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Chapter 12

CLIMATE AND LIVELIHOOD CHANGE IN NORTH EAST GHANA

Ton Dietz, David Millar, Saa Dittoh, Francis Obeng and Edward Ofori-Sarpong[1]

12.1 INTRODUCTION

Northern Ghana is a sub-humid area, combining areas with high population densities and high reported levels of land degradation with scarcely populated areas, which have low levels of land degradation. It consists of three administrative Regions: Upper East Region (densely populated, around Bolgatanga and Bawku in particular), Upper West Region (pockets of dense population - around Wa, Nandom and Lawra - amidst low population densities), and Northern Region (mainly low population densities, with the exception of the area of the major town of Ghana's northern area: Tamale. The ICCD research was concentrated in the Bolgatanga area, but later extended to include the Nandom area in Upper West (as the start of a proposal to develop a Climate Change Preparedness Programme in Northern Ghana, financed by the University of Amsterdam). In the absence of useful longitudinal data at the village or household levels, it was decided to organise two expert meetings (workshops), in collaboration with the University of Development Studies at Tamale, the University of Ghana at Legon and a local NGO, CECIK.

Most of the research activities for ICCD took place in the so-called Bolgatanga cell, an area between 10° and 11° North and 0° and 1° West. It covers the eastern part of Upper East Region and the north-eastern part of Northern Region. Around 1960 the cell had an average population density of less than 50 inhabitants per square kilometre (although by that time, parts of the northern area already had densities far beyond that). On average, though, the density still could be regarded as 'low' compared to other drylands in the tropics. Currently, the Bolgatanga cell has between 0.7 and 0.8 million inhabitants, which means an average population density of between 60 and 70 inhabitants per square kilometre; high in relative terms. The part of the cell, which is located in the Upper East Region, has a very high population density with an average of 200 persons per square kilometre.

12.1 CROPS AND LAND USE DYNAMICS IN NORTHERN GHANA

Crops that are relevant in the northern parts of Ghana include maize, sorghum, millets, rice, groundnuts and cotton. Most of the crop (harvest area) data recorded by the FAO for these crops for Ghana as a whole can be attributed to the northern areas.

Maize has almost always been the most important grain crop of Ghana, in terms of hectarage (although more important in the centre-north areas and not in the upper-north areas). The maize area increased from between 200,000 and 300,000 ha in the 1960s to a level between 600,000 and 700,000 ha in the late 1990s. The year 1984 was an absolute peak year, with 720,000 ha. The years 1965 and 1978 were the lowest with less than 200,000 ha.

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[1] Dietz, A.J., & D. Millar, 1999, Dietz, A.J. & D. Millar, 1999a, b, c, Dietz, T. & D. Millar et al., (in prep.), Geest, K. van der, (2002), Osie-Adjei, P., 2000, Rijkes, P., 2000, and Schijf, A., (in prep.). The authors also want to acknowledge the support by Saskia Jordens, Annemieke van Haastrecht, Richard Yeboah and the many participants in three workshops in Bolgatanga.

Sorghum and millets are the most important crops for the upper north areas. The sorghum area increased with ups and downs from 150,000 ha in the 1960s to more than 300,000 ha in the late 1990s. The area of millet production increased from 100,000 ha in the early 1960s to 180,000 ha in the late 1990s, but with higher figures in between (more than 240,000 ha in 1970, 1979 and 1989).

The rice (paddy) area increased from 25,000 ha in the early 1960s, to more than 105,000 ha in the late 1990s. This can be regarded a steep increase. However, rice hectarage showed extreme fluctuations: up to 130,000 ha in 1977, down to 40,000 ha again in 1983. Part of it is irrigated.

The area of groundnuts production was 60,000 ha in the early 1960s, decreased to half of this in the mid 1960s and increased to fluctuating levels around 90,000 ha in the 1970s, 120,000 ha in the 1980s and more than 160,000 ha in the late 1990s. The seed cotton production area has always been much less. From almost zero in 1960 to 25,000 ha in 1970, down again to almost zero in 1978, but increasing considerably until the 1990s (up to 50,000 ha).

Looking at the 'northern crops' as a whole we can notice a steep increase in total area: from less than 600,000 ha in 1960 to more than 1.4 million ha in the late 1990s. In the total Ghanaian area of arable crops the 'northern crops' increased its share from one-third to half of the land use importance. Probably there are two causes: arable land use in the north increased, following an impressive increase in the rural population; but also: 'northern crops' steadily 'moved south'.

Using estimated area and estimated production data, the FAO data also suggest changes (and fluctuations) in yield levels. These will be given in Table 12.1.

Table 12-1 Ghana, 'northern crops', 1960-1998, yield levels (in kg ha^{-1}).

Crop	Av yield 1960-1998	Lowest Yield (yr)	Highest Yield (yr)	Standard deviation yields (and %/av)	Yield level 1960s	Yield level 1970s	Yield level 1980s	Yield level 1990s
maize	1155	430 ('83)	1648 ('98)	258 (22)	1200	1100	1000	1400
sorghum	753	482 ('83)	1124 ('96)	161 (21)	600	700	700	900
millets	665	477 ('65)	1020 ('96)	131 (20)	600	600	700	800
rice	1234	590 ('82)	2075 ('98)	438 (35)	1100	900	1200	1800
groundnuts	1033	670 ('91)	1697 ('80)	248 (24)	900	1200	1200	800
seed cotton	696	305 ('70)	1014 ('85)	208 (30)	500	600	800	no data

Source: FAO data; compiled by Maaike Snel and Jacoline Plomp, supervised by Marcel Put, in March 1999.

The FAO data suggest a number of interesting conclusions about yield developments:

- For all grains the 1990s seem to be 'breakthrough years' with suddenly much increased yield levels. This improvement is not recorded for groundnuts (decrease) and for cotton (no data yet);
- For maize and rice the 1970s show poorer crops than the 1960s, for millets stagnating levels, for sorghum some improvement and for the cash crops groundnuts and cotton much improved yield levels;
- The 1980s show a further deterioration for maize, stagnation for sorghum and groundnuts, and improved levels for millets and cotton;
- In terms of average yields of the grain crops for the period as a whole, rice leads, followed by maize, sorghum and millets. It is interesting to note that maize had better average yields than rice in the 1960s and 1970s;
- Looking at the standard deviation of annual crop yield data, and comparing those with average yield figures it is evident that millets are the least risky crop (in terms of yield fluctuations), but closely followed by sorghum and, surprisingly, by maize. Also groundnuts have quite comparable levels of fluctuations. Both rice and cotton are 'gamble crops', with rather extreme fluctuations.

Increased hectarage and increased yield levels for all major grains have resulted in a considerable increase in grain production. In the early 1960s total grain production reached 410 m. kg, or 60 kg cap^{-1} for Ghana as a whole. In the late 1990s the total production had more than quadrupled, to 1790 m. kg, or 105 kg cap^{-1} for Ghana as a whole, despite a 250% increase in the number of people since 1960 (from 7 to 20 million inhabitants). This very positive result can mainly be attributed to the 1990s, when both yield levels dramatically improved and hectarages increased.

The FAO yield data allow a preliminary analysis of relatively bad years in productivity terms: all years with a lower yield than the previous year are called 'bad years'. A really bad year shows when all six crops have lower yields than the previous year. A year in which all crops show improved yields compared to the previous year can be regarded as a 'good year' or at least (much) better than the previous year. Table 12.2 shows the results. Three years have been extreme, with 1975 as the year with the worst experience, when all six crops had lower yields compared to 1974, but 1980 and 1982 were problematic as well. In 1980 only groundnuts and in 1982 only cotton had better results than in 1979 resp. 1981; all other crops fared worse. The analysis also shows that the 1990s were much better than previous decades in terms of short-term yield deterioration.

Table 12-2 Yield data of six 'northern crops' compared with previous years (1962-1998).*

Decades Crops with lower yields than previous year	1960s	1970s	1980s	1990s**
all 6 crops	-	1975	-	-
5 crops	-	-	1980, 1982	-
4 crops	-	-	-	-
3 crops	1962, 1965, 1967, 1968, 1969	1970, 1976	1983, 1989	1990, 1991, 1994
2 crops	1963	1972, 1974, 1977	1981, 1984, 1988	1997
1 crop	1964, 1966	1971, 1973, 1978	1986, 1987	1992, 1996
no crops	-	1979	1985	1993, 1995, 1998

* Maize, sorghum, millets, rice, groundnuts, cotton.

** For the period 1993-1998 cotton yield data are missing, so there are only five crops.

Source: calculations, using FAO data compiled by Maaike Snel and Jacoline Plomp, supervised by Marcel Put, in March 1999.

For the food security situation in the upper north area sorghum and millets have always been most important. In the 1960-98 period there were nine years in which both the sorghum yield and the millet yield were less than the previous year; an indication of food security problems; these years were 1965, 1968, 1975, 1980, 1982 and 1983, 1990, 1994 and 1997.

The northern part of Ghana can also be regarded as the most important livestock area of the country. Livestock production trends can also be found by using the FAO database. Total (commercial) meat production steadily improved in the 1960s, from a level of 60,000 metric tonnes to about 80,000 metric tonnes. After 1976 there was a major increase, to a level of 140,000 metric tonnes in 1984 and afterwards this level was maintained. However, the recorded beef and veal production in Ghana shows a slightly downward trend from the 1960s until now, although it can also be said that the period 1974-78 showed a tremendous downfall, and after that the production improved again to the current level which is still slightly below the high 1970-74 level of 22,000 metric tonnes. Both goat meat and mutton and lamb production steadily improved from 3,000 metric tonnes each in the early 1960s to 6,000 metric tonnes each currently. Other meat includes chicken, guinea fowl and pig meat.

Commercial milk production increased from a level of 10,000 metric tonnes in the early 1960s to 24,000 metric tonnes currently. There was a steady increase with the exception of a severe crisis between 1974 and 1980. The Ghanaian production of meat and milk combined remained rather stable per capita, at a level of 10 kg cap^{-1} per annum.

Table 12.3 gives the production data in a summarised form. Looking at the production variability (standard deviation divided by the mean for the period as a whole) it becomes clear that beef and veal production was the most stable livestock food, closely followed by goat meat, mutton/lamb and milk. Total meat production showed the largest fluctuations (because of chicken, fowls and pigs).

Table 12.-3 Livestock production in Ghana, 1961-1998 (in metric tonnes).

Product	Average Production	Minimum (yr)	Maximum (yr)	Standard Deviation (and SD/av)	Production level 1960s	1970s	1980s	1990s
Meat Total	107,055	61,284 ('62)	143,923 ('98)	31,610 (30%)	70,000	100,000	120,000	140,000
Beef & Veal	19,213	12,995 ('78)	23,000 ('69)	2,661 (14%)	22,000	17,000	18,000	20,000
Goat Meat	4,295	3,040 ('65)	5,938 ('98)	821 (19%)	3,000	4,000	4,000	5,000
Mutton & Lamb	4,910	3,102 ('62)	6,545 ('98)	1,102 (22%)	3,000	5,000	5,000	6,000
Milk	18,621	9,750 ('61)	23,920 ('95)	4,052 (22%)	14,000	16,000	19,000	23,000

Source: FAO data; compiled by Maaike Snel and Jacoline Plomp, supervised by Marcel Put, in March 1999.

Food security does not only mean the capacity to feed the population with food that is produced in the country itself. Food security can also be facilitated by food import. Food imports can come through food aid or through trade. In Ghana the food aid component of food imports has mostly been small. According to food aid data for the period after 1970 the average cereal imports were about 80,000 metric tonnes. There were peaks in 1977-80, 1983-85, 1987, 1991 (an absolute peak of 200,000 metric tonnes), and 1992-93. Cereal aid mainly consisted of wheat, wheat flour and rice, although coarse grains were included as well. After 1993 cereal aid gradually came to an end.

The US dollar value of total agricultural imports in Ghana has risen steeply: from a level of 50 m$ in the early 1960s to 350 m$ currently. The increase mainly started in 1986. Registered livestock imports decreased considerably, though: from a level of 120,000 annual cattle imports in 1961 to almost zero after 1975 ($ value: from about 8 m$ to less than 1 m$). The import of goats decreased from 130,000 per year to almost zero after 1977 (value dropped from 1.5 m$ to less than 0.2 m$) and the import of sheep from 100,000 to less than 10,000 after 1978 (value dropped from 1.2 m$ to 0.6 m$). Most animals used to come from Burkina Faso, but after the 1974 drought the livestock trade petered out (at least the registered trade). Nowadays most agricultural imports consist of food grains, but FAO data are lacking.

Between 1960 and 1998 the consumption of food in Ghana as a whole (per capita) shows a change in composition, with a much higher importance of grains in the average diet, and hence a greater importance for the 'northern crops' (and for grain imports):

- maize consumption increased from a level of 20-25 kg cap^{-1} in the early 1960s to 35-40 in the 1990s, with peaks first around 1970 and after 1984;
- rice consumption is on the increase, from 10 kg cap^{-1} until 1990 to between 20 and 30 kg cap^{-1} in the 1990s;
- millet consumption was rather stable, with 8 kg cap^{-1} (peaks in the 1970s); sorghum consumption increased (from 9 kg cap^{-1} in the early 1960s to 13 kg cap^{-1} nowadays, but after rather low levels of 6-7 kg cap^{-1} in the 1980s;
- groundnut consumption first increased from a level of 2 kg cap^{-1} to between 4 and 6 between 1970 and 1990, and down again to a level of between 2 and 3 kg cap^{-1} in the 1990s
- meat consumption was rather stable, at 10 kg cap^{-1} (but less beef, veal, goat, and mutton), while milk consumption deteriorated (between 6 and 12 kg cap^{-1} before 1978 and between 2 and 6 kg cap^{-1} afterwards).

12.2 AN ANALYSIS OF CLIMATE DATA FOR THE BOLGATANGA AREA

According to UNESCO's aridity assessment (based on data for the period between 1930 and 1960), the whole Bolgatanga cell belongs to the sub-humid zone. However, it can be deducted from rainfall data about the years between 1960 and 1997 that especially the period 1982-1986 (or maybe even 1974-1988) had a semi-arid climate. Noteworthy drought risk years were 1962-63, 1967, 1970, 1977, 1981, 1984, 1990, and probably 1995 and 1997.

Ghanaian climatologist Prof. Ofori Sarpong did a survey for all data that exist about rainfall in northern Ghana as a whole, for the period 1900-1993. The average rainfall for this area (which is considerably bigger than the Bolgatanga cell and which includes rainfall stations to the more humid south as well) for the century as a whole was slightly higher than 1200 mm. The five-year moving average (see Figure 12.1) shows interesting and quite substantial fluctuations. The century started with a bad rainfall situation between 1900 and 1915, with droughts in 1904 and 1912. The late 1910s were good, with an all-time annual peak of close to 2000 mm in the year 1917, followed by drought again in 1918-1920, The period 1920-1935 was more or less average, followed by a dry period between 1935 and 1945. The period 1945 till 1975 was very good as a whole, with the exception of 1957-1960 (1960 being extremely bad). After 1975 the rainfall situation deteriorates a lot, reaching averages of 200 mm below the level for the century as a whole. However, after 1985 the situation improves somewhat.

The study area proper is located in the sub-humid zone of northern Ghana, with alternating wet and dry seasons. The climate is influenced by the convergence of two air masses, the boundary of which is called the Inter-Tropical Convergence Zone. The one air mass is continental and dry and is associated with the Azores High, which extends over the Sahara and gives rise to the north-easterly Trade Winds of 'harmattan'. In the dry season almost every part of Ghana comes under the influence of these winds. The other is the moist tropical air mass, which originates from the South-Atlantic anticyclone and is associated with the moist south-easterly winds, which bring copious rainfall to Ghana during the rainy season. The boundary fluctuates north-south. In the Bolgatanga cell, annual rainfall averages about 850-1100 mm in the northern part and 1000-1200 mm in the southern part. Figure 12.2 shows the 5-year moving average for Bawku in the driest part of the research area. Rainfall is concentrated in the period from April to October, during which 95% of the precipitation occurs. The Monsoon rains reach their peak levels in August with about 1/4th of the annual rainfall. Rainfall intensity can be high during this period, with rainstorms causing severe erosion of unprotected soils.

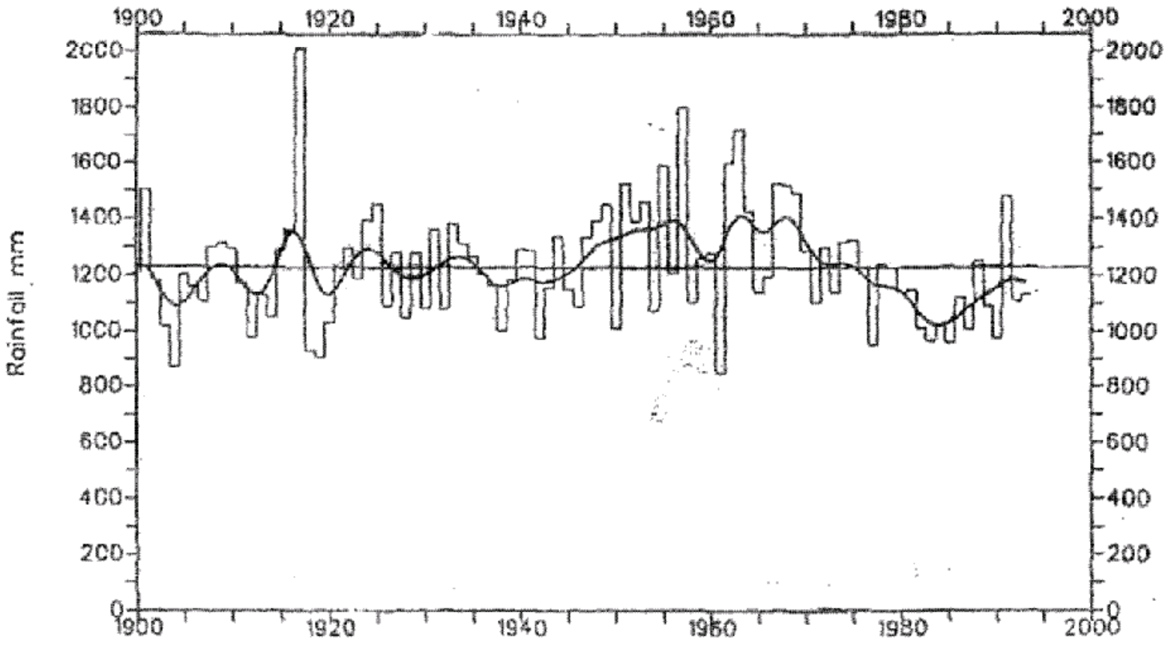

Figure 12.1 Rainfall in northern Ghana, 1900-1993.

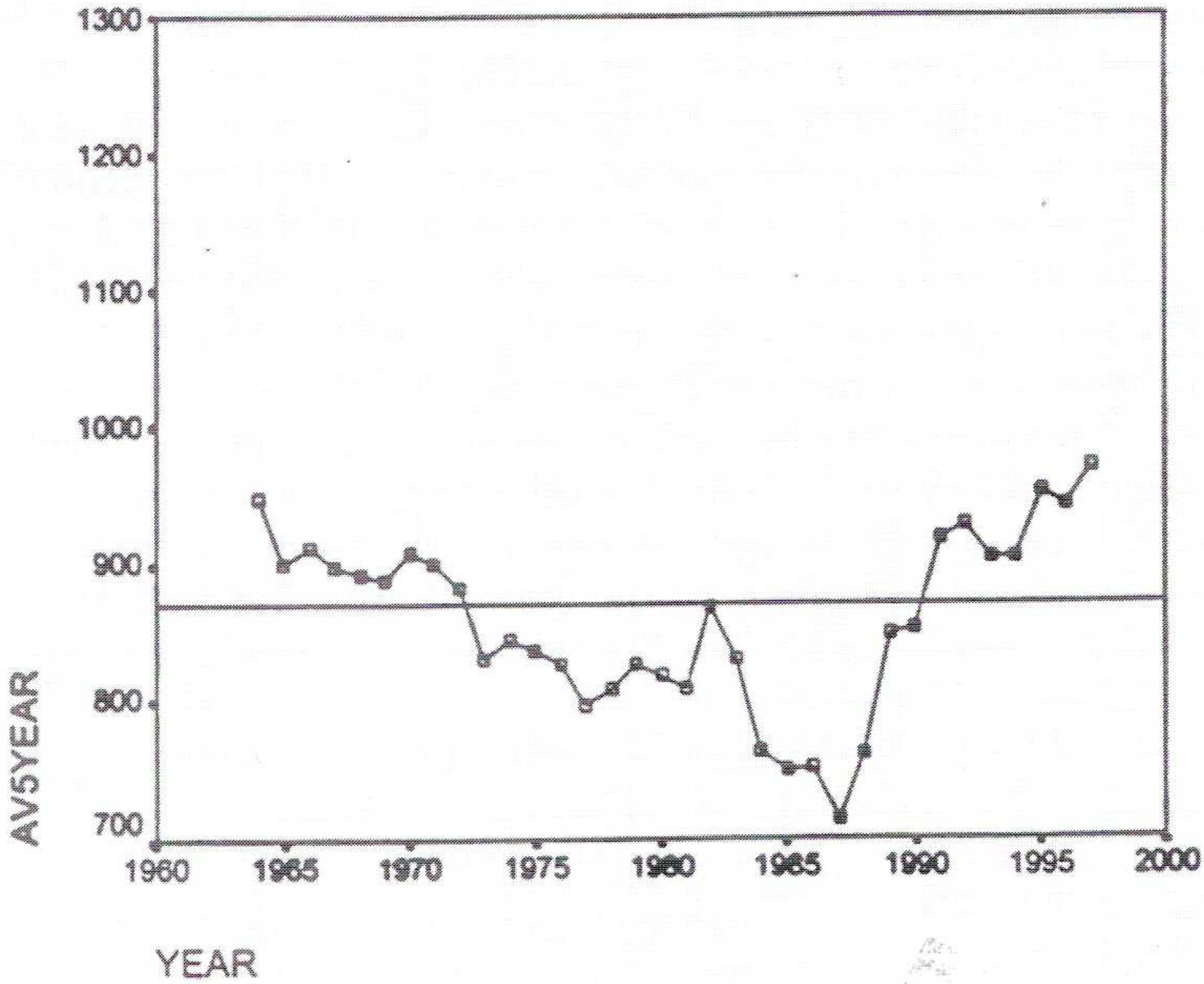

Figure 12.2 *Rainfall in Bawku, 1960-1997, 5-year moving average.*

Temperatures are high throughout the year, averaging about 28°C (with a range between 26-32 °C). An analysis of temperature trends in northern Ghana shows a gradual increase (up to 1 °C) during the 20th Century. During the dry season from November to April day and night temperatures are high, up to 46 °C during the day in the shade (with the exception of night temperatures in December and January, which are relatively low, e.g. 15 °C). High temperatures, dry conditions and (harmattan) wind encourage bush fires. Relative humidity is strongly fluctuating, less than 35% during the dry season, and more than 70% during the rainy season. Diurnal fluctuation is large as well, with the highest humidity recorded in the morning, when it is often greater than 90% from July to September, while the lowest is recorded in the late afternoon. The length of the growing period for rain-fed crops is more than 80 days in the southern part and less than 60 days in the north-eastern part.

Long-term climate data up to the current period exist for three relevant stations: Gambaga in the central part of the area, Bawku, just outside the north-eastern corner of the cell, and Navrongo, just outside the north-western corner of the cell. Data from FAO's Agrhymet source are slightly different from data given by ISRIC, because reference years differ. For Gambaga the first source can be used to calculate an average annual rainfall (based on 1960-1997) of 966 mm. ISRIC gives 950 mm. In the rainy season (defined as five months, March-September) averages are 855 mm resp. 813 mm. August is clearly the wettest month, followed by September and July. For Navrongo the FAO and ISRIC data give more or less the same results: 966 mm on average and 840 mm in the rainy season (however: for

Navrongo eight years are missing in the FAO data set). For Bawku we only have FAO data, showing an annual average of 871 mm, of which 733 mm in the rainy season. Gambaga and Navrongo receive more rain compared to Bawku. There are also other rainfall stations in the area (e.g. Zuarungu, Bolgatanga, Nakong, Paga, Sandema, Wiaga, Binduri, Garu, Kugri, Vea), but for those centres there are only a few years available and the Ghana Meteorological Services Dept. does not regard these data as very reliable. There has been a period in which they engaged schools to carry out rainfall measurements, but during school holidays results became very unreliable (according to a meteorologist working in the area it was not always clear if they measured water or urine…). For Navrongo and Bawku (and for a rainfall station at the Vea Dam site, in the north-western part of the research area) we received data for the years 1994-1997 from the Ghana Meteorological Services Department at Bolgatanga.

Annual rainfall totals can be quite different from year to year. In Gambaga the lowest rainfall measured during the 1960-1993 period was 731 mm (in 1962 and in 1977) and the highest rainfall was 1222 mm (in 1991). In Navrongo the extremes were 776 mm (1984) and 1272 mm (1973) and in Bawku 644 mm (1983) and 1118 mm (1989). If we combine the data for these three stations (although part of the years deficient for Navrongo) we get an assessment of the rainfall differences between the years for the region as a whole. For 1994-97 we combine the data for Navrongo, Bawku and Vea. Low rainfall years (or worse: periods) have been 1961-62, 1964-65, 1972, 1977, 1981, 1983-87, 1990, 1992-93 and 1995 or more in detail (see Table 12.4).

Table 12.4 Relative good and bad rainfall years in Upper East Region, 1960-1997.

mm	year
<700	1977
700-799	1983, 1984, 1985, 1990
800-899	1961, 1962, 1964, 1965, 1972, 1981, 1986, 1987, 1992, 1993, 1995
900-999	1966, 1967, 1970, 1971, 1973, 1974, 1975, 1976, 1978, 1980, 1982, 1988, 1997
1000-1099	1960, 1968, 1969, 1979, 1994, 1996
1100-1199	1963, 1989, 1991

Is there a rainfall trend in the area? The combined rainfall data for the research area as a whole shows an upward trend in the 1960s (a five-year average figure that moves from about 940 mm to more than 1000 mm in 1969) and a more or less continuous trend downwards from 1000 mm in 1969 until slightly above 800 mm in 1985. In the second half of the 1980s the trend improves again and does so rather rapidly (to an average of 975 mm in 1990), after which year the trend moves slightly downwards again, towards a level of 930 mm in the mid 1990s. The lowest point was reached in the 1981-'87 period, after which the 'Sahelian crisis' seems to be over in many other parts of western Africa as well. Data for the period 1985-1997 do certainly not suggest a further deterioration of the rainfall situation.

Annual rainfall data are not the most relevant to use for an analysis of agricultural (crop cultivation) risks. Data for the growth season are much more important and especially if they take into account if there are dangerous dry spells during the rainy season. For the ICCD project a 'Drought Index' was developed with a six-point scale, from no (0) to extreme (5) drought risks for the cultivation of sorghum and millets (see 4.3.1). During the period 1960-'93 there have been 13 years with no drought risks (index 0) in Gambaga, 12 years with very light drought risks (Drought Index 1), 7 years with light drought risks (Drought Index 2), and (surprisingly) 2 years with extreme drought risks (Drought Index 5). These two extreme years were 1962 and 1970. However, in 1962 the drought risk for Navrongo and Bawku was only very light (Drought Index 1), while they were light (Drought Index 2) in those two centres in 1970. The average drought risk assessment for Gambaga was 1.1, which is on average very light. In Navrongo the number of years with no drought risk (Drought Index 0) was much lower: only five, while there were 11 years with very light drought risks and 9 with light drought risks. There was one year (1967) with a moderate drought risk (Drought Index 3). On average the drought risk was only slightly above the one for Gambaga: 1.2 (but based on only 26 years of data). In Bawku the average drought risks were considerably higher: 1.8. Here there was only one year without drought risks, 16 years had a very light drought risk, 16 a light drought risk while one year (1980) had a moderate drought risk. Within the study region in most years the drought risk figures do not show a consistent pattern. If we consider an index of 2 or higher as a signal of drought problems (in relative terms) there are only six years in which all three rainfall stations show the same relatively problematic situation: for 1963, 1970, probably 1977, 1981, 1984, and 1990. Out of those years only 1977, 1984 and 1990 also had a relatively low annual rainfall total.

Detailed analysis of the rainfall situation 1987-1997 and of the variation in agricultural productivity: how to explain the lack of consistency?

For the years 1987-1997 'official' data exist about the agricultural production per hectare in Upper East Region, for five crops: millet, sorghum, groundnuts, maize and rice. For 11 rainfall stations in this region and 2 in the nearby parts of Northern Region we also have rainfall data, both annual and monthly, which enable us to calculate the drought risk assessment per station per year and for the area as a whole (although not far all stations data are complete).

The period covered starts after the bad rainfall period of the late 1970s and early 1980s. The years 1987-1994 are generally quite good, with 1990-91 a bit less so in Upper East (but 1991 not in Northern; there 1987 and partly 1988 were quite bad, as well as 1992-93). In Upper East the period 1995-1997 is worse though, with Drought Risk Assessment figures 2.6 for 1996 and 2.5 for 1997, against an average for the period of 1.4. On an annual basis the rainfall situation was not the worst for these two recent years during this period, though. The average rainfall annual total was lowest in 1990 (808 mm, with a Drought Index of 1.7). It was highest in 1989 (1158 mm) with the lowest average Drought Index (0.3)

Looking at the regional details, the large resemblance is striking in some years (e.g. 1987-1989 with Drought Index figures either 0 or 1), while in other years the location mattered a lot: in 1996 and 1997 the Drought Index was 1 in the best areas, but the Drought Index suggests an absolute crop failure (Drought Index 5) in some other parts, like Nakong in 1996 and Paga in 1997. The overall situation in 1996, (see Table 12.5), was one of good rainfall in June (in some places even starting in May), a rather dangerous dry spell in most of the area in July, and abundant rainfall in August, continuing in most areas into September. In Nakong - in the extreme north-western part of Upper East Region - the season started late, July was exceptionally good, but August exceptionally bad and most farmers will have experienced severe difficulties. In places nearby, like Navrongo and Wiaga, the situation was not bad at all, though. In Kugri, in the extreme eastern part of UER, the month of July posed a problem, but thanks to surplus rainfall in June, the soil was probably moist enough for the crops to survive. In Walewale, in northern region, the same situation could be found. Here, surplus rainfall in June probably was not enough, so farmers were faced with a high risk of crop failure, especially those farmers with their fields in uphill and sandy locations. In 1997, (see Table 12.6), the overall rainfall situation was not very promising. In a place like Paga it was even very bad in all months.

Table 12.5 Bolgatanga study area, rainfall in the rainy season, 1996, in mm.

Rainfall Station	May	June	July	August	September	Drought Risk Assessment
Upper East Region						
Bawku	139	149	71	257	261	3
Binduri	175	117	71	117	71	3
Garu	126	170	98	316	231	1
Kugri	82	175	70	258	73	4
Zuarungu	64	nd	nd	578	298	nd
Vea Dam	141	196	73	278	245	3
Navrongo	195	207	108	301	207	1
Paga	51	87	nd	nd	nd	nd
Wiaga	140	212	129	344	314	1
Sandema	71	124	nd	323	232	nd
Nakong	29	98	149	36	130	5
Northern Region						
Gambaga	141	196	73	278	245	3
Walewale	135	98	67	325	210	5 (?)
Average	115	152	91	284	210	2.9

Table 12.6 Bolgatanga study area, rainfall in the rainy season, 1997, in mm.

Rainfall Station	May	June	July	August	September	Drought Risk Assessment
Upper East Region						
Bawku	105	236	115	216	201	1
Binduri	82	187	99	169	210	1
Garu	125	238	92	233	186	1
Kugri	124	228	85	204	145	3
Zuarungu	101	231	76	153	225	3
Vea Dam	99	194	103	128	209	1
Navrongo	156	204	91	195	179	3
Paga	62	31	30	70	62	5
Wiaga	68	123	76	125	151	3
Sandema	89	159	73	148	131	3
Nakong	52	140	134	80	173	3
Northern Region						
Gambaga	99	194	103	128	209	1
Walewale	139	91	173	116	116	?
Average	101	174	96	151	169	2.3

Acknowledgement: rainfall data were provided by the Meteorological Services Departments in Bolgatanga and Tamale; drought risk assessment calculations were done by Dr Marcel Put, based on a computer model developed by Dr Sjoerd de Vos.

Table 12.7 and 12.8 show the variability of crop harvests for five crops in the same period for Upper East Region as a whole and link the yield indexes of these crops to the Drought Index data. If the Drought Index would be a good 'predictor' of yield levels, there would be a negative correlation between yield index data and drought risk assessment data. The correlation that is found, though, is completely spurious, for all crops individually and for the five crops combined. On the basis of Drought Index data the year 1996 could be expected to be the worst performing year. Instead, it was almost the best year as far as yield levels (kg ha^{-1}) were concerned, with the exception of groundnuts. The year 1997 was almost as bad in Drought Index terms, and then indeed the yield situation proved to be bad (with rice as an exception). The best years in yield terms for individual crops were all years with a relatively high Drought Index: 1995 for millet and rice (Drought Index 1.7), 1996 for sorghum (Drought Index 2.6), and 1991 for maize (Drought Index 1.7). Only groundnuts had its best performance in a year with a low Drought Index (1987: Drought Index 0.7).

Table 12.7 Harvest estimates (index figures) in Upper East Region, 1987-1997.

Year / Crop	Millet	Sorghum	Groundnuts	Maize	Rice	Five crops
1987	76	77	140	88	63	89
1988	82	116	83	92	74	89
1989	101	110	87	64	120	96
1990	70	92	74	88	40	73
1991	72	82	99	153	95	100
1992	70	84	98	118	102	94
1993	142	99	113	112	98	113
1994	101	86	104	100	120	102
1995	158	113	111	115	144	128
1996	145	145	96	106	132	125
1997	81	96	98	59	108	88
Average in kg ha^{-1} (index = 100)	740	830	820	850	1670	982 (unweighted)

Source: Ministry of Food and Agriculture UER, annual reports, for the kg ha^{-1} estimates, based on expert assessment by MOFA field-level staff at district level, converted to an estimate at regional level by the Head of the MOFA at UER level. The staff making these judgements continuously changes.

For millets and sorghum, providing the bulk of food grains in Upper East Region, there have been three years during this period when yield levels for both crops dropped compared to the previous year: 1990, 1994 and 1997. If we compare this with the data for (northern) Ghana as a whole, the same years were mentioned. The data about the 'bad years' in the last decade seem to be consistent. For Upper East particularly the situation in 1997 must have been rather dramatic: compared to the yield level in 1996 the millet yield was 44% less and the sorghum yield 34% less.

Table 12.8 Harvest indexes compared with Drought Risk Assessments in Upper East Region for five crops, based on data for 1987-1997.

Crop/ Drought Index	0.3	0.7	0.7	0.9	0.9	1.2	1.7	1.7	1.7	2.5	2.6
Year	1989	1994	1987	1988	1992	1993	1995	1990	1991	1997	1996
Millet	101	76	101	82	70	142	158	70	72	81	145
Sorghum	110	77	86	116	84	99	113	92	82	96	145
Groundnuts	87	104	140	83	98	113	111	74	99	98	96
Maize	64	88	100	92	118	112	115	88	153	59	106
Rice	120	63	120	74	102	98	144	40	95	108	132
All five	96	89	102	89	94	113	128	73	100	88	125

We may conclude that we are confronted with a situation that is difficult to explain: the expectations about the role the Drought Index could play as a tool in crop performance assessments appear to be illusions. Worse even, if Drought Index data are so problematic in predicting harvest levels of crops, and especially for crops for which the Drought Index has been developed - in this case millet and sorghum -, it can also not function as a tool in harvest scenarios following climate change.

So it is wise to brainstorm about the various reasons why the correlations between yield levels and Drought Index data are so spurious.

A workshop in Ghana in March 1999 (Bolgatanga) discussed at length about the various reasons. A training session of CERES PhD students in the Netherlands did the same on March 30, 1999 (Hilversum). We acknowledge their contributions to this section.

- The reliability of the rainfall data can be regarded as rather questionable. Bad recording and mistakes while copying data from one level to the next can cause problems of interpretation.

Changes in personnel can cause gaps in reliability and care. Higher-level 'corrections' of lower-level data can sometimes be very confusing;

- The rainfall data are point data. We have tried to use as many stations as possible to arrive at a 'regional figure'. However, the large intra-regional variations and the fact that rainfall often comes in localised rainstorms, makes any 'up-scaling' of point data to area data questionable. The location of the rainfall stations might also not give a representative overview of the most important agricultural production areas. Some productive areas might not be easily accessible for agricultural staff during the harvest months, due to the road conditions and lack of transport;
- The yield data can be regarded as very questionable as well. In Chapter 7 a condensed comparative analysis was presented of statistical relationships between rainfall and crop yields for a number of areas, including Bolgatanga. Here, strong doubts were expressed about the yield data for this particular area. Crop acreage, kg ha^{-1} assessments and total production figures are based on 'expert' assessments (by local low-level personnel of the MOFA) at district headquarters, later up-scaled to the level of the Region as a whole. Agriculture is mainly subsistence oriented. It is unclear whether 'eating from the field' in the pre-harvest period is included, if volume assessments are based on 'wet' or 'dry' harvests, and if yield assessments are based on representative samples or just a guess from the office. In a situation where not all planted land is also harvested, and where mixed cropping is the norm, mistakes can easily be made and confusion reigns. Later, higher-level civil servants arrive at a 'regional' figure. "(Some) Garbage In, (More) Garbage Out". Some civil servants tend to increase the yield data, either because their reference farmers tend to be the rich and more successful ones, or because they want to 'prove' that their extension and other efforts have been successful. During perceived drought situations the opposite can also happen: harvests are underreported, and the food crisis exaggerated, to impress on national decision makers the urgent need for relief food;
- The yield data for particular crops might not refer to responses to the rainfall situation, but to genetic improvements in particular varieties or crops; or to changes in fertilisation, use of pesticides, irrigation, water harvesting and drainage, and farm management techniques (as a result of changes in extension or otherwise) ; it might also reflect gradual changes in soil fertility, which over an 11-year period can be considerable;
- The Drought Index might be faulty, or the cut-off points between classes wrong. The Drought Index method itself is based on monthly rainfall data. For soil moisture assessments (relevant for the jump from Drought Index 3 to Drought Index 4 and from Drought Index 4 to Drought Index 5) more detailed analysis would in fact be required: based on weekly or 10-day averages and specifying for different soil and landscape types. In the Drought Index method the rainfall data are taken from real measurements, but the temperature data and evapo-transpiration data are estimated and 'static'. It is probable though that during droughts actual temperatures are higher (and more fluctuating) and hence actual evapo-transpiration is higher as well, resulting in even more drought stress for plants;
- The Drought Index method does not take into account that plant moisture needs vary over the growing cycle of plants, with the highest moisture needs somewhere in the middle: the impact of a dry spell in July can thus even be more dramatic than the Drought Index model predicts;
- The yield variability because of nature's whims is of course not only a result of droughts. Excess rainfall at the wrong time can also be quite devastating. Harvests rotting in the field, excessive weeds, pests (e.g. fungi in maize) and plant diseases can cause havoc. For quite a number of millet and even sorghum varieties that are locally used a lower rainfall and higher Drought Index (e.g. between 2 and 3) could even be a more optimal situation than a Drought Index between 0 and 2;
- The most important factor to explain the differences between Drought Index scores and yield levels is probably the preventive, coping and adaptive strategies of the farmers:
- Many farmers combine a rather large variety of crops and crop varieties and various rounds of seeding, to spread risks and harvest moments; many farmers start with fast-maturing millets, followed by other millets and sorghum, and some maize and beans, often in the same fields, and with overlapping farm management cycles. During a drought they give up on more risky crops as

far as drought stress is concerned and concentrate their efforts on crops and varieties which are more likely to succeed;

- Many farmers combine various locations, with different soils, exposure to the sun, slope, and water conditions. In many parts of the area farmers combine 'compound farms' and 'bush farms' with different, but varying time and care investments, depending on the quality of the season; especially on compound farms, near the homestead, additional care (adding water, better weeding, manure application) can result in good harvests, even if the rainfall situation is quite bad;
- There probably is an inverted U-shaped curve of care (and labour investments): when the rainfall situation is good, farmers tend to be 'lazy' (that is: they prefer leisure or other types of work above hard agricultural labour); when the rainfall situation begins to be tricky farmers increase their care (e.g. apply more manure; re-sowing if needed) and labour input (more weeding); when the rainfall situation deteriorates further farmers tend to give up and spend time on non-agricultural alternatives. A perception of drought can also alter labour patterns (e.g. more child labour). Each farmer will have different behavioural patterns in this respect, so the combined effort is a result of highly varying farm management practices. The overall result is that yields during good years will not necessarily be better compared to yields during drought years, except for very dry years, when most farmers give up. In the research area these extreme conditions hardly occurred though;
- After a good year, with relatively abundant harvest and a good food stock, farmers probably tend to 'relax' their effort; after a bad year farmers tend to increase their acreage, they tend to favour less risky crops/varieties and spend more time in their expanded fields. However, they often have to spread their efforts over larger areas, and fields further apart; during and after a bad year their 'effort capacity' can also be undermined by a higher disease occurrence and higher labour investments in activities outside home agriculture (e.g. 'hunger trips');
- After a very bad year there might be a seed problem. Many farmers have to buy, barter or 'beg' seeds, sometimes with unknown characteristics, which creates a more insecure situation, but also a higher 'experimentation attitude'. After a very bad year food donations and other institutional interventions can change attitudes of farmers towards farming and farm effort.

"In a dry year there will be a good harvest. Formerly the young did not understand, but now they do." (old farmer in Bongo).

12.3 ARE THERE INDICATIONS OF CLIMATIC CHANGE IN THE STUDY AREA?

It is evident that a comparison between the rainfall situation in the middle of the 20th century with the period 1970-1990 reveals a major climate deterioration, but that after the late 1980s the situation improved again, until the 1997 drought which was generally seen as problematic, but not causing a major crisis. The farmers who were interviewed generally saw a lot of evidence of long-term climatic change. They observe a change in the natural vegetation and in the relative importance of some trees (e.g. the gradual disappearance of the economically important *dawadawa* tree). They also observe lower water reliability and a shift in the planting season. In the past many farmers already started in April, or even late March, but many have changed to May or even June. The early maturing millet varieties are on the increase, late millet is disappearing, and in the mix of white and red sorghum the more drought-tolerant red varieties become more important. People say that the traditional signs of the start of the rainy season are no longer reliable: the behaviour of birds, and ants, the changing of the winds, the coming of new leaves, the water tables in wells, the harvest of *dawadawa* trees. People are confused nowadays. Also they regard the rainy season as more uncertain and shorter than before. People who used to rely on riverbed cultivation after the rainy season are nowadays regularly confronted with dry riverbeds that are 'dead'. Farmers also observe a growing importance of sheep and goats and a diminishing emphasis on cattle, which are confronted with an increasing 'feed stress' unlike sheep and especially goats. On the other hand cotton is observed to be on the increase, especially in the southern part of the study area, near Langbensi.

People report that the number of 'swimming pools' has become much less (especially pools along rivers have disappeared) and that also many running streams become stagnant water pools more early in the season than before. As a result the water quality from those sources becomes worse and there are more mosquitoes breeding. Some water sources, which used to be good, now became salty. In addition chemical pollution (pesticides; mining chemicals) has increased. However, due to much improved modern drinking water supplies, the average quality of drinking water has improved a lot, certainly for the urban population. Hand-dug wells and bore-holes provided by some NGOs helped a lot. It is interesting to note that in urban areas all over northern Ghana, water is rapidly commercialising, with water vendors selling water to those without proper own provisions.

12.4 WHAT WERE THE DRIVING FORCES OF LAND USE CHANGE?

A number of geographical trends in land use in the last decades are worth mentioning:

- a shift towards the valley (Volta) and marshy (Nasia) lands, enabled by lower health risks (eradication of tsetse fly) and changes in farm technology (oxen ploughs);
- the development of irrigated agriculture in a number of 'schemes', and with it the expansion of commercial rice and vegetable cultivation; From the mid 1960s onwards the valleys of the major and minor tributaries of the Nasia river, as well as a number of small-scale irrigation areas (e.g. Vea) have become the main areas of rice production in Northern Ghana. During the 1960s many small water dams have been constructed; according to representatives from the Ministry of Food and Agriculture there were more than 200 or even 250 in Upper East Region alone (An IFAD-funded project counted 256 of them). An average dam can irrigate 10 hectares of land, mainly for tomatoes, onions or other vegetables, or even rice. According to a natural resource management expert in the area the Region needs at least 450 additional dams. Most of the existing small dams silted up during the 1970s and '80s. Recently a start has been made to rehabilitate these dams and encourage farmers to use them for dry-season cultivation. In 1999 44 of these dams had been rehabilitated and their use as areas of intensive cultivation of rice and horticultural produce has indeed increased considerably. People have come to see their importance and much more effort is put in maintaining and preserving the dams;
- many (parts of) so-called bush farms were converted to compound farms (due to population growth and establishment of many new farm households by the new generation), resulting in intensification and better care; many farmers still try to maintain multi-location farming, though, combining compound with bush farming, and - if possible - a stake in either irrigated farms or in niches with low drought chances (soils with high water retention capacity; marshy areas).
- the growing importance of cotton cultivation could be seen as part of a 'southern shift' of the cotton belt; and one of the consequences of climate change. What used to be 'normal' in southern Burkina Faso and Mali now becomes 'normal' in northern Ghana. However, it is too easy to see this as a straightforward 'proof' of climate change. The increasing activities of cotton factories in the area, the recent attention it gets from government agencies and in 'public opinion', and the better access to cotton inputs are all factors which can also be seen as important;
- many farmers have been trying to cultivate more land during the last decade; where possible (so not in Bongo and in the most densely populated parts of the Gambaga area) holdings have been expanding. This can be regarded as a response of farmers to higher risks, but it can also be seen as a move towards more commercial agriculture and a response to generally more favourable agricultural market conditions for Ghana after the economic crisis of the 1970s and '80s had ended.

12.5 WHAT ARE THE CHANGES IN COPING STRATEGIES WITH REGARD TO DROUGHT?

It can be observed that people are changing the composition of livelihood portfolios by relying more on non-agricultural sources of income, by adding more market-oriented agricultural activities (cotton, onions, tomatoes) and by changing their food production strategies to more drought-adapted varieties on the one hand and to less water-stressed fields on the other hand (where they produce vegetables and rice). Animal husbandry is changing as well, with relatively more emphasis on goats, pigs and fowls. Many old people told the researchers that they fear that the body of indigenous knowledge that enabled them to survive stress situations in the past (including the traditional institutions of land chiefs (*tindanas*), soothsayers, rainmakers and medicine men) is disappearing. "If nothing is done to re-discover this heritage", says Grandfather Akkare Adongo, "the next severe stress will find us all in our graves, for we cannot cope with it".

What will probably happen in case of (further) climate deterioration? If the temperature will increase with on average one or two degrees and rainfall will deteriorate with 20% the area will clearly become semi-arid (P/ETP < 0.45), with rainfall between 700 and 800 mm. A probably shorter and less reliable rainy season will result in an average drought risk situation between 2 and 3, with a higher chance of drought risk situations of 4 and 5. Depending on market price developments for animals, groundnuts, onions, tomatoes and cotton in the southern parts of Ghana it can be a possible strategy for farmers to rely less on autarchic food production at household level, and to try and diversify agricultural and non-agricultural risks. The southern move of the cotton belt could mean a major challenge, with secure marketing arrangements and price levels as an important prerequisite for gaining farmer's trust. With cotton and groundnuts as dryland crops in non-valley fields and rice, tomatoes and other vegetables in valley/riverine areas the area could be expected to move away from a strong reliance on the millet-sorghum-legumes complex. With more emphasis on higher-yielding, but drought-tolerant millet and sorghum varieties the most densely populated areas could be assisted in a necessary intensification process (higher average yields per hectare). The farming experiences and practices of the many immigrant farmers from Burkina Faso (who often are from the same ethnic macro-group of Mossi-related cultural backgrounds) can be trusted to show interesting possibilities.

12.6 HOW TO MITIGATE THE CLIMATE CHANGE RISKS?

It is evident that increased chances of low harvests from time to time will mean that more farm households will be confronted with inadequate cereals from their own fields to get them to the next harvest. Old traditions might be revived to try and store harvests from excess years and this means that areas where people still can expand their fields (within Upper East the areas in between the Voltas, and areas towards the west and south; and in Northern Region considerable areas in the Nasia and Volta valleys) should be supported in producing and storing more cereals. For the densely populated areas (like Bongo, Bawku, Gambaga) market-led forms of intensification might be a solution, supported by increased forms of irrigation (water dams) and water harvesting techniques. In these areas it is also obvious to us that agricultural depopulation should be encouraged. The natural increase of the population should be lowered, or it can be done by out-migration, more remittances and more non-farm income. It would probably be a wise decision to encourage more children to go to secondary schools, especially in the most densely populated areas, as a preparation for either out-migration or non-farm activities in the area itself. The recent approach to sell food aid instead of giving it out for free or as 'food for work' should be encouraged, with exception of arrangements for old and sick people. Traders perform key roles in a more commercially oriented food acquisition system and the infrastructure for trade should be safeguarded. Food aid arrangements can easily undermine existing systems of commercial exchange of food.

What research activities are most urgent to be better prepared for climate change? During the 1999 workshop in Bolgatanga the following suggestions were done for further studies related to climate change observation and mitigation:

- Is it indeed true that indicator species in the natural vegetation show that 'normal' species are disappearing and that more 'northern' (Burkina) species are becoming more important? What commercial/useful species of the zone 200-300 kilometres more to the north could be developed more rapidly in the Bolgatanga region?
- Is it true that hydrological features are having a lower quality than before (less water in the Volta and other rivers; seasonal rivers drying up more rapidly; groundwater tables going down; dams drying up)?
- How important is the influx of immigration from Burkina Faso and if engaged in farming, how do their farm practices differ from those of the indigenous population? Are farm practices of immigrants from the north more appropriate for drought conditions? Do immigrants from the north generally get lower quality land?

- If indeed micro-differences in terrain are so important for farmer's strategies it would be good to start in-depth research over a number of years in which a few farmers with diversified plots are being followed with regard to their actual land use practices, their harvests and the rainfall conditions.
- If farmers tend to drift to riverine and (ex-)marshy areas what does this mean in terms of crop risks (e.g. floods; crop diseases) and human health risks (water-borne diseases)?
- More research is needed to explain the differences in yields between farmers and to explain the seeming incompatibility of rainfall (drought risk) data and harvest data over years.
- Is it indeed true that 'wealthy' farmers are those who never experience food shortages using their own fields or is there a category of farmers on the increase who specialise in more lucrative commercial crops at the expense of autarchic food security at the farm level? How risky is this strategy in terms of food stability and income variability?
- It is important to find out if land tenure changes result in land use changes and changes in land management practices; do 'private owners' take more risks? Do they experience a higher yield variability between bad rainfall years and good rainfall years?
- Is it indeed true that the non-agricultural element in livelihood portfolios is increasing and that this is becoming an important element of food stability and food security at the household level?
- If it is true that migrant (remittance) income becomes more important, how important is labour migration for what types of households? Is the image correct of multi-location, intra-lineage assistance in dire times or could lineage network analysis indicate a more restrictive mutual support system?
- Is it true that state and NGO food aid kills initiative and severely threatens existing mutual assistance patterns?
- Is there a changing cost-benefit situation with regard to wood/charcoal versus other energy sources? What are the experiences of forest rehabilitation (e.g. in shrine and grove areas; on hillsides; on watersheds)?

The survey research revealed a number of issues, which should be covered in a more in-depth follow-up study, if that is going to take place:

- the role of sacred water bodies in environmental preservation; their role in biodiversity;
- the institutional structures and organisation to regulate water use during stress situations;
- the order of use of 'strategies' during stress and the order of loss as a result of stress;
- Regenerative efforts after one stress period to pre-empt losses afterwards;
- monitoring change e.g. the use of resource mapping to empirically ascertain change.

In general it is recommended to start monitoring studies (e.g. by using the same villages) to find easy early warning indicators of stress by combining efforts of the Ministry of Energy, Ministry of Food and Agriculture, Ministry of Lands and Forests, the Meteorological Service and strategic persons in the region.

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