Investments in water resources are needed to make people who depend on agriculture and animal husbandry less dependent on rainfall (irrigation, water harvesting technology, water for animals). While developing groundwater levels should be monitored and groundwater depletion prevented.

Take advantage of climate change agreements

The policies on subsidies should be redefined to take advantage of international agreements, e.g. on 'carbon sinks'.

Strengthen farmer's organizations, community-based organizations and NGOs

Non-governmental organizations, community-based organizations and farmers' organizations should be strengthened and these institutions should be involved in the formulation and implementation of (government and donor) policies. The institutional capacity of these non-governmental agencies is crucial in coping with deteriorating situations. The strengthening of government institutions (central and local) should never undermine the resilience of the local-level non-governmental institutions. But it is also important not to overestimate the potentials

of harmonious community-level solutions (see Turner, 1999).

UNEP's policy recommendations

In the GEO-4 book of UNEP, the section on vulnerabilities in drylands also includes a list of policy recommendations (Jäger and Kok, 2008). Two of those are regarded as most crucial. The first one is the necessary improvement of tenure security (and it was added: "for example through cooperatives"). Improving tenure would improve farmer's willingness to invest in all types of soil and water conservation measures, combining their traditional knowledge with externally introduced ideas. This policy recommendation overlaps with the ICCD one on access security.

The second key recommendation has to do with the provision of more equal access to global markets (and particularly for cotton; see Goreux and Macrae, 2003), a recommendation that was not formulated by the African ICCD experts in 2000. It shows the renewed belief in primary exports, thanks to relatively high prices between 2004 and 2007, the increased emphasis on fair trade, and the prospects for commercial agro-fuel production. In the ICCD research more emphasis was put on the importance of developing better market linkages between rural hinterlands and the expanding urban centers in the region. Primary export-driven economic growth will certainly play its part, but the urban expansion in the West African drylands itself and in the Coastal areas of West Africa can still be seen as a more important driver of change in the agricultural drylands than the further expansion of cotton and groundnuts. We agree with the caution about export-driven growth in the drylands, as expressed by Mayrand *et al.* (2005). The relatively good prices of primary exports that started in the mid 2000s may be over for some time to come as a result of the implosion of the world economy after September 2008.

UNEP adds another important policy recommendation for dryland development and poverty alleviation. It expects growing resource-related conflicts, and puts a lot of emphasis on the need to develop environmental and developmental cooperation platforms, negotiating access and sharing, and building trust across national, ethnic, language and religious boundaries (Jäger and Kok, 2008).

Conclusion: The Prospects for Dryland West Africa are Not Necessarily Gloomy, but they Might Become So

If indeed there is a decreasing rainfall trend in most of dryland West Africa, the livelihood system might collapse under stress. A lot will depend on the severity and the duration of bad years, and of recovery periods in between, and on the resilience of local social security systems, coupled with external assistance. Although the continuation of foreign development aid will remain crucial in the Sahelian area, the financial support coming from the West African coastal economy will probably be (and become) more important. This partly depends on the political willingness of the governments to use coastal wealth (e.g. oil in Nigeria) to invest in the north, but also on the continuation of massive private remittances from the coastal areas to the Sahelian source areas of migration. Remittances in the Sahelian urban areas might trigger a further development of

circum-urban agricultural, water and energy resources. With adequate land and water policies this might be done in ecologically and socially sustainable ways. A gradual depopulation of the most marginal areas will then be (temporarily?) compensated by concentration of people in and around expanding urban regions. The future for the West African agricultural drylands is not necessarily gloomy. However, the system may breakdown during droughts. One may fear that religion will be used as a major catalyst for political support to exclusionist claims (e.g., Islam versus Christianity) and may result in massive violence and rapid deterioration of local livelihood options, resulting in a large death toll and mass migration southward and overseas. These may then indeed be called 'environmental refugees' (Meyers, 1993; also see Meze- Hausken, 2000 for an interesting case study from dryland Ethiopia; and Bates (2002) for an attempt at classification), although it will be obvious that demographic change, including migration depends on many other factors. The issue of drought or environmental refugees as a result of climate change is often based on hearsay and speculation, instead of being based on sound empirical research (Kibreab, 2002). The relationships between climate change, dryland development (or disaster), environmental dynamics, and demographic turmoil in West Africa and in all other drylands are too urgent to be ignored, but they are also too important to be left to overzealous hit-and-run scientists and policymakers, who undermine seriousness of issues by overemphasizing their cause. There is a lot that we simply don't know yet.

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