Sahelian livelihoods on the rebound. A critical analysis of rainfall drought index and yields in Sahelian agriculture

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Chapter 7

SAHELIAN LIVELIHOODS ON THE REBOUND

A critical analysis of rainfall, drought index and yields in Sahelian agriculture

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Abstract: In this chapter an attempt is made to find statistical relations between rainfall, yield levels and the drought index. For the whole of the study region, average yield data was compared with average annual rainfall as derived from Meteorological services databases. Data from all available rainfall stations within such a study region was included to generate this simple average rainfall figure. Two drought indices were added to the analysis. No clear relation could be determined.

1. MODELS AND DATABASES

To test assumptions about a statistical relationship between rainfall and crop yields in a region like the Sahel and the usefulness of a 'drought risk assessment' approach (see Chapter 3 and 6) it is wise to consider the availability and reliability of rainfall and yield data and the level of scale which is regarded as most appropriate for this analysis. Originally, the regional (district) level was considered to be the level at which data would be available. However, data proved to be available at a lower level than previously thought, although the quality of this data was again limited because it had been collected for an entirely different purpose (most often the monitoring of national production by the Ministry of Agriculture of the respective countries).

For the whole of the study region, average yield data (as derived from secondary data sources such as regional, provincial or district Ministry of Agriculture statistical files and annexes) was compared with average annual rainfall as derived from Meteorological services databases. Data from all available rainfall stations within such a study region was included to generate this simple average rainfall figure.

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We also developed a Drought Index (DI). When combined, these methods of average and Drought Index together can be compared with that of the national Rainfall Index (RI) developed by Gommes and Petrassi (1994). The RI allows comparisons to be made between years and between countries. It is calculated for each country by taking a national annual precipitation average weighted according to the long-term precipitation averages of all the individual stations. Gommes and Petrassi demonstrate that the national RI correlates well with national crop yield levels in Africa.

The Drought Index as we used it (see Chapter 6) needs data on precipitation, temperature and potential evaporation and only weather stations that measure this data could be included in the analysis. However, since most weather stations do not gauge the last two variables on a year-to-year basis, it was decided to select those stations that have time series on monthly precipitation (P) and monthly averages on temperature (T) and potential evaporation (ETP). To allow for comparisons between data from different weather stations, the only stations selected were those with precipitation data for the period 1960-1997. ETP can be determined in three ways, each having its own advantages and limitations (Dietz et al 1998). To get a reasonable spread of weather stations over our study area, it was decided to include all stations that calculate ETP data, irrespective of the method used.

There are various advantages of the method used here as regards presenting rainfall and drought trends in the form of the RI or DI. The country-size or regional scale is designed to correlate with other country-wide and regional statistics, especially on agricultural production. The RI as used by Gommes and Petrassi is independent of absolute amounts of rainfall, which may be very localized. It allows general comparisons to be made regarding an entire country. Because of the long-term record, a frequency distribution of RI values is available which allows historical comparisons to be made. If the record is not complete for an individual station, the RI can still be calculated without that station. This allows a long-term RI record. There are also several disadvantages. Because the RI is weighted by annual rainfall, those stations in wetter areas of a country (which, by nature, are often the more agriculturally productive areas) have a greater influence on the RI than stations in drier areas. The simple annual average as used by us is not subject to this problem and the regional (provincial/ district) scale permits this if trends are correlated with agricultural data at the same scale. The DI can be regressed with higher-level data only and does not permit conclusions beyond the level of its analysis. Only part of the variability found at the lower levels is directly influenced by these higher-level variables. However, both the RI by Gommes and Petrassi and the DI as used by us may be less useful when examining overall drought conditions and the hydrological, environmental, and societal impacts resulting from it at any other level.

Similar problems are found in relation to agricultural production and productivity data. At the aggregate level these latter variables, however measured, may be representative of regional trends, but at the level of the farm or plot, it may be that only a minor portion of production and yield variability as experienced by the decision-making farmer is actually related to the rainfall situation of any particular season. All other variables, even those related to the actual DI used (soil moisture retention capacity, infiltration capacity and thus the determinants of the soil moisture storage factor in the DI), are actually determined at the much lower level of scale: the farm, plot or even part-of-plot level. At the plot and farm level, labour, technology, inputs and other non-climatic and economic variables play an important role in determining the soil moisture storage factor and this is methodologically difficult to include in the analysis as all these variables change over the years and most importantly within years due to the reaction of decision makers to the rainfall of any particular year. We might therefore find that millet and sorghum crop yields in dry years are better than in wet years simply because more attention is being paid to these crops in dry years (reseeding on different plots, more labour in weeding and soil moisture infiltration, etc) to the detriment of attention for crops that depend on relatively favourable rainfall patterns.

One way of finding out more about this problem of level of analysis and type of variable in relation to predictive value of the regression between rainfall regimes and production and yields is to carry out an analysis at a number of levels in the same region for the same period. We do this retrospectively in this chapter (using all the data collected in the framework of the ICCD study). Data from the three case study areas for which we have detailed information at more than one level (Ghana, Mali and Burkina Faso) are being used to answer the above question.

2. AN ANALYSIS OF RAINFALL AND YIELD DATA FOR NORTHERN GHANA, MALI AND BURKINA

In the three countries concerned, four regions were studied in depth, with the focus on the relationships between rainfall, the drought index and various other variables. In Ghana, the Bolgatanga region in the Northeast, and the Upper West Region in the Northwest were studied. Here, the analysis of rainfall and yields remained at regional level, without additional fieldwork veing carried out to collect data at village or household level as was the case in the other study countries. In Mali, data was collected at village level in the region of Koutiala and Sikasso, but the aggregate data has been used here to carry out a similar analysis as that carried out for the northern Ghana region. Finally, in Burkina Faso, the data was used that had been collected by the Ministry of Agriculture and Animal Resources (MARA/DSAP) in the Kaya region of Sanmatenga and Bam provinces.

2.1 Northern Ghana

Usually, analyses at the higher levels of regions and states are characterised by a substantial correlation between rainfall and production and productivity figures over time (Brons et al 1998). Various lower level sources of variability (individual, household and villages) even out and major trends are isolated and show a high degree of correlation. The fact that these higher-level correlations are so low in the case of Ghana is therefore rather surprising and forces us to think of alternative models for yield predictions.

The data is presented in Table 7.1 and is based on the ICCD report on the northern Ghana region of Bolgatanga (Dietz & Millar 1999) and on an M.A. thesis on Upper West Region (Van der Geest, 2002).

Table 7.1 Yield estimates and correlations with rainfall and DI, Bolgatanga, Ghana, 1987-1997

Kg/ha					**Average**	**Average**		
Year	**Millet**	**Sorghum**	**Groundnuts**	**Maize**	**Rice**	**Average**	**Rainfall**	**DI**
1987	562.4	639.1	1148	748	1052.1	873.98	983	0.7
1988	606.8	962.8	680.6	782	1235.8	873.98	936	0.9
1989	747.4	913	713.4	544	2004	942.72	1158	0.3
1990	518	763.6	606.8	748	668	716.86	808	1.7
1991	532.8	680.6	811.8	1300.5	1586.5	982	1050	1.7
1992	518	697.2	803.6	1003	1703.4	923.08	929	0.9
1993	1050.8	821.7	926.6	952	1636.6	1109.66	836	1.2
1994	747.4	713.8	852.8	850	2004	1001.64	1069	0.7
1995	1169.2	937.9	910.2	977.5	2404.8	1256.96	838	1.7
1996	1073	1203.5	787.2	901	2204.4	1227.5	976	2.6
1997	599.4	796.8	803.6	501.5	1803.6	864.16	864	2.5
Average	740	830	820	850	1670	982	949	1.4
Correlation								
Rainfall	-0.18	-0.03	0.02	-0.02	0.27	0.01		
DI	0.11	0.31	-0.16	0.19	0.16	0.12		
Corrected correlation (1989 deleted)								
rainfall	-0.24	-0.18	0.23	0.38	0.17	0.07		
DI	0.21	0.51	-0.42	0.02	0.33	0.12		

Note: The figures for 1989 were of doubtful quality and have been deleted in the second correlation analysis. Pearson’s correlation for rainfall and, Spearman’s for DI were used.

The correlation coefficients are not very high and none are significant apart from the correlation between rice yields and rainfall as a growth trend proxy. However, a number of conclusions can be drawn. First of all, the correlation between DI and crop yields is higher on average than between rainfall and crop yields. However, the low coefficients for rainfall and the high but positive coefficients for the DI are surprising. The coefficients were expected to be high and positive for rainfall (more rain means higher yields, ceteris paribus) and high and negative for the DI (higher DI means more risk of crop failure). Moreover, the correlation between DI and sorghum is higher than for any other crop, but again it is positive, which is particularly unexpected since the DI was designed to predict yields for this relatively drought-adaptive crop. In the case of groundnuts, maize and rice, the DI does not appear to be a good predictor at all. On the other hand, the correlation between rainfall figures and crop yields is extremely low and negative for millet and sorghum, and rather high and positive for groundnuts and for rice, which seems to imply that these crops are attracted by high rainfall conditions. This applies to rice as well, even if yield is independent of the soil moisture content over the growing season due to the use of irrigation. However, none of the coefficients is significant at the 0.01 level (nor the 0.05 level).

Another rather interesting finding is that the outliers in the analysis seem to be the result of mistakes in the dataset, as the yields for rice and millet are similar in both 1989 and 1994. As the data for sorghum for 1989 also seems to be too low for the rainfall of that year, it is assumed that the data for that year may be incorrect. Excluding these figures, the correlation coefficients are more extreme as is indicated in the lowest two lines of the above table. A clear negative relationship appears between groundnuts and maize (somewhat less pronounced) and the DI, and a high correlation appears between these crops and rainfall. This is what we would expect, so it seems that the rainfall and DI data can be used to predict crop yields of maize and groundnuts, although for maize the relationship seems not to be so robust as the coefficient shifts between the two correlation analyses. There is a positive and high correlation between rice and the DI in the second analysis. The result for millet and sorghum and their relationship to rainfall and DI is even more problematic now than in the earlier analysis. Not only are the signs the same, they are now more negative (rainfall) and positive (DI) than before. Clearly, if not for the non-significant character of the relationships, there may be some truth in the remark of an old farmer in Bongo, North-eastern Ghana that: ‘In a dry year there will be a good harvest. Formerly the young did not understand, but now they do.’ The question is: why would this be so?

In order to compare this data with another region in Ghana for which we have similar data, we now turn to the Upper West Region, where similar research was carried out within the framework of the ICCD project (Van der Geest 2002). The data is similar in structure and has been analysed in a similar manner. The results are shown in the following table.

Table 7.2 Yield estimates and correlations with rainfall and DI, Ghana, Upper West Region, 1986-1998.

Year	Millet	Sorghum	Groundnuts	Maize	Yams	Average*	Rainfall	DI
1986	700	700	1300	900	6000	900	865.4	2.67
1987	700	700	1500	700	5100	900	822	1
1988	800	700	1700	1500	5100	1175	850.1	1
1989	600	600	1600	800	5000	900	1065.2	0.75
1990	800	1000	300	1000	7200	775	731.7	3.5
1991	600	700	800	1300	12000	850	1101.2	3
1992	700	900	800	200	13500	650	845.4	1.25
1993	1000	1400	1600	500	13600	1125	1078.1	0.75
1994	1100	1400	1600	1400	10500	1375	1167.1	1
1995	1100	1300	1500	1400	11000	1325	1420.4	1
1996	1100	1300	1200	1100	10800	1175	996.5	3.25
1997	1100	1100	1400	1000	10100	1150	1063.5	1
1998	1000	1200	1400	1100	8500	1175	958.4	2.25
Average	869	1000	1285	992	9108	1037	997.31	1.7
Correlation								
Rainfall	0.49	0.49	0.42	0.39	0.44	0.64		
DI	-0.06	-0.04	-0.854**	0.17	0.1	-0.382**		

Notes
* Average of grain crops and groundnuts, excluding yams.
** significant at the .01 level.
Rainfall and DI data on the basis of four stations, yield estimates from the Ministry of Food and Agriculture.
Pearson's correlation was taken for the analysis of rainfall and Spearman's for DI

Again, there is only one statistically significant relationship, namely that between the DI and groundnut yields. All the other relationships are insignificant at the 0.01 level (though significant at the 0.1 level for millet, sorghum and maize). That is, the relationships are as expected (positive for rainfall-grain yields, negative for DI and grain yields) with the exception of maize and yams. The correlation between average grain yields taken as an aggregate and rainfall is high and significant. Interestingly, however, it appears that there is a steady growth of yields of the most important cereals over time, irrespective of rainfall or DI. If we take the year to be an indication of a trend, there is a high and significant correlation (r = 0.8 at the 0.01 level for both millet and sorghum). A similar relationship was found in the case of rice in the Bolgatanga region (r = 0.7 at the 0.05 level).

These results are less surprising than those obtained in the Bolgatanga region and suggest that the data quality in the Bolgatanga may be faulty, or that other variables are more dominant in this region.

These other variables do not induce a growth trend as there is only a positive and significant correlation between rice and such a trend in the Bolgatanga region, while in the Upper West region all drought crops (millet, sorghum and yams) show a clearly positive and significant correlation.

2.2 The regional level analysis in Mali

The analysis in Mali had a different point of departure, but for reasons of comparability we will first discuss the data at the regional level, before analysing the findings at village level.

Table 7.3 shows the data on yield estimates, rainfall and DI and the correlations at regional level for the Koutiala-Sikasso region in southern Mali.

This region of Koutiala-Sikasso is quite comparable to the northern Ghana region in terms of rainfall and DI levels and average grain yields. The correlation between rainfall and yields of the important cereals is between .67 and .87, which is reasonably high. One of the reasons may be that the data used for the analysis comes from a large area, covering a 200 km North to South zone. This forces the rainfall variable to the fore, while at the lower levels and in smaller areas rainfall is similar for most sites and other variables appear to be important. However, both cotton (coefficient of .21) and rice (with .11) have very low coefficients, indicating that for the region as a whole there is no clear relationship between rainfall and yields for these two crops. We will see later that, within this zone, rice and cotton production tends to be attracted by adequate rainfall conditions. All the correlations between grain crops (and groundnuts) and rainfall are highly significant (at the 0.01 level).

The same does not apply to the relationship between DI and crop yields. Unexpectedly, the correlations between DI and yields for the various products appear to be variable. In the case of groundnuts, it is high and negative as expected, but for the other products the coefficient is either low and negative (maize) or even positive (millet and sorghum). Rice shows a negative and relatively high coefficient, but cotton shows a positive and reasonably high coefficient, which is remarkable. None of the coefficients is significant at the 0.01 or 0.05 level. These findings again point to the inadequacy of the DI as a way of predicting the yields of dryland crops such as millet and sorghum at the level of the region. It implies that some serious thinking will have to be applied to the adaptation of the index if it is to be used in dryland research other than in the area where it was originally developed (in India).

Table 7.3 Yield estimates and correlations with rainfall and DI, Mali: Koutiala and Sikasso, 1984-1998.

Kg/ha Year	Millet	Sorghum	Maize	Groundnut	Cotton	Rice	Average rainfall	Average DI
1984	1047	1233	1328	715	1251	745	914	2.3
1985	1324	1093	1537	939	1240	905	1017	2
1986	1186	1017	1802	1120	1329	1183	1103	1.7
1987	879	953	1385	992	1307	1241	977	1
1988	1028	750	1309	832	1340	905	893	1
1989	889	852	1385	875	1184	1679	993	2.3
1990	1146	1030	1575	768	1352	964	989	3.5
1991	1087	979	1707	1024	1262	1562	1101	1
1992	622	712	1347	768	1095	1343	854	1
1993	543	623	1157	587	1240	1591	833	2
1994	771	674	1347	800	1095	1343	874	
1995	781	801	1556	854	1251	1372	958	
1996	988	1271	1897	1067	1117	1460	1128	1
1997	860		1674	653	1066	1256	934	1.9
1998	948		1812	759	1020	1340		
Average	940	922	1521	850	1210	1259	969	1.7
Correlation								
Rainfall	0.673**	0.703**	0.870**	0.852**	0.21	0.12		
DI	0.23	0.22	-0.18	-0.47	0.09	-0.16		

Note:
Rainfall estimates on the basis of nine stations, DI on the basis of the three stations for which the necessary detailed data are available.
** Significant at the 0.01 level
Pearson's correlation is used for rainfall, and Spearman's for DI

Comparing the analysis in Ghana and Mali, the conclusion may be that the data for Ghana (and especially the Bolgatanga region) is probably incorrect as the correlation coefficients are generally lower than in the case of Mali, while the level of analysis and the general size of this region (North-South) is comparable. The fact that in both cases there does not seem to be a proper relationship between positive rainfall and negative DI correlations indicates that the DI may be inappropriate. The Upper West Region data is between these two extremes.

2.2.1 The village-level analysis in Mali

The village-level analysis in Mali was based on an extensive database including variables related to land use, crop productivity, farm characteristics, village characteristics and economic and bio-physical external conditions (Brons *et al* 1999). The data was restructured to allow an analysis at village level. Principle Component Analysis was applied to reduce the dataset to an number of independent components that systematically reflected village characteristics. Subsequently, for a limited number of important cropping systems, multiple regression analysis was applied. We will follow this route to arrive at an analysis of one of the most important cropping systems in the discussion on rainfall-yield relationships.

The result of the PCA is a reduction for 43 villages of 26 variables into 7 main components or factors (Brons et al 1999: 19-20). The cumulative percentage of the explained variance is 76 percent. The components can be described as follows:

Commercial grain production

This factor is characterised by a substantial village area of diversified grain production for commercial purposes (rice but also maize, millet and sorghum) which generates high gross margins and revenues. Moreover, the joint high yield levels of groundnut points to some diversification taking place into the production of leguminous crops and the positive effects of generally high input levels. It should be noted that this strategy can only be followed when rainfall risks (e.g. low rainfall but also high variability) are limited or controllable.

Commercial cotton production

This factor indicates that high investments for input purchases in commercial cotton production generate a surplus that can be used to satisfy consumption expenditures. Specialisation in cotton production is mainly feasible due to favourable agro-climatic conditions (high rainfall and low rainfall variability) that enable substantial investments for input use.

Livestock farmers

Villages where farmers possess relatively high amounts of cattle and oxen can be found in the Northern region (where livestock production has a comparative advantage) and in the cotton areas, which are characterised by relatively favourable land endowments. Investments in cattle purchases here are usually financed from (earlier) cotton revenues. Inputs for livestock production are limited and returns per hectare are low. Part of the livestock production is located close to villages and specialises in dairy products. The population in these villages relies on commercial purchases of grains to satisfy food security and is very successful in this respect. These villages are not significantly affected by soil degradation. This can be understood from the recent understanding that pastoral and livestock production as a system may be better adapted to local ecological restrictions and a high market involvement than was previously understood.

Commercial rice production

Villages that diversify into rice cultivation and specialise as far as grain production is concerned are strongly dependent on stable rainfall patterns. Rice was introduced originally as a major diversification crop and initial investments are financed out of cotton revenues, which are relatively high per area unit. In the medium term, the farming systems become more dependent on rice as a major crop and this leads to a new type of specialisation at village level. Commercial rice production is mainly selected by farmers with limited land resources; those who are able to exploit a labour-intensive cropping system albeit with low labour productivity. This is once again a reminder of the favourable relationship between market involvement and food security considerations, which depends on a specific set of variables, such as distance to markets, to function.

Extensive grain production

Villages that offer large areas per person may still rely on extensive grain production for food self-sufficiency. The availability of oxen facilitates the required land preparation and weeding activities for an extension of the cultivated area. Reliance on extensive grains production mainly occurs in villages with low, but stable, rainfall patterns. This system guarantees high net revenues (low external input costs) and adequate food security levels. Apparently, the high income levels encourage activities in the non-agricultural sector (as a relationship vice versa could not be established). This is the component with the highest score on the number of non-agricultural activities per 1000 habitants.

Sustainable subsistence farming

This component is not represented by a significant factor score in any of the agricultural indicators or rather, it us the only component which scores high on indicators of what it may not be: it is not degraded, nor close to services, the latter pointing to less favourable socio-economic conditions. With little agricultural development, low land use intensity and a favourable state of the natural resource conditions compared to the other components, it is a component which seems characteristic of an early stage of agricultural development in the region, now only found in remote areas.

Marginal subsistence farming

In the less developed villages where there are relatively few farms equipped with oxen traction and little non-agricultural activity, farmers maintain diversified farming systems without this having any particular implications for yield levels. These farmers have a small number of livestock and often only incomplete equipment. Due to the considerable distance to the cities, off-farm employment options are equally limited. Low levels of education and health also inhibit participation in the labour market. The combined effect of the features in this component is a regular occurrence of food shortage. This component compares unfavourably with the former in that the food security situation is rather bad.

We will present an analysis and estimate the importance of the various inputs and conditions including rainfall in agriculture at village level. A limited number of cropping systems are particularly relevant here. An analysis of all crops and the determining variables of productivity is relevant to all components and in particular the dominant systems of commercial grain production, commercial cotton production, livestock farming, commercial rice production and extensive grain production. The grain producing cropping systems, whether commercial or otherwise, will be analysed separately, as well as the cropping system for maize, which is the only grain for which correlations at the expected level and sign were found in the regional analyses in Ghana and Mali (and Burkina Faso as we will see). We will present a limited number of production functions: gross revenue per ha is estimated for all crops taken together (all the above components), for grain production and for maize. Table 7.4 shows the result.

This analysis shows that, in the complete model, for all cropping systems identified earlier as components, rainfall does not appear as a significant variable that can explain revenues. Instead, inputs in terms of human labour and animal traction are the determinant. Rain does play a role as regards the grain-production based components, but the labour inputs are again important, as are the soil characteristics. This illustrates the labour-intensive character of grain production in this area, while the appearance of the degradation variable and soil characteristics in general may be interpreted as the expression of a process of soil mining taking place during intensive grain production in the absence of adequate input levels. For the maize cropping system in particular, total area cultivated and again the inputs in terms of animal traction and expenditure on fertilisers appear as significant variables. The reduced model shows that rainfall is a significant variable at the level of all cropping systems and for grain-based production in general. This does apply so much to the maize production-based cropping system. Maize, and cereal-based cropping system revenues are generally influenced by input levels (labour, expenses) and soil characteristics.

The relatively lower r-squares show that at the level of the villages studied, the explanatory power of the models is lower than the simple models at the regional levels of Ghana, Mali and Burkina Faso, and even lower than the r-square value of a similar production functions for the study region in Burkina Faso, as we will show. For all cropping systems together, rainfall does appear to be the most important variable in explaining variability in revenues.

Table 7.4 Gross revenue per ha, Cobb-Douglas production functions, complete and reduced model.

Complete model	**All crops**			**Grain**			**Maize**		
	Coef.	*t-value*	*Sign.*	*Coef.*	*t-value*	*Sign.*	*Coef.*	*t-value*	*Sign.*
Intercept	-2.75	1.23		3.85	1.35		1.06	0.35	**
Total Area	0.08	0.83		0	0.04		0.12	0.9	**
Rainfall 1997	0.66	2.18		0.35	1.7	**	0.29	0.7	
Persons per ha #	0.27	1.66	*	0.48	2.37	**	0.51	2.34	
Oxen per ha #	0.41	2.54	**	0.67	1.74	**	0.46	2.07	*
Expenses per ha	0.02	0.14		-0.05	0.32		0	0	**
Degradation index	0.07	1.48		0.12	2.16	**	0.09	1.51	
Clay dummy	0.18	1.52		0.36	2.33	**	0.47	2.87	
Sand dummy	0.19	1.69		0.24	1.62		0.31	2.02	
Distance education	0.02	1.42		0.01	0.86		0.02	1.2	
Drought index 1997	0.01	0.07		0.05	0.53		0.07	0.73	
Adjusted r-square	0.47			0.31			0.29		
Reduced model									
Intercept				5.42	2.41	**			
Rainfall 1997	0.72	3.26	***	0.54	1.85	**			
Persons per ha				0.44	2.28	**	0.5	2.44	**
Oxen per ha	0.37	2.36	**				0.41	1.87	**
Expenses per ha	0.06	1.74	**				0.1	2.13	**
Clay dummy				0.1	1.84	**	0.4	2.51	**
Sand dummy				0.21	1.69	*	0.25	1.69	**
Adjusted r-square	0.47			0.29			0.34		

Notes: Rainfall based on May-October figures (94 percent of total). Clay and sand dummies as opposed to gravely soil. Significance levels are one-tailed.

In all cases, except for maize, rainfall is an important determinant of crop yields and revenues, but sufficient rainfall is most important for farmers specialising in commercially oriented (grain) strategies. Access to external inputs has the greatest influence on aggregated gross revenues and on maize yields, while animal traction is especially important for maize production. Access to land is hardly ever a constraining factor, but access to sufficient labour is the most relevant factor for both commercial and subsistence cereal production.

2.3 The household level analysis in Burkina Faso

The analysis in Burkina Faso was founded on a comparative basis of datasets from two different periods and analysed the relationship between climate and other variables with production, productivity and land use change at household level. Again, for reasons of comparability we will first discuss the data at regional level and continue afterwards with an analysis of the findings at household level.

The following table presents data on yield estimates, rainfall and DI and correlations at this regional level.

Table 7.5 Yield estimates and correlations with rainfall and DI, Burkina Faso, 1984-1998.

Kg/ha			**Average**	**Average**				
Year	**Millet**	**Sorghum**	**Maize**	**Groundnut**	**Cotton**	**Rice**	**rainfall**	**DI**
1984	407	376	109	396	377	2036	490	2.7
1985	533	514	715	505	191	2068	459	3.3
1986	529	618	617	618	568	1437	518	2.7
1987	300	328	153	357	388	1882	451	1.7
1988	776	704	1445	818	534	921	724	2
1989	376	474	617	985	777	1613	603	3.3
1990	428	498	1048	706		197	503	3
1991	639	841	595	453		255	712	3.3
1992	495	765	1055	1398		255	650	2
1993	608	851	1003	880	957	1918	564	2.3
1994		689	794	801	187		943	1
1995	546	709	890	703	431		648	3.3
1996	495	629	1048	1000	500		613	2
1997	288	381	210	308	236	431	554	2
Average	494	598	736	709	468	1183	602	2.5
Correlation								
Rainfall	0.69	0.68	0.39	0.32	-0.05	-0.53		
DI	0.16	0.03	-0.03	-0.15	0.26	0.06		
Correlation on the basis of the period 1968-1997								
Rainfall	0.614**	0.558**	0.33	0.1	-0.13	0.14		
DI	-0.13	-0.17	-0.05	0.08	0.04	-0.09		

Notes:

Rainfall figures are derived from the nine stations within the study region.
DI figures are based on figures for Kaya, Ouahigouya and Tougouri stations.
Yields are based on data for Sanmatenga Province in which much of the Kaya region is located.
Empty cells have no data.
** significant at the 0.01 level

As in the earlier cases, there are variations across the various crops as to the correlation between rainfall and yields, with millet and sorghum having high, positive and significant coefficients between rainfall and crop yields, and low and positive (though insignificant) coefficients between DI and yields. This is similar to what was found in Mali and at this level, the level for which it was designed, it seems that the DI is not behaving what as expected. Correlations between rice yields and rainfall and DI rice are quite similar to that found in Mali. The fact that yield levels fluctuate enormously is reason for care.

As far as other crops are concerned, it can also be said that higher rainfall levels do not always mean higher yields. We plotted the data for groundnuts and it appears that the relationship between rainfall and yields for this crop has become ever more negative in the course of the last few decades. The following plot shows the result.

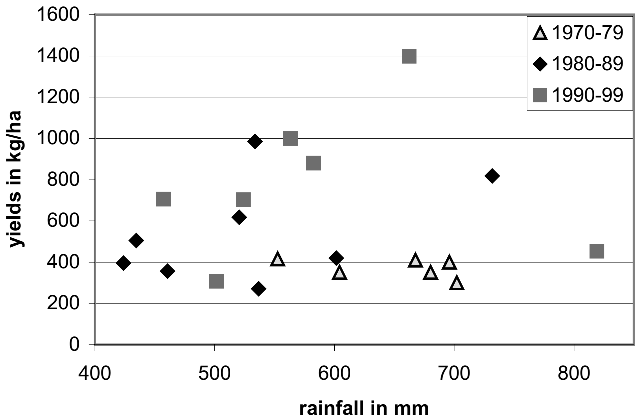

Figure 7.1. Relationship between rainfall in mm and groundnut yields in kg per ha, per decade, 1970-1999 *(See colour section, p. 461).*

The relationship changes in the course of time, indicating there is an intervening variable hidden in the dataset as presented in table 7.6. It may be caused by the selection of new varieties of groundnuts in response to favourable rainfall and high input levels. The lowest yields, occurring at low rainfall levels, are not below the level of the earlier varieties, while the highest yields occur with average rainfall levels and are very much above the highest yields achieved before. It may also be the case that we see the effect of adaptation to these average rainfall levels, with low yields when rainfall levels are very low and moisture is short, and high rainfall levels when damage through disease and waterlogging or flooding occurs. The graph also shows the resilience of the earlier system where yields of around 400 kg per hectare where achieved regardless of the rainfall level.

Table 7.6 Changing relationships over time between rainfall and groundnut yields

Period	Slope of the linear regression coefficient
1970 - 1979	-0.32
1980 - 1989	1.09
1990 - 1999	0.15

2.3.1 The household level analysis in Burkina Faso

For the household level analysis of yields and its independent variables, a dataset was used for the period 1993 to 1998, as collected by the monitoring and data collection service of the Ministry of Agriculture and Livestock Resources (MARA/DSAP), the Enquête Nationale sur l'Agriculture (ENSA) (Brons et al, 2000). This dataset was collected at household and plot level and is much more detailed though with a certain bias towards the purpose of its collection.

The following production function shows the result for the analysis of yields in kg/ha of millet and sorghum (as first crop). Information on the database and the regions are presented in Brons *et al.* (2000).

Table 7.7 Yields of millet and sorghum in kg per ha, Cobb-Douglas production functions, per region.

Complete model	**South**			**Centre**			**North**		
	Coeff.	*t-value*	*Sign.*	*Coeff.*	*t-value*	*Sign.*	*Coeff.*	*t-value*	*Sign.*
Area	1.07	13.7	***	1.17	14.7	***	1.23	18.4	***
Labour	0	0.1		-0.12	1.5		-0.16	2.4	***
Fertiliser	0.03	2.7	***	0.01	2.1	**	0.02	2	**
Rainfall	-0.1	0.3		0.06	0.3		0.39	2.9	***
Dummies									
Intercept	-3.19	1.7	*	-4.07	2.9	***	-6.54	7.5	***
Manure	0.1	2.2	**	0.11	2.6	***	0.01	0.3	
Manual soil preparation	-0.06	0.6		0.04	0.4		0.23	2.2	**
Animal soil preparation	0.07	0.9		0	0		-0.06	1.1	
Erosion control	-0.01	0.2		0.07	1.6		0.01	0.1	
Household plot	0.49	4.7	***	0.29	2.5	*	-0.11	0.7	
Cowpea intercrop	-0.02	0.3		-0.02	0.3		0.37	0.6	
Other intercrop	-0.1	0.9		-0.11	1.6		-0.04	0.5	
Plain	-0.1	1.5		-0.07	1.3		-0.05	0.9	
Slope	-0.15	1.8	*	-0.28	3.7	***	-0.12	1	
Near village	0.13	3	***	0.07	1.5		0.72	1.6	
Sorghum	0.16	3.9	***	0.15	3.9	***	0.09	2.1	**
Adjusted r-square	0.79			0.78			0.79		

Note:

The dummies are defined as opposed to no application of the relevant variable, except for Household plot (versus individually owned plot), Plain (versus basin-located plot), Slope (idem), Near village (versus at a distance) and Sorghum (versus Millet).

Household characteristics other than labour were insignificant and were left out of the model. Other variables at plot level are available but the data quality is limited and dummies were included to capture at least some of the explanatory power of these variables at this level.

The marginal productivity of land is the single most important and most significant variable in the model, with fertiliser application coming second. Labour appears only as a significant variable in the North, but with a negative sign. Probably, other and unobserved household characteristics are influential in explaining output variability from the labour coefficient. Rainfall appears only as a significant variable in the most northerly zone of the study while in the other zones it is not significantly different from zero.

The dummies show that the southern and central zones have quite similar significant scores on the dummy variables, with manure application and variables indicating access (both in terms of ownership and spatially) being important as well. Slope as opposed to basin location of fields is significant in these two zones as well, with the expected sign. Soil preparation in the north is a significant variable.

In conclusion one could say that at household level the area and fertiliser use are the most important factors in explaining yield differences, with rainfall being important and significant in the North only. Of the dummies at plot level, variables pertaining to access to land and manure (south and central) and manual soil preparation are significant and of the expected sign, though the coefficients are not always very high.

3. CONCLUSIONS FROM THE CASE STUDIES

It remained unclear for a long time why there should be no negative relationship between millet and sorghum and the DI in some cases. Together with the evidence from Mali and Ghana, we can now say that the DI, though developed for dryland regions and dryland crops, does not seem to predict yield levels very well. Also, it is now questionable whether the data on the Ghana Bolgatanga area is correct, when compared with a similar analysis (at the similar level of the region) in another region of Ghana and in two other countries. The DI coefficients for the other crops in Ghana are also not very high and often have the wrong sign. The data and findings at regional level for Mali are more comparable with those of Burkina Faso, with the exception of rice and cotton perhaps. For the Sahelian-Soudanian region as a whole there is no clear relationship between rainfall and yields for the two cash crops of rice and cotton. Within this zone, rice and cotton production tends to be an attractive option in the event of adequate rainfall conditions. This indicated that though the production and yields of these cash crops is insensitive to actual annual rainfall, it still needs higher average rainfall, harnessed through soil and water management. In areas where cultivation takes place in lower lying areas (the bas fonds), the highest rainfall levels cause damage and the crop is then more affected by flooding than by drought. Despite all this, the average rainfall remains a better and more significant predictor of yields, particularly of the dryland crops of millet and sorghum, than the DI.

Still, there are a number of remarkable explanations for some of the low correlations. The example of groundnut yields in Burkina Faso shows that the data, when split in decades, shows that considerable yield increases can be expected for rainfall levels around the average, either as a result of a process of adaptation of crops to the rainfall regimes, or as a result of soil selection for this crop and the addition of other inputs such as fertiliser, manure or labour.

The two Cobb-Douglas production functions, though different in implementation, can be compared when we look at the results for grains in the case of Mali, and Burkina Faso.