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QUANTIFYING THE CARRYING CAPACITY OF LAND IN A DEGRADING ENVIRONMENT

The case of selected villages in three agro-ecological zones of West Africa.

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Contents

1. Context

Though the human-induced degradation of natural resources in the semi-arid regions of West Africa has been subject to several studies, the impact of this degradation on the change of well-being of- and decision taking by the land-users is hardly known. Van Haaften and Vijver (1996) showed that the well-being (psychological carrying capacity; ccp.) of present land users appears to be relatively higher in assumed more degraded regions but that a high recent rate of land degradation appears to lead to decline of the ccp. Decline of ccp. was associated with more stress and marginalization, with all imaginable consequences at familial, regional- and global level.

The following aims to verify the above by means of longitudinal study. Indicators of ccp. were gathered in 31 villages in West Africa and stratified as a function of agro-ecological zoning. Indicators for (the rates of) land degradation will be assessed and empirically related with ccp.

2. Land degradation

Objective

Quantification of the rates of change of indicators of land degradation, carrying capacity being one of the indicators, in order to relate with indicators of human well being for selected villages in West Africa

Abstract

The potential biophysical carrying capacity of land (ccl.) indicates the level of production at which yearly supply of food and income is balanced with the yearly demand. Land degradation endangers this balance and the psychological carrying capacity (ccp.). A framework is brought into development that allows to consistently analyze relevant (f)actors in their order of significance to relate land degradation and ccp., applicable at various levels of scale and data availability. Geographic localization of the villages of interview allowed for the characterization of so-called Village Systems (VS's), aggregations of Land Use Systems, composed of land and land use. Not localized villages were grouped into regional VS's. Land qualities were subject to change as defined by four processes of land degradation, namely climatic change, erosion, loss of vegetative cover and nutrient depletion. Matching the changing land qualities with constant land use requirements (an extensively managed sorghum crop for all VS's) allowed for the simulation of the change of productivity. Defining a constant demand equal to the productivity of the last year of simulation (storage = zero) allowed to calculate the accumulation of a virtual storage during the preceding years (ccl.). The slopes of accumulation (or decline) were scored for each VS to be correlated with ccp. Similarly, the rates of the underlying processes of land degradation were scored to be correlated with ccp. In the southern region, the ccl. declined continuously from 1960 till the last year of simulation while in the northern region the ccl. declined till 1979/1980 and then increased again. The performance of this framework can be improved by substituting the present visual approach of analysis of available geo-information by a more appropriate approach of analysis of geo-information.

2.1. Introduction

In the case of the Sahel, it has been argued by Kessler and Breman (1995) that several of the ecological processes leading to impoverishment and social desintegration are not primarily induced by overexploitation and land degradation, but rather result from the vagaries of insecure rainfall patterns. Whether this lemma holds depends on the time frame defined as the vagaries are incidental and as such unlikely to uphold processes. In the case of West Africa the zones with insecure rainfall patterns correspond with zones of overexploitation and land degradation. In comparison to the Sahelian and Sudanian zone (in this study corresponding with the Dogon and Zoundweogo area respectively), is the in between fringe (Sanmatenga) both subject to the severest soil degradation (UNEP / ISRIC, 1990) and the highest population pressure in 1980 in comparison to the population carrying capacity (world bank, 1987). Van Haaften and van de Vijver (1996) showed that psychological carrying capacity (ccp.) generally was highest in strongly degraded areas. Recent strong land degradation led to a marked decline in ccp. Evidently, the ccp. is reduced where supply fails to meet demand. Not surprisingly the areas with these highest rates of degradation corresponded with areas with highest population growth. De Graaff (1997) extrapolated figures, generated by Kessler (1994) and based on Breman (1992), which indicate annual population growth in Sanmatenga and Zoundweogo lesser and higher (1.8% and 2.2%) than the annual population growth of Burkina Faso which was 2% from 1960 to 1985 according to Pieri (1989), referring to the world bank. In order to separate the impact of the rate of increase population pressure from the rate of decrease of population carrying capacity due to land degradation, is focused on land degradation. Kessler and Breman (1995) state that the human dimensions of land degradation appear to be closely related with the biophysical carrying capacity of the land and hence with deterioration of land-use conditions.

Referring to the framework for land evaluation (1976), aspects of land are soil, physiography, vegetation, hydrology, weather etc. Land degradation implies processes of change of one or more of these aspects. Unless time frame or scale referenced, the description of processes of change is futile as contended by Fresco and Kroonenberg (1992).

Besides the impact of possibly declining reserves on ccp. is it questioned whether the degradation of the environment is consciously experienced by land users and whether it has impact on the ccp. Soils which are degraded with surfaces generally sealed and without vegetation cover are known as such by Mossi agriculturists by the name of Zipélé and as Kollangol by the Peulh pastoralists.

2.2. Methodology

Concepts, processes and methods of assessment of land degradation in the Sahel are summarized by Mulder and Wiersum (1995). Three basic approaches of assessment were mentioned, namely based on 'universal criteria', 'variable criteria' and 'indigenous perception'. The following exclusively refers to the 'universal criteria' approach. This approach allows statistical interpretation by means of the Multiple Indicators / Multiple Causes model.

'Independent' processes of land degradation were defined and quantified and, as a dependent variable, the rates of change of carrying capacity were simulated and scored for each Village System. The availability of required data were inventoried at various scales. Only a limited amount of data was treated because of the reconnaissance nature of this study combined with the actual unavailability of some required data at the moment of start of analysis.

First, reference VS's, not subject to land degradation, were defined.

2.2.1. <u>Definition of Village Systems</u>

Six villages could be geographically located. The remaining villages of psychological research could be grouped together into five distinguished regions. The total of distinguished VS's was eleven. At the moment of reporting an arc-info coverage with village locations for Burkina Faso became available, which will be used for more diversified analysis.

A Village System (VS) is defined as the aggregation of spatially diversified land use systems (combinations of land and land use), analogue to Farming Systems as defined by Driessen and Konijn (1992) and unified to 1 ha.

Land use was defined in terms of crop and management. It was assumed that the simulation of just one crop reflects the impact of land degradation similarly for agriculturists and pastoralists. Identified crop for all VS's was a sorghum variety with characteristics as defined by Driessen et al. (1997) and as annexed. Management characteristics were defined invariable in time and space, with exception of sowing date which varied as a function of climatic zonation (space) and yearly simulated soil humidity. (See annex). A land use intensity of 100% was assumed.
In fact, better data on land cover were available but not processed (IGBP / LUCC program; Africa Land Cover Data Base with a resolution of 1*1 km^2). Processing would have led to a better distinction between the impact of land degradation on agriculture and on pasture, especially if one assumes that population growth figures reflect the speed at which the cultivated area expands and fallow periods shorten.

Land was defined in terms of weather and soil. Weather data were derived from the synoptic stations of Dori and Ouagadougou, representative for respectively the Dogon and Zoundweogo areas. The Sanmatenga area is represented by simple interpolation. Data till 1992 of nearby located rainfall stations are available in a monthly format provided by FAO but interpretation would require daily weather generation which was reasoned to be not worthwhile in the context of the present study. Used were series of 33 years (1960-1992) of daily figures. At present, the meteorological service of Burkina Faso is preparing the data for 1993-1997.

Soil types were distinguished on the basis of visual interpretation of the digitized soil map of the world (FAO/UNESCO, 1991), having a resolution of about 9*9 km^2 at the considered latitudes and indicating the relative frequency of occurrence of major and minor soil types per map unit.
Because the associated attributes were not available, the distinguished soil types were interpreted and characterized as follows.

- hydrologic characteristics associated with texture classes as suggested by Driessen and Konijn (1991).

- suggested soil surface water infiltration characteristics referred to daily dynamics and were verified and adapted when necessary with data from Hoogmoed and Stroosnijder (1996), Penning de Vries and Djitèye (1991) and Valentin and Casenova (1989).
- soil depths and surface water storage capacities were derived from the thumb
- soil fertility characteristics adopted from Leenaars (1993).

For VS's in Sanmatenga, soil type differentiation was derived from tabulated frequencies of local soil types per geomorphologic unit per geologic stratum (Nébié et.al. 1995) and translated to FAO soil types (Driessen et.al. 1997). The frequencies of occurrence of the geomorphologic units per located village were derived from TM-images of 1986 of Sanmatenga (van Asten and van de Pol, 1996). For located villages in Zoundweogo, the tabulated frequencies of geomorphologic units per geologic stratum were assumed to substitute the frequencies as derived from the FAO/UNESCO soil map (annex 2)

Frequencies of occurrence of sealed soil surfaces per VS (in 1986) were derived on the above mentioned basis. For the Dogon area, sealing occurrence was assumed to equal the occurrence in the Ante-Birrimian geologic stratum.

Table: VS specific soil distribution

	Dogon	Sanmatenga					Zoundweogo		
			Kaya	Tagalla	Kiemna	Kondiboto		Kaibo	Barce
Arenosols	47,5	12,5	0	0	25	10	5	0	10
Rego- & Lithosols	30	30	27,5	45	5	20	20	30	15
Lixisols	0	25	27,5	5	50	50	30	10	45
Cambisols	12,5	17,5	30	30	5	15	30	40	20
Sealed soils	10	15	15	20	15	5	15	20	10
	100	100	100	100	100	100	100	100	100

2.2.2. <u>Definition and numeric scores of land degradation</u>

Land degradation refers to several processes which can be characterized by different degrees, stages and rates (Mulders and Wiersum, 1995). Processes identified as significant in the West African context were climatic change, erosion, loss of vegetation and nutrient depletion.

2.2.2.1. Climatic change

Whether the change of weather must be considered as a process of land degradation is disputable. At different temporal scales, weather fluctuates. Illustrative are the next two graphs on paleo-weather change since the late pleistocene and weather change since 1950.

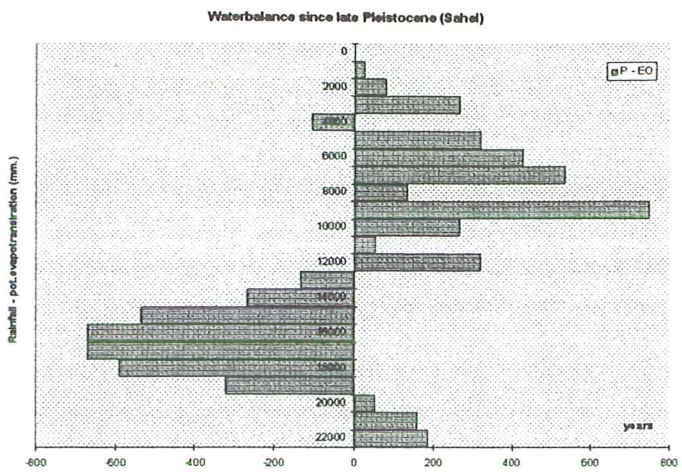

Fig. 1. Paleo-climatic water balances, relative to the present water balance in the South Sahelian zone (yearly rainfall = 550 mm. & yearly potential evapo-transpiration = 2200 mm.) as interpreted from Servant (1973)).

According to Lockwood (1988), the in fig.1 illustrated cyclic changes of climate are probably due to the Milankovitch mechanism of earth orbital changes. During this century CO2 concentrations increase with an annual rate of about 0,5 to 1,5 ppm, suggested to be associated with higher humidity and a rise of temperature of 1,5 to 4,5 °C when CO2 concentrations would be doubled. In the tropics however no clear evidence is found for this latter suggestion. Climatic anomalies associated with the so-called Southern Oscillation events however are reported to be highly persistent. Marine temperatures fluctuate with about 0,6 °C with the coldest (and driest) period centered around 1905-1910 and the warmest (and wettest) in the 1940's. A full cycle takes about 65-75 years what corresponds with the pattern illustrated in fig. 2. If so, one could expect a tendency of increasing humidity until a peak somewhere around 2025. It is a function of the (human induced) resilience of the Land Use Systems whether net tendency during a full cycle will be negative or positive. 2015-2025

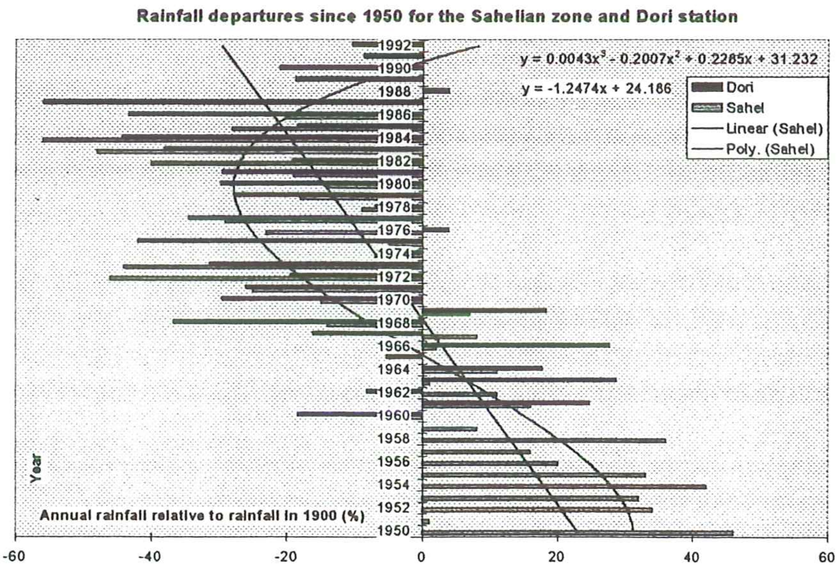

Fig. 2. Rainfall departures since 1950 for the Sahelian zone (Tucker et.al 1991) and Dori station, relative to the rainfall in 1900 (%)

The change of weather and the impact of change of weather were assessed by analysis of sets of 33 consecutive years of daily data of the synoptic stations of Dori and Ouagadougou. Scored were the slopes of change of averaged maximum temperature, of averaged seasonal rainfall, averaged seasonal water balances (rainfall minus potential evapotranspiration) and the averaged yearly number of rainy days as well as the slopes of change of water limited potential carrying capacity. Illustrative for the latter is fig. 3, which suggests that the decline of the productivity capacity due to climatic change started early in the Sahelian zone and then stabilized while the decline in the Soudanian zone started more recently.

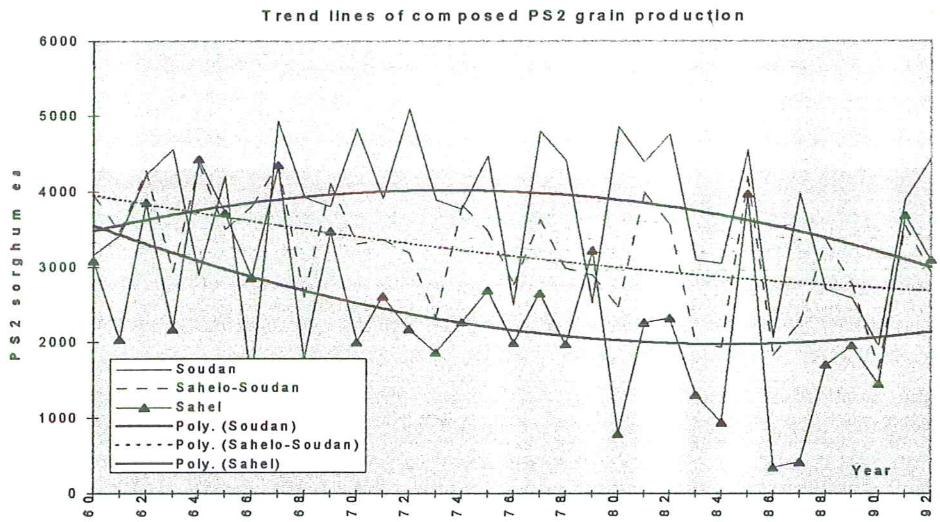

Fig. 3. Trends of composed simulated water limited productivity per climatic zone.

2.2.2.2. Rate of erosion

Soil erosion and soil formation alternate as a function of the above described alternation of climatic circumstances. In the meanwhile, the altitude of the uplands decreases. P.e. in the context of the Sanmatenga area, relicts of former drainage lines are present in the form of indurated plateaux at various altitudes. The most common plateaux are located at about 30 to 60 m. above the present drainage lines and are thought to be indurated during the late Pleistocene (Würm), some 15.000 years ago. This would imply an erosive rate of some 2 to 4 mm. of soil loss per year. Estimating the sub-boreal induration (some 4000 years b.p.) located some 5 to 20 m. above the present day bas-glacis, an erosive rate of some 1 to 5 mm. per year would be concluded.

In the present study VS specific yearly erosion is made a function of daily run-off, determined by daily rainfall, soil surface water infiltration capacity (per hour) and soil surface water storage capacity. Simulated (growth of) vegetative cover fraction (0-1) was related with a daily infiltration capacity of 0 to 100% of the defined infiltration capacity.

Refering to Hoogmoed and Stroosnijder (1995), Casenave and Valentin (1989) and Stoorvogel and Smaling (1990), run-off varies between some 10 to 70 % of the rainfall. Yearly soil loss is estimated to be some 5 to 20 tons / ha. Deducted was an average erosivity of some 0,005 cm soil per cm run-off (which corresponds roughly with some 1 mm. per year). This erosivity was applied, irrespective of toposequential position.

Only in the group of regosols and lithosols, the loss of soil depth due to erosion had effect on simulated productivity.

2.2.2.3. Loss of vegetation cover.

Eolian activities during Würm led to the formation of dunes with sands originating in dry river bassins. The more lighter fractions (silt) reached further southwards and the main concentrations were deposited along the footslopes of hilly areas and plateaux. This eolian deposition still goes on. Footslopes are prone to water erosion and surface water runoff transports the eolian materials down slope where they cover entire tracts of lowland soils. Due to their texture, these materials are very sensible to crust formation what results in a rapid decline of infiltration capacity of increasing tracts of lowland soils. Aerial photo interpretation (Leenaars, 1996) clearly confirms the above process. These tracts of erosion and deposition are nearly without any vegetation cover and locally known as Zipélé (in Moré) and Kollangol (in Fullani). Once spots of sealed 'impermeable' soils start to interconnect, erosion accelerates rapidly.

The degree of soil surface sealing for the Sanmatenga area was derived from tabulated occurrences of Zipélé per geologic stratum (Nébié et.al. 1995). Similar values were assumed for the two geologic strata in Zoundweogo. Occurrence in the Dogon was assumed to be equal to the occurrence in the Antebirrimian stratum. For located villages the occurrence of Zipélé's was estimated by means of TM images of 1986. The degrees were assumed to be 0% in 1960 and the rate of loss of vegetation cover and soil surface sealing from 1960 to 1992 was simply assessed by linear interpolation. Subsequently, soil type distribution per VS per year was adapted.

Reference sorptivity and water transmission rate values were derived from data as published by Hoogmoed and Stroosnijder (1995).

2.2.2.4. Nutrient depletion

Pieri (1989) suggests a yearly net mineralization rate of soil organic matter of 1% under cultivation and of 2% when labored. The yearly rate of 1% of nutrient depletion was assumed for all situations. Different nutrient contents were defined for the different soil types. Of coarse, the value of 1% nutrient depletion should be corrected for the (changing) cropping index (period of cultivation versus period of fallow).
The yearly nutrient limited production was simply calculated by assuming a nitrogen recovery fraction of 50% for all situations and all years and multiplying the nitrogen sufficiency factor (relative to water limited requirements) with the simulated water limited production.
Nutrient limited simulated grain yields appeared to correspond rather well with realistic yields. The frequency that the simulated production became water limited differed as a function of soil type and weather station. Figure 4 illustrates the performance of sorghum on lixisols in the Sahel.

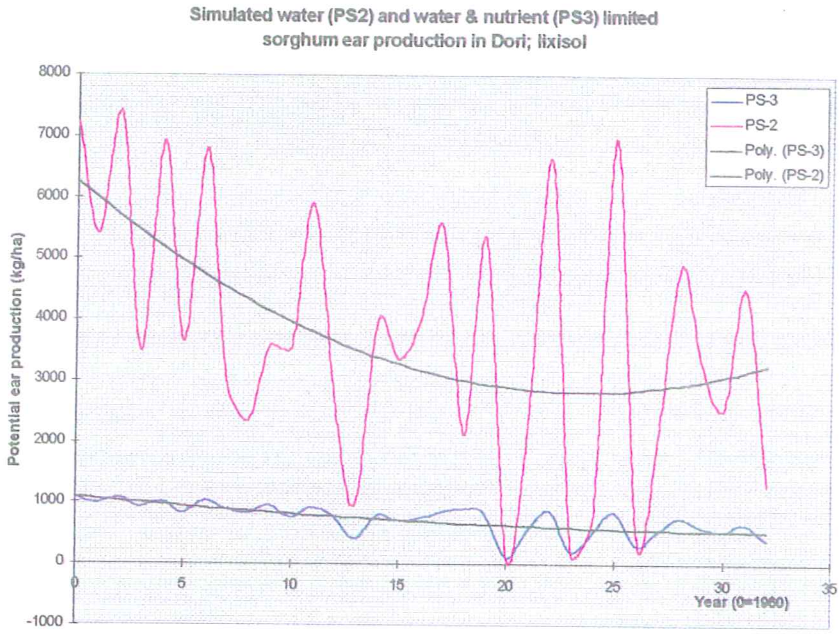

Fig. 4. Simulated water limited (PS2) and water- & nutrient limited (PS3) sorghum ear production on a lixisols in the Sahel

2.2.2.5. Flooding

As a function of the assessed daily erosion, the frequency of lowland flooding could be estimated. Lowlands were fixed to occupy some 10% of the area.

2.2.2.6. Salinization

Though salinity s taken into consideration, no multi-year accumulation was assessed.

2.2.3. <u>Simulation of the change of carrying capacities and of storage</u>

Bio-physical carrying capacity (ccl.) per VS was expressed as kg grain / ha (1 person requires minimally 250 kg grain/year). Estimation of the yearly ccl. simply concerned water and nutrient limited crop growth simulation per soil type and subsequent aggregation. Because the scale of soil type distinction was similar for the VS's identified at village and regional scale, aggregation procedure was similar for both types of VS (weighted composition). Simulation took place by means of the dynamic crop growth model as described by Driessen and Konijn (1992). Some adaptations were needed to allow for simulating the impact of the land degradation processes on land and nutrient limited productivity.

In order to interpret the inter annual variability of simulated productivity, it was chosen to accumulate yearly grain production into storage. Storage was defined zero in the last year of simulation (1992) what corresponds with a virtual consumption equal to production. During time, consumption remained constant and storage changed as illustrated in fig. 5. Fig. 5 clearly illustrates that the storage decreased rapidly until a minimum was reached for the Dogon and Sanmatenga VS's. Since then the storage increased again for these situations.

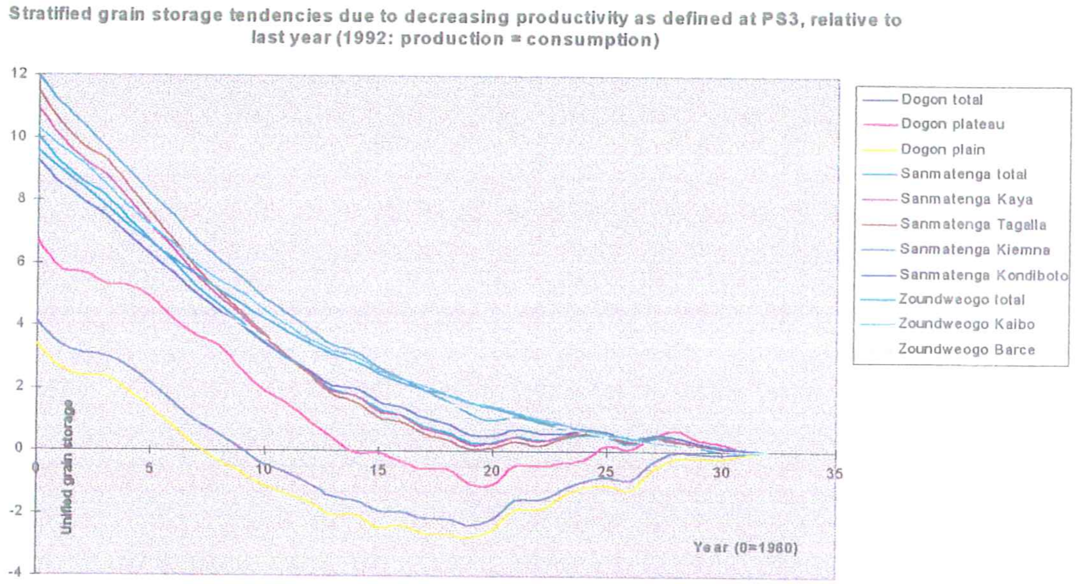

Fig. 5. Simulated change of grain storage due to decreasing water- and nutrient limited productivity, relative to the storage in the last year.

2.2.4. Assessment of the numeric scores for carrying capacity and land degradation

Numeric scores for the change of carrying capacity or storage correspond with the coefficients of slope as calculated by simple linear regression. Because of the break of trend in 1979/1980, these coefficients were calculated over the period from 1980 onwards. Fig. 6 illustrates the calculated trend lines for ccl. Numeric scoring of the rates of change of the underlying processes was done in a similar way, in where the yearly absolute values were made relative to the values for 1992 set at zero.

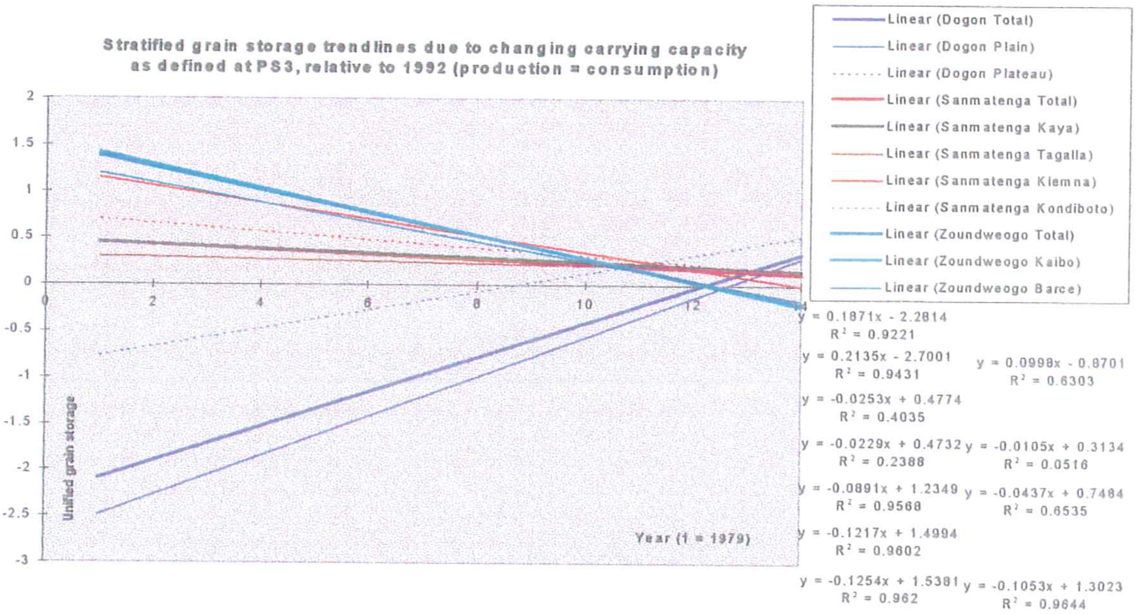

Fig. 6. Slopes of change of grain storage (ccl.) since 1979.

2.3. Results

2.3.1 Numeric scores for carrying capacity and land degradation

The numeric scores to be correlated with ccp. are tabulated here below. The scores for the processes of land degradation are considered as 'independent' variables and by means of multi-variable correlation, the relative explanatory values with respect to ccp. can be assessed. Similarly, the relative explanatory values with respect to ccl. can be assessed. Instead correlating the processes with ccp., the dependent variable ccl. can be correlated with ccp.

		Scores	Weather					Erosion		V.cover	N.depletion
VS	ID	CCL.	Tmax.	Rain	Balance	R.days	Season	Runoff	Soil loss		
Dogon	1	0,187	-0,002	0,0288	-0,166	0,0127	0,0032	0,0176	0,178	0,06	1
Sanmatenga	4	-0,025	-0,0016	0,0209	0,011	0,0094	0,0021	0,0207	0,241	0,093	1
Sanmatenga Kaya	5	-0,023	-0,0016	0,0209	0,011	0,0094	0,0021	0,0216	0,241	0,107	1
Sanmatenga Tagalla	6	-0,011	-0,0016	0,0209	0,011	0,0094	0,0021	0,0232	0,241	0,14	1
Sanmatenga Kiemna	7	-0,089	-0,0016	0,0209	0,011	0,0094	0,0021	0,0182	0,241	0,107	1
Sanmatenga Kondiboto	8	-0,044	-0,0016	0,0209	0,011	0,0094	0,0021	0,0155	0,241	0,033	1
Zoundweogo	9	-0,122	-0,0013	0,0154	0,188	0,0073	0,0026	0,0264	0,304	0,093	1
Zoundweogo Kaibo	10	-0,125	-0,0013	0,0154	0,188	0,0073	0,0026	0,0273	0,304	0,14	1
Zoundweogo Barce	11	-0,105	-0,0013	0,0154	0,188	0,0073	0,0026	0,0259	0,304	0,06	1

2.4. Conclusions and discussion

A framework was developed that allows to consistently analyze relevant bio-physical indicators in their order of significance to relate with psychological indicators, and proved applicable at various levels of scale and data availability. Bio-physical scores were generated to be correlated with psychological scores on the common basis of geographic location. Because of interdisciplinary testing nature of the present study and the large amount of bio-physical factors involved in scoring land degradation, this study had no intention to generate scores with high explanatory value and high accuracy. Nevertheless some trends appeared visible and the application of more appropriate tools for analysis of geo-information (GIS) is highly recommended to verify these. Climatic change since 1960 clearly led to a decline in accumulative grain storage. Weather conditions became more favorable form 1979/1980 onwards which however only was reflected in an increasing storage for the Village Systems of the northern zone (Dogon area) where productivity is frequently water limited. Storage for the Village Systems of the southern zone (Zoundweogo area) continued declining due to the continuing nutrient depletion and the low frequency that productivity is water limited.

The reconnaissance nature of application The data analyzed and the definitions of the dynamics of were limited in explanatory value. The incapability at the start of analysis to assess the geographic location and thus the associated land characteristics of most of the villages of interview was a major reason for this.

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Annex 1. Extract from BKF GIS database as presented by Groten and Ilboudo (1996)

Information générale,infrastructure, information socio-economique (S):

S1. Burkina Faso
S2. Unités administratives; liée à des statistiques tabulaires
S3. Coordinées
S5. Villages & population (± 8000)
S7. Principaux groupes etniques
S8. Densité de population / province, departements
S9. Croissance de population / province, departement
S10. Bilan céréaliers 1986-1988 (verificative material)

Types de terrain (T):

T1. Geomorphologie (9 unités, détaillé)
T2. Carte des sols (moyennement détaillé)
T3. Carte des sols (peu détaillé)
T4. Carte geologique (peu détaillé)
T5. PGCN (base des données geologique, pedologique et hydrologique; détaillé)
T6. Altitude (modèle 3-dimensionnel)
T7. Erosion hydrique (grossière)
T8. Erosion éolienne (grossière)
T9. Degradation physique des sols (grossière; 5 classes)

Hydrologie - agrométéorologie (H):

H1. Bassins versants (détaillé)
H4. Stations Météo (pluviometrie moyenne (1960-1986) de 145 points)
H5. Isolignes (pluviométrie interpolée)
H6. Dates favorables aux semis des céréales)
H7. Longuer de la période de croissance

Végétation - occupation du sol - pâturages (V):

V1. Carte de végétation (peu détaillé; 1:1000.000)
V5. Classification multitemporelle NOAA (en prep. ITC; résolution de 7.6 km)
V6. Estimation de biomasse disponible (à partir de NOAA 1982 - 1995)
V7. Nombre de betail en UBT / km² (cartes provinces)
V8. Nombre de betail en UBT / 100 habitants (cartes provinces)

Images satéllitaires (I):

I1. Données indice de végétation décadaire, 1982 - 1995 (resolution 7.6 km)
I2. Données indice de végétation décadaire, 1990 - 1991 (resolution 1.1 km, non-complète)
I5. Différentes scènes SPOT et LANDSAT; du Nord, Centre et SudOuest

Annex 2. Major land unit aggregation

		Dogon	Kaya	Manga
Weather (33 years)		Dori	½ + ½	Ouagadougou
Major soil types (%):				
Q. Arenosols	Ql. luvic	30	7.5	
	Qc. cambic	20		
L. Lithosols		20	7.5	
L. Luvisols	Lg. gleyic		15	
	Lf. ferric		7.5	12.5
	Lp. plinthic		22.5	25
R. Regosols	Re. eutric	10	30	12.5
B. Cambisols	Bv. vertic		10	
V. Vertisols	Vc. chromic	20		37.5
W. Planosols	Ws. solodic			12.5
		100%	100%	100%

Annex 3. Some parameter values used for simulation

Annex 3a. Weather parameter settings for Dori, 1960 1 jan- 1feb. (Dori60.dat)

"DORI-60",14.02,-.03,277
1,32.2,14.3,0,.25,.7,7.97,.67
2,32.29,14.39,0,.25,.73,8.19,.7
3,32.2,14,0,.26,.71,8.46,.67
4,32.29,13.6,0,.27,.68,8.03,.65
5,32.09,13.69,0,.27,.74,8.37,.7
6,32.2,13.8,0,.27,.68,7.48,.65
7,32.09,13.89,0,.28,.69,7.9,.66
8,32.5,13.8,0,.27,.7,7.74,.67
9,32.5,13.6,0,.27,.7,8.16,.67
10,32.29,13.19,0,.28,.71,8.4,.67
11,32.29,13.39,0,.27,.69,8.16,.65
12,32.29,13.5,0,.28,.68,7.77,.65
13,32.7,14,0,.28,.7,8.13,.67
14,32.59,14,0,.27,.69,7.84,.66
15,32.2,14.1,0,.27,.68,7.44,.65
16,32.2,14.69,0,.26,.69,7.57,.66
17,32.7,14.19,0,.25,.68,8.09,.65
18,33.2,14.19,0,.25,.69,8.13,.66
19,32.9,14.3,0,.25,.72,8.19,.68
20,32.59,13.89,0,.26,.69,8.16,.66
21,32.5,14.19,0,.26,.68,7.56,.65
22,33,14.1,0,.24,.74,8.47,.71
23,33,14.39,0,.25,.76,8.88,.72
24,33.2,13.89,0,.26,.78,9.49,.73
25,33.2,14.3,0,.24,.79,9.63,.74
26,33.29,14.1,0,.25,.79,9.69,.74
27,33.09,15,0,.25,.81,9.78,.76
28,32.9,14.6,0,.24,.81,9.75,.76
29,33.4,14.39,0,.24,.78,9.31,.74
30,33.7,14.39,0,.25,.78,9.6,.73
31,34,15,0,.24,.8,10.05,.75
32,34.2,15.6,0,.24,.84,10.29,.79

Annex 3b. Soil physical parameter settings (Faosoil.dat)

"Arenosols(s)"
.4,.1
100,650,.15,.1
30,60
.28,200,25,1.2,1,1
"Lixisols(ls)"
.45,.03
130,100,.07,13
20,15
.135,100,25,1.2,1,1
"Regosols"
.25,.03
130,50,.07,13
15,10
.135,30,15,1.2,1,1
"Vertic Cambisols (c)"
.5,.007
260,25,.03,3
10,5

.056,160,50,2.4,1,1
"Crusted Arenosols (s)"
.4,.1
100,650,.15,.1
3,6
.28,200,20,1,1,1
"Crusted Lixisols (ls)"
.45,.03
130,100,.07,13
2,1.5
.135,100,20,1,1,1
"Crusted Regosols"
.25,.03
130,50,.07,13
1.5,1
.135,30,15,1,1,1
"Crusted Vertic Cambisols (c)"
.5,.007
260,25,.03,3
1,.5
.056,160,40,2,1,1

Annex 3c. Crop physiology parameter settings (Bkfcrop.dat)

"Dossier general"
"C4",10,1700,975,8,.61,150,8,16000
22,16,.5,1.1,.035,.01,.015,.01
0,40,.05,.5
.72,.72,.69,.74,.01,.004,.0011,.0005
8
0,.22,.34,.56,.61,.65,.7,1
.45,.55,.65,.25,.13,0,0,0
.55,.35,.25,.05,0,0,0,0
0,.1,.1,.7,.8,.85,0,0
0,0,0,0,.07,.15,1,1

Annex 3d. Land Use System management parameter settings (Dorimana.dat).

1,"1",185,40,25,.1
1,1,1,1,1,"A",1,1,1
1,1,1,1,1,1
2,"2",185,45,25,.1
20000,3000,2,0,555,"F",60,120,0
1,1,1,1,3,1
3,"2",185,45,25,.1
20000,3000,.2,0,555,"F",60,120,0
1,1,1,0,0,1
4,"2",185,45,25,.1
20000,3000,.02,0,555,"F",60,120,0
1,1,1,0,0,1
5,"2",155,70,50,.1
20000,3000,.2,0,555,"F",60,120,0
1,1,1,0,0,1
6,"2",285,45,50,.1
20000,3000,.2,0,222,"F",50,100,5
1,1,1,0,0,1

Annex 3e. Land Use System identifiers for sorghum (Dluss.dat)

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"BKF\DORIMANA.DAT","BKF\BKFCROP.DAT"
"BKF\FAOSOIL.DAT","BKF\DORI\DORI",33
1,1,1,0,60,10,"BKF\DORIOUT\D1S"
2,1,1,0,70,10,"BKF\DORIOUT\D1S"
3,1,1,0,80,10,"BKF\DORIOUT\D1S"
4,1,1,0,90,3,"BKF\DORIOUT\D1S"
5,3,1,1,60,10,"BKF\DORIOUT\D2SrA"
6,3,1,1,70,10,"BKF\DORIOUT\D2SrA"
7,3,1,1,80,10,"BKF\DORIOUT\D2SrA"
8,3,1,1,90,3,"BKF\DORIOUT\D2SrA"
9,3,1,2,60,10,"BKF\DORIOUT\D2SrL"
10,3,1,2,70,10,"BKF\DORIOUT\D2SrL"
11,3,1,2,80,10,"BKF\DORIOUT\D2SrL"
12,3,1,2,90,3,"BKF\DORIOUT\D2SrL"
13,3,1,3,60,10,"BKF\DORIOUT\D2SrR"
14,3,1,3,70,10,"BKF\DORIOUT\D2SrR"
15,3,1,3,80,10,"BKF\DORIOUT\D2SrR"
16,3,1,3,90,3,"BKF\DORIOUT\D2SrR"
17,3,1,4,60,10,"BKF\DORIOUT\D2SrC"
18,3,1,4,70,10,"BKF\DORIOUT\D2SrC"
19,3,1,4,80,10,"BKF\DORIOUT\D2SrC"
20,3,1,4,90,3,"BKF\DORIOUT\D2SrC"
21,4,1,5,60,10,"BKF\DORIOUT\D2SrAC"
22,4,1,5,70,10,"BKF\DORIOUT\D2SrAC"
23,4,1,5,80,10,"BKF\DORIOUT\D2SrAC"
24,4,1,5,90,3,"BKF\DORIOUT\D2SrAC"
25,4,1,6,60,10,"BKF\DORIOUT\D2SrLC"
26,4,1,6,70,10,"BKF\DORIOUT\D2SrLC"
27,4,1,6,80,10,"BKF\DORIOUT\D2SrLC"
28,4,1,6,90,3,"BKF\DORIOUT\D2SrLC"
29,4,1,7,60,10,"BKF\DORIOUT\D2SrRC"
30,4,1,7,70,10,"BKF\DORIOUT\D2SrRC"
31,4,1,7,80,10,"BKF\DORIOUT\D2SrRC"
32,4,1,7,90,3,"BKF\DORIOUT\D2SrRC"
33,4,1,8,60,10,"BKF\DORIOUT\D2SrCC"
34,4,1,8,70,10,"BKF\DORIOUT\D2SrCC"
35,4,1,8,80,10,"BKF\DORIOUT\D2SrCC"
36,4,1,8,90,3,"BKF\DORIOUT\D2SrCC"
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