Environ Dev Sustain (2006) 8:553–567
DOI 10.1007/s10668-006-9055-2

ORIGINAL PAPER

Woody vegetation change in Sahelian West Africa: evidence from local knowledge

A. Wezel · A. M. Lykke

Received: 30 September 2004 / Accepted: 21 September 2005 /
Published online: 4 July 2006

Abstract Vegetation changes in Sahelian West Africa have been increasingly investigated since 1970 due to the catastrophic droughts in the early 1970s and 1980s and the following decades with below average precipitation. In most cases this was done by remote sensing and vegetation studies. In recent years, local knowledge of farmers and pastoralists about vegetation changes has been increasingly investigated. In this paper, information from different case studies in three West African countries (Burkina Faso, Niger, Senegal) was used to analyse and evaluate vegetation changes in the Sahel. In total, data were analysed from 25 villages, where the local people were asked to mention plant species and qualify their present occurrence compared to the past. In total, 111 woody species were mentioned as having changed compared to the past, of which 79% were classified as having decreased or disappeared. For each single location 8–59 different woody species were mentioned. In most cases, these are valuable species of socio-economic importance. Only 11% of the species was classified as increasing or new (0–12 were mentioned per location), the later being mainly exotic species. Ten percent were categorised differently among villages. A comparison of local knowledge from different locations provide regional scale information on endangered species and thereby crucial information for making insightful priorities for assisted regeneration, reforestation and conservation strategies.

Keywords Degradation · Dynamics · Ethnobotany · Local knowledge · Participatory rural appraisal (PRA) · Sahel · Semi-arid · Shrubs · Trees

A. Wezel
Institute of Landscape and Plant Ecology, University of Hohenheim, Stuttgart, Germany

A. Wezel (✉)
Wilhams 25, 87547 Missen, Germany
e-mail: alexanderwezel@tiscali.de

A. M. Lykke
Institute of Biological Sciences, University of Aarhus, Universitetsparken, Building 1540, 8000 Aarhus C, Denmark

Introduction

The West African Sahel has for long been affected by different types of vegetation changes. Natural long-term climatic changes and following vegetation changes have been documented for the last centuries (Lézine, 1989). Short-term changes became obvious with the droughts of the 1970s and 1980s (Claude, Grouzis, & Milleville, 1991; IEMVT, 1977). The climate in the Sahel is characterised by a high inter-annual rainfall variability, which can alter vegetation cover enormously from year to year (Tucker, Dregne, & Newcomb, 1991). Human resource use has a long tradition in semi-arid West Africa. The influence of man on the natural savanna vegetation can be traced back as long as 9,000 years (Anhuf, 1995), and examples of human influenced vegetation changes in the past due to agro-pastoral activities have been reported from northern Burkina Faso (Ballouche & Neumann, 1995). Today, most areas of the Sahel are used for cropping and/or grazing. In many places tree cover has decreased due to cultivation, wood cutting and overgrazing (Bandré, 1996; Breman & Kessler, 1995). Human impact is seen as the most important factor for these changes over the last decades (LeHouérou, 2002; Wezel and Rath, 2002), but climate might also have some importance (Nicholson, Tucker, & Ba, 1998).

Vegetation changes influence the rural economy in the Sahel as a broad spectrum of natural plants is used for food, fodder, firewood or medicinal purposes (e.g., Bandré, 1996; Bergeret & Ribot, 1990; Gakou, Force, & McLaughlin, 1994; Guinko & Pasgo, 1992; Kéré, 1998; von Maydell, 1992). Species decline affect all aspects of daily life; health, nutrition and income of individual households.

In recent years, the knowledge and the perception of local rural people in the Sahel was increasingly used to understand the extent of vegetation changes during the last decades (Gonzalez, 2001; Hahn-Hadjali & Thiombiano, 2000; Lykke, Kristensen, & Ganaba, 2004; Wezel & Haigis, 2000). This method showed to be a relatively quick and reliable source of information without the necessity of sophisticated technical apparatus. A further advantage is the availability of information on a single species basis, which can be directly used for local resource management (Wezel, 2004). However, such information is only available for single case studies and lacks an overall analysis. The purpose of this paper is to bring together different case studies to analyse if similar trends of species change can be found for different parts of the Sahel or if species are affected on a local scale only.

Study area

The Sahel is characterised by large plains interrupted by shallow valleys, temporary water areas (mares) and longitudinal sand dunes. The plains are characterized by open savanna with relatively low (mainly less than 10 m tall), spiny woody species, particularly *Acacia* spp. and *Balanites aegyptiaca*. Annual grasses appear with the first rains in June–July and cover the soil until September. The valleys and temporary water areas (mares) contain a cover of perennial grasses and denser woody vegetation dominated by relatively large, evergreen species. The sand dunes have sparse vegetation dominated by annual grasses and scattered trees, e.g., *Combretum glutinosum* and *Faidherbia albida*. A band of evergreen woody vegetation often fringes the dune system where rainwater accumulates.

The predominant land use is either cropping or livestock rearing. The dominance of either activity strongly depends on the ethnic groups living in the respective areas, e.g., the Fulani have a preference for livestock rearing, whereas the Djerma, Haussa and Gourmanchté are predominately engaged with millet or maize cropping (see Table 1).

Methods

Seven case studies from three West African countries were used to analyse and evaluate vegetation changes in the Sahel; four studies published from Burkina Faso (Hahn-Hadjali & Thiombiano, 2000; Knierim, 1991; Lykke et al., 2004; Müller & Wittig, 2002), one from Senegal (Sadio, Dione, & Ngom, 2000), one from Niger (Wezel & Haigis, 2000) and unpublished data from Burkina Faso (Fig. 1). The common data basis of all case studies is the perception of local people about changes in woody vegetation in the Sahel. People were asked to mention plant species and qualify their present occurrence compared to the past, meaning 20–50 years ago according to age of interviewed people. Informants belonged to different ethnic groups of farmers and pastoralists. Both, men and women were interviewed with a preference for elderly people (above 50 years). Detailed information of each case study is presented in Table 1. Raw data from the above mentioned studies were combined and analysed, together with the unpublished data. In four of the cases studies the interviews were carried out with individuals, in the other three studies data was collected through group discussions. The criteria for species selection was not equivalent for all studies (Table 1), but to minimise the methodological differences, data of Hahn-Hadjali and Thiombiano (2000), Wezel and Haigis (2000) and Lykke et al. (2004) were re-analysed with

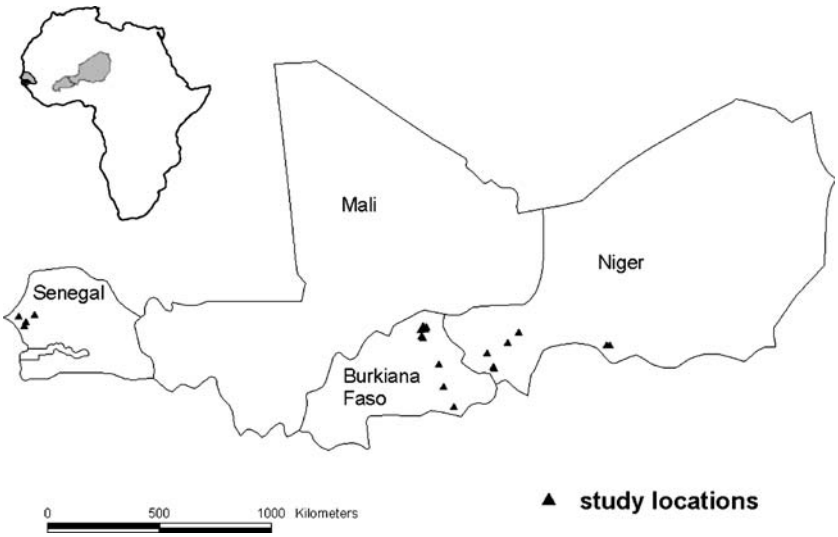

Fig. 1 Location of the study areas in West Africa

Table 1 Parameters from the different case studies on local knowledge about vegetation change

	Lykke et al. (2004)	Unpublished data	Hahn-Hadjali and Thiombiano (2000)	Wezel and Haigis (2000)	Müller and Wittig (2002)	Sadio et al. (2000)	Knierim (1991)
Country	Burkina Faso	Burkina Faso	Burkina Faso	Niger	Burkina Faso	Senegal	Burkina Faso
Average precipitation	400	400	570–850	330–580	400	400–500	400–500
Ethnic group	Fulani	Fulani	Gourmantché	Djerma, Haussa	Fulani	Sereer, Wolof	Fulani
Number of villages analysed	5	3	3	7	2	4	2[a]
Village codes	L1–5	U1–3	H1–3	W1–7	M1–2	S1–4	K1
Total number of interviews	100	33	45	253	Group discussion	Group discussion	Group discussion
Asked for species that are/have	Increasing, declining (or extinct)	Increasing, declining (or extinct)	Endangered (decreasing), disappeared	New, increasing, decreasing, disappeared	Increasing, decreasing, disappeared	Still existing, becoming rare, disappeared	Decreased/disappeared
Selection criteria of species for inclusion on species list	First, 59 species were selected in 21 group discussions; then 100 individual interviews were conducted; species that were attributed by at least 20% of the interviewees to the different categories were enrolled	First, 59 species were selected in 21 group discussions; then 100 individual interviews were conducted; species that were attributed by at least 20% of the interviewees to the different categories were enrolled	Interviews with free listing of species; species that were attributed by at least 20% of the interviewees to the different categories were included	Interviews with free listing of species; species that were attributed by at least 20% of the interviewees to the different categories were included	First a species list was created in several group discussion; then all species on the list were classified to the different categories in the group discussion	Species change categories were first attributed to four different time periods (< 1960, 1960–1972, 1972–1990, 1999); then the changes over the four time periods were used for final categorisation	Several group discussion with free listing of species

[a]Although two villages were visited, only one common list of species is available that has been treated in the analyses as one village

similar criteria for the selection of species. Only species that were mentioned by at least 20% of the informants in one village as either disappeared, declining, increasing or new were entered in the species list and thus considered for the analysis. In general, species that could not be translated to scientific names or for which the same common name is used were not included in the analysis. The scientific names of the plant species follow (IPNI, 2004).

The Sahelian Zone in West Africa is defined as the semi-arid area receiving 200–600 mm average annual precipitation. Although two study sites in Burkina Faso (sites H2 and H3 in Table 2) are located in the Northern Sudanian Zone, they are included in the species list because they allow comparing species changes, e.g., for *Vittelaria paradoxa* or *Khaya senegalensis*, which have a core distribution in this Zone, but occur within their northern limit of geographic range in the Sahelian Zone.

To analyse similarities between the 25 different villages, a cluster analysis was carried out. Only decreasing/disappeared species for each study village entered the model as a binomial variable. Single linkage and Euclidean distance was used for the computation of the classification.

Results

The local people from 23 different Sahelian villages (the two study villages from the Sudanian Zone were not considered here) mentioned 111 woody species as having changed compared to the past (Table 2). In total, 88 species (79%) were classified as having decreased or disappeared (Fig. 2). The following species were mentioned from more than 10 locations: *Acacia ataxacantha*, *A. senegal*, *A. seyal*, *A. ehrenbergiana*, *Adansonia digitata*, *Boscia senegalensis*, *Ceiba pentandra*, *Dalbergia melanoxylon*, *Ficus gnaphalocarpa*, *Grewia bicolor*, *Khaya senegalensis*, *Maerua crassifolia*, *Pterocarpus lucens*, *Sclerocary birrea* and *Tamarindus indica*. Only 12 species were classified as having increased or as newly introduced. Finally, 11 species were classified differently among villages indicating significant difference between case studies, e.g., *Acacia tortilis*, *Faidherbia albida* or *Parinari macrophylla* disappeared in Senegal but increased in Niger, whereas *Combretum glutinosum* and *Ziziphus mauritiana* reflect differences within the locations in Niger.

In average, 28 species were mentioned in each village (with a range from 8 to 64 species). In average 88% were decreasing/disappeared (range 4–59) and 12% were increasing/new (range 0–12).

Nine species were mentioned at many locations in Burkina Faso, Niger and Senegal: *Acacia ataxacantha*, *A. seyal*, *Boscia senegalensis*, *Ceiba pentandra*, *Combretum glutinosum*, *C. micranthum*, *Diospyros mespiliformis*, *Grewia bicolor* and *Tamarindus indica*. Nevertheless, these species show slightly different patterns. Some of them were more often mentioned in Burkina Faso, others more frequently in Niger or in Senegal. The cluster analysis carried out with decreasing and disappeared species showed that in general a higher similarity is found within the respective case studies. Three main clusters were found (cluster 1: S1–4; cluster 2: W1–7; cluster 3: L1–5 and U1–3). Two locations in Burkina Faso (H1, H2) were most distinct from all others, followed by H3, K1, M2 and M1.

Table 2 Species mentioned by local people in the Sahel as having changed compared to the past (↘ decreasing, 🡻 disappeared, ⇗ increasing, ⇮ new)

	Burkina Faso					Burkina Faso			Niger							Burkina Faso	Burkina Faso		Senegal				Burkina Faso	Burkina Faso[a]	
Village	Fo	Be	Me	Di	As	Ta	Bi	Gu	Ci	Da	Bu	Se	Li	Ki	So	Bo	Ti	Ko	DR	NS	Ng	So	Pé, Bu	Fa	Pa
Village code	L1	L2	L3	L4	L5	U1	U2	U3	W1	W2	W3	W4	W5	W6	W7	H1	M1	M2	S1	S2	S3	S4	K1	H2	H3
Decreasing/disappeared																									
*Acacia ataxacantha**	↘	↘				↘	↘	↘	↘		↘					🡻			↘	🡻	🡻	↘		🡻	🡻
Acacia erythrocalyx																		🡻							
Acacia laeta									↘																
Acacia macrostachya																			↘	↘	↘	↘			
*Acacia nilotica**	↘						↘	↘									↘	↘[b]	↘	↘		↘	↘		
Acacia polyacantha	↘	↘	↘	↘	↘	↘	↘	↘																	
*Acacia senegal**	↘	↘	↘	↘	↘	↘	↘	↘									🡻[b]	🡻	🡻	🡻	🡻	🡻	↘		
*Acacia seyal**					↘	↘	↘	↘					↘				⇗	↘	↘	↘	↘	↘	↘		
Acacia ehrenbergiana	↘	↘	↘	↘	↘	↘	↘	↘										↘	🡻	🡻	🡻	↘		↘	
*Adansonia digitata**	↘	↘	↘	↘	↘	↘	↘	↘		⇗				↘	↘	↘		🡻					↘	↘	
Afrormosia laxiflora																🡻								🡻	
Andira inermis	↘	↘		↘	↘	↘	↘	↘																🡻	🡻
Anona senegalensis																🡻							↘	↘	
Anogeissus leiocarpa								↘								↘	↘	↘	↘					↘	
Bauhinia rufescens							↘	↘									↘	🡻							
Bombax costatum																↘			🡻		🡻			↘	
Borassus aethiopium														↘	↘									⇮	↘
Boscia angustifolia	↘	↘	↘	↘	↘											↘		🡻							
Boscia salicifolia	↘	↘	↘	↘	↘	↘	↘	↘																	
*Boscia senegalensis**		↘	↘	↘	↘	↘	↘	↘	⇗	↘						🡻			↘		↘	↘	↘	↘	
Boswellia dalzelii										🡻		↘				↘								↘	
Burkea africana										🡻						↘								⇮	
*Cadaba farinosa**	↘	↘	↘	↘	↘	↘	↘	↘			↘					↘									
Capparis corymbosa																↘								↘	
Capparis sepiaria		↘		↘		↘	↘																		
Ceiba pentandra														🡻		🡻			🡻	↘	↘			↘	↘
Celtis integrifolia																🡻		🡻					↘	🡻	🡻

Table 2 continued

	Burkina Faso					Burkina Faso			Niger							Burkina Faso	Burkina Faso		Senegal				Burkina Faso	Burkina Faso[a]	
Village	Fo	Be	Me	Di	As	Ta	Bi	Gu	Ci	Da	Bu	Se	Li	Ki	So	Bo	Ti	Ko	DR	NS	Ng	So	Pé, Bu	Fa	Pa
Village code	L1	L2	L3	L4	L5	U1	U2	U3	W1	W2	W3	W4	W5	W6	W7	H1	M1	M2	S1	S2	S3	S4	K1	H2	H3
Celtis toka	↘	↘	↘	↘	↘	↘	↘	↘																	
Combretum aculeatum		↘				↘	↘	↘									↘	↘							
*Combretum micranthum**					↘		↘		↘							↘		↘		↘	↘	↘	↘	↘	
Combretum molle																↓									
Combretum nigricans									↘		↘		↘			↘								↘	
Combretum paniculatum																↘								↘	
*Commiphora africana**	↘	↘	↘	↘	↘	↘	↘	↘	↘							↘									
Cordyla pinnata																			↓	↓	↓				
Crataeva religiosa (syn. *C. adansonii*)	↘	↘	↘	↘	↘	↘	↘	↘																↓	↘
Crossopteryx febrifuga																↓									
Dalbergia melanoxylon	↘	↘	↘	↘	↘	↘	↘	↘								↓	↓	↓					↘		
Daniellia oliveri																↓								↘	
Detarium microcarpum										↓		↘			↘								↘		
Dichrostachys cinerea						↘	↘	↘								↘	↓	↓							
*Diospyros mespiliformis**				↘	↘			↘		↘						↘		↘	↘		↘		↘	↘	
Entada africana																↓								↘	
Erythrina senegalensis																↓								↓	
Feretia apodanthera						↘	↘	↘																	
*Ficus gnaphalocarpa** (syn. *F. sycomorus*)	↘	↘	↘	↘	↘	↘	↘	↘								↓			↓	↓	↓	↓	↘	↘	↘
Ficus platyphylla										↓				↘											
Gardenia erubescens										↓						↓								↘	
Gardenia ternifolia	↘	↘	↘	↘	↘	↘	↘	↘								↓								↘	
*Grewia bicolor**	↘	↘	↘		↘	↘	↘	↘		↘		↘					↓	↓	↓	↘	↓	↓	↘		

Table 2 continued

	Burkina Faso					Burkina Faso			Niger							Burkina Faso	Burkina Faso		Senegal				Burkina Faso	Burkina Faso[a]	
Village	Fo	Be	Me	Di	As	Ta	Bi	Gu	Ci	Da	Bu	Se	Li	Ki	So	Bo	Ti	Ko	DR	NS	Ng	So	Pé, Bu	Fa	Pa
Village code	L1	L2	L3	L4	L5	U1	U2	U3	W1	W2	W3	W4	W5	W6	W7	H1	M1	M2	S1	S2	S3	S4	K1	H2	H3
Grewia flavescens		↘	↘	↘		↘	↘	↘																	
Grewia tenax		↘		↘		↘	↘	↘																	
*Grewia villosa**	↘	↘	↘		↘	↘	↘	↘		↓															
*Hyphaene thebaica**	↘			↘	↘	↘	↘	↘			↘			↘	↘	↓	⇗								
*Khaya senegalensis**	↘	↘	↘	↘	↘	↘	↘	↘			↘			↘		↘							↘	↘	↘
Kigelia africana	↘	↘	↘	↘	↘	↘	↘																		
Lannea microcarpa											↘					↘									
Lannea velutina																↓								↘	
Leptadenia hastata		↘					↘	↘																	
Leptadenia pyrotechnica	↘			↘	↘	↘		↘																	
Maerua angolensis	↘	↘	↘				↘	↘																	
*Maerua crassifolia**	↘	↘	↘	↘	↘	↘	↘	↘	↘									↓					↘		
Mitragyna inermis	↘		↘	↘	↘		↘	↘								↘		↘					↘	↘	
Moringa oleifera																			↓	↘	↓	↓			
Nauclea latifolia																↓								↘	
*Parkia biglobosa**														↘	↘	↘			↓	↓	↓	↓		↘	↘
Phoenix dactylifera	↘			↘	↘	↘	↘	↘																	
Piliostigma thonningii																↓				↘	↘	↘			
*Prosopis africana**											↘				↘	↓			↓	↓	↓	↓		↓	
Pseudocedrela kotschyi																↓								↓	
Pteleopsis suberosa																↓								↘	
Pterocarpus erinaceus																↘								↘	
*Pterocarpus lucens**	↘	↘	↘		↘	↘	↘	↘								↘	↓						↘		
*Sclerocarya birrea**	↘	↘	↘	↘	↘		↘	↘	↘	↘		⇗					↘	↘					↘		↘
Securidaca longepedunculata																↓								↘	⇗

Table 2 continued

	Burkina Faso					Burkina Faso			Niger								Burkina Faso	Burkina Faso		Senegal				Burkina Faso	Burkina Faso[a]	
Village	Fo	Be	Me	Di	As	Ta	Bi	Gu	Ci	Da	Bu	Se	Li	Ki	So	Bo	Ti	Ko	DR	NS	Ng	So	Pé, Bu	Fa	Pa
Village code	L1	L2	L3	L4	L5	U1	U2	U3	W1	W2	W3	W4	W5	W6	W7	H1	M1	M2	S1	S2	S3	S4	K1	H2	H3
Securinega virosa (syn. *Flueggea virosa*)	↘	↘	↘			↘	↘	↘																	
Senna sieberiana (syn. *Cassia sieberiana*)																			↓	↓	↓				
Sterculia setigera																			↓	↓	↓	↓			
Stereospermum kunthianum	↘	↘	↘	↘	↘	↘	↘	↘								↘									
Strychnos spinosa																↘									
*Tamarindus indica**		↘	↘	↘	↘		↘	↘		↘		⇗				↘		↘	↓				↘	↘	
Terminalia avicennioides									↓	↘	↱					↘							↘		
Terminalia laxiflora																↘								↘	↘
Terminalia macroptera																↘								↘	↘
Vitellaria paradoxa										↓						↘							↘	↘	↘
Vitex doniana	↘	↘	↘	↘	↘	↘	↘	↘								↘								↘	
*Ximenia americana**	↘	↘	↘		↘	↘	↘	↘		↘		↘				↘									
Ziziphus mucronata	↘	↘	↘			↘	↘	↘																	
Increasing/new																									
Acacia torulosa												↱													
Acacia tumida										↱															
Anacardium occidentale																⇗								⇗	⇗
Eucalyptus camadulensis											↱	↱	↱	↱	↱	⇗								⇗	⇗
Euphorbia balsamifera																	⇗								
Gmelina arborea																⇗								⇗	⇗
Lannea fruticosa												⇗													
Mangifera indica																⇗								⇗	⇗

Table 2 continued

	Burkina Faso					Burkina Faso			Niger							Burkina Faso	Burkina Faso		Senegal				Burkina Faso	Burkina Faso[a]	
Village	Fo	Be	Me	Di	As	Ta	Bi	Gu	Ci	Da	Bu	Se	Li	Ki	So	Bo	Ti	Ko	DR	NS	Ng	So	Pé, Bu	Fa	Pa
Village code	L1	L2	L3	L4	L5	U1	U2	U3	W1	W2	W3	W4	W5	W6	W7	H1	M1	M2	S1	S2	S3	S4	K1	H2	H3
Parkinsonia aculeata											↑				↑										
Prosopis juliflora																	↑	↑							
Senna siamea (syn. *Cassia siamea*)																↗								↗	↗
Ziziphus spina-christi										↑															
Differently categorised																									
Acacia tortilis (syn. *A. raddiana*)	↗	↗	↗	↗	↗	↗	↗	↗									↗	↗	↘	↘	↘	↘			
Azadirachta indica					↘					↗	↑	↑	↗	↑	↑		↑	↑	↘	↓		↓			
Balanites aegyptiaca									↘	↘	↗		↗	↗			↗	↗					↘		
Calotropis procera		↘	↘	↘	↘	↘	↘	↘											↗	↗	↗	↗			
*Combretum glutinosum**	↘	↘	↘	↘	↘		↘	↘				↙	↘	↗	↘	↘		↘		↓	↘		↘	↘	
Faidherbia albida (syn. *Acacia albida*)	↘			↘	↘		↘	↘	↗	↗	↗	↙		↗	↗	↓	↗						↘	↓	↓
Guiera senegalensis	↘	↘	↘	↘	↘	↘	↘	↘			↗	↙	↘	↗		↘		↘					↘		
Parinari macrophylla											↗			↗	↗				↓	↓	↓	↓			
Piliostigma reticulatum											↗	↙		↗	↗	↘	↘	↘			↘	↘	↘		↘
Senna singueana (syn. *Cassia singueana*)												↙				↓								↘	
*Ziziphus mauritiana**									↘		↗	↙	↘			↘	↘	↘	↘				↘		

Further species at H2 and H3 locations: *Afzelia africana* H2 ⇂, H2 ⇂; *Dombeya multiflora* H2 ⇂; *Gardenia sokotensis* H2 ⇂; *Isoberlinia doka* H3 ⇂; *Parinari curatellifolia* H2 ↘, H3 ⇂; *Pavetta crasipes* H2 ⇂; *Saba senegalensis* H2 ↘, H2 ⇂; *Terminalia glaucescens* H2 ⇂; *Terminalia mollis* H2 ⇂, H3 ⇂; *Trichilia emetica* H2 ↘

*Key species for resource management in the Sahel (species that are declining or have disappeared in many villages)

[a]Villages in the Sudanian Zone of Burkina Faso

[b]It is replanted in recent years

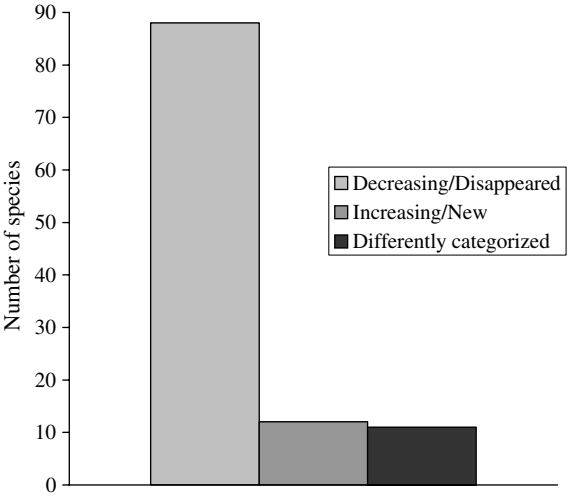

Fig. 2 Woody species mentioned by local people in the Sahel as having changed in abundance. All species were mentioned by at least 20% of the informants in one of the study village as either disappeared, declining, increasing or new

Discussion

Decreasing and disappeared species

Local knowledge indicates that many species have decreased in numbers compared to the past, some species that existed 20 or 30 years ago have disappeared at various locations. The decline affects all aspects of daily life of the local people, such as nutrition, medicine, firewood, construction, and tools. Species are also used for handicrafts and fodder. Most declining and disappeared species are of high socio-economic importance (details for uses see Hahn-Hadjali and Thiombiano (2000), Wezel and Haigis (2000), Lykke et al. (2004), SEPASAL (2005)).

Increasing and new species

The number of increasing and new species was low compared to decreasing and disappeared species. The former were mentioned only for a few and often for only one location (see Table 2). They are all exotic, except for *Lannea fruticosa* which belongs to the original flora of the Sahel (Arbonnier, 2000). Most of them were introduced by different development projects, especially in Niger, where most new species occurred. In some of these villages natural regeneration of woody species was promoted by development projects (Rinaudo, 1996; Taylor & Rands, 1992 see also Wezel & Haigis, 2000).

Differently categorised species

Not all species could be assigned to the categories decreasing/disappeared or as increasing/new; 11 species show local or regional differences. On one hand this might to be caused by projects in Niger promoting natural regeneration, which seem to be able to inverse the trend for at least some species from decreasing to increasing, e.g., *Balanites aegyptiaca*, *Combretum glutinosum*, *Guiera senegalensis* and *Ziziphus*

mauritiana. On the other hand, species such as *Acacia tortilis*, *Calotropis procera*, *Faidherbia albida* or *Parinari macrophylla* show clear differences between different countries. In the case of *Parinari macrophylla* it seems to be its very localised occurrence (Arbonnier, 2000). The fact that *Ziziphus mauritiana* is not decreasing at L1–5 and U1–3 locations might be due to its status as a holy species in these areas, which means that it is protected by traditional bans and therefore never cut for firewood (Ganaba, Ouadba, & Bognounou, 1998). In other study villages, firewood cutting or other uses might be the cause for decreasing *Ziziphus* numbers. The difference between the increase of *Acacia tortilis* in Burkina Faso and the decrease in Senegal could be caused by differences in agricultural preferences of the local ethnic groups. Intensive grazing in the villages in Burkina Faso with prevailing pastoral land use leads to bush encroachment, whereas the opposite is evident for the predominantly cropped areas in Senegal.

Similarity of locations

There is no single location totally different from the others, underlining that a general decline of species in the Sahel takes place. The most dissimilar locations are those located in the Northern Sudanian Zone (H2) or on the southern border of the Sahelian Zone (H1). In contrast, the H3 location, the southernmost location in the Northern Sudanian Zone, shows a medium similarity with many other locations, thus indicating that many declining or disappeared species in the Sahel show the same trends in the Northern Sudanian Zone. This is especially important for species, which have a wide zone of distribution (from about 400 up to 900 mm precipitation), but occur within their northern limit of geographic range in the Sahelian Zone. These species can indicate which factors are causing species change; if species decrease or disappear in the Sudanian Zone, but still exist in the Sahelian Zone, the reason for the change cannot be the climate change often mentioned (Hôte, Mahé, Somé, & Triboulet, 2002; Hulme, 2001). Instead, human impact has to be the major factor. This seems to be the case for: *A. ataxacantha*, *A. digitata*, *A. inermis*, *A. leiocarpa*, *B. aethiopium*, *B. senegalensis*, *C. pentandra*, *C. glutinosum*, *C. micranthum*, *C. nigricans*, *C. religiosa*, *D. mespiliformis*, *F. albida, F. gnaphalocarpa*, *G. ternifolia*, *K. senegalensis*, *M. inermis*, *P. biglobosa*, *P. reticulatum*, *P. africana*, *S. birrea*, *T. indica*, *V. paradoxa*, *V. doniana*. Some of these species were also reported as decreasing in other areas in the Sudanian Zone in southern Burkina Faso (Lykke, Mertz, & Ganaba, 2002, Kristensen & Balslev, 2003).

Reliability of local information

A clear correspondence among answers from independent informants and villages show that the local perceptions of vegetation changes are reliable. Possible problems with translations from local names to scientific names or general communication problems can be minimised by using a certain limit for integrating species into the analyses. We used the 20% threshold for the data from individual interviews to exclude species that were mentioned by only one or very few people at a location and thus might be arbitrary. This of course poses the problem that naturally rare species might be under-represented or not listed. In one of the studies in Burkina Faso, it could be shown that this is normally not the case, as most people knew nearly all of the woody species occurring in the area (Lykke, Fog, & Madsen, 1999). In this

area vegetation surveys were made to compare local knowledge to scientific field studies (Lykke et al., 2004). The study concluded that local people are obvious informants for detailed information about environmental change and can give additional information about rare species compared to vegetation studies. In free-listing interviews it might occur that rare species are overlooked, but by having normally between 4 to 10 persons in such a discussion this can be minimised.

Resource management and development

The large number of declining/disappearing species reveals a need for improved resource management. In order to allow a focus on the most endangered species in regional and local resource management, key species were extracted (see species with * in Table 2). Common characteristic of key species is that they are declining/disappearing in many areas. This key species list can serve as a support tool for regional and local resource management, although up-scaling to the whole Sahelian Zone from a few case studies might not be useful for all local conditions. The fact that most of the key species identified, are multi-purpose species used in many ways by the local population, underlines that management of woody vegetation plays a crucial role.

Natural regeneration of many species is low because young seedling are often grazed by livestock or eliminated by annual clearing of fields. To improve regeneration, some species need to be specifically protected from being grazed or by selective clearing of fields. This seems to be the easiest, cheapest and most promising way, as shown by some successful projects. In southern Niger, most of the peasant promoting regeneration of natural woody species on their fields benefited from sufficient wood production for their household and increasing sustainable crop yields after 2–3 years (Taylor & Rand, 1992, see also Joet, Jouve, & Banoin, 1998; Rinaudo, 1996).

An important issue for woody species management is land and tree tenure. In Niger for example, the forest law ''Code Forestier'' is obviously not effective to protect trees from being cut. The ''Code Forestier'' allows only people to use trees when they can prove that they planted the trees themselves. This is not easy for local farmers and contradicts the tradition, where a tenant farmer is not allowed to plant trees because this might lead to a long-term claim to the trees or even to the ground (Alloké & Issoufou, 1991, Neef, 1999, Sambou, Lykke, & Goudiaby, 2003).

Conclusions

There is an overwhelming trend of decreasing and disappearing woody species in Sahelian West Africa. The present study gives a clear overview of the status of a large number of species. Some local differences exist which can be partly explained by local species conservation status such as holy species or the prevailing land use systems of the different ethnic groups. Although efforts exist to increase woody species numbers or simply vegetation cover, they are mostly focused on the local level. This reveals a need for an improved resource management of species declining throughout the Sahel, which should be based at both local and regional levels. The list given in the present study provides a guide to select indigenous woody species for the promotion of natural regeneration, reforestation and other forms of multiplication.

Acknowledgements We thank Karen Hahn-Hadjali and Adjima Thiombiano very much for supplying us with the raw data from their case study as well as for their comments to this paper. We further thank Elke Mannigel for corrections on the paper.

References

Alloké, P., & Issoufou, M. (1991). Le rapport entre la tenure foncière et la tenure de l'arbre. Study prepared by Research Centre for Economic Development of the University of Michigan for Secrétariat Permanent du Code Rural, Ministère de l'Agriculture et de l'Elevage, Niamey, Niger, 96 pp.

Anhuf, D. (1995). Paleoclimate and paleovegetation in West Africa. In N.E. West (ed.), *Proceedings of the Fifth International Rangeland Congress*, Vol. 1 (pp. 11–12). Salt Lake City, July 23–28.

Arbonnier, M. (2000). *Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest*. Montpellier, Paris: CIRAD – MNHN – UICN, 541 pp.

Ballouche, A., & Neumann, K. (1995). A new contribution to the Holocene vegetation history of the West African Sahel: pollen from Oursi, Burkina Faso and charcoal from three sites in northeast Nigeria. *Vegetation History and Archaeobotany, 4*, 31–39.

Bandré, E. (1996). Anthropisation du couvert végétal dans la province de Namentenga et ses conséquences socio-économiques. Cas de la région de Tougouri, en zone sub-sahélienne (centre nord du Burkina Faso). *Berichte des Sonderforschungsbereiches 268*, Vol. 7 (pp. 17–31). Frankfurt, Germany.

Bergeret, A., & Ribot, J. C. (1990). *L'arbre nourricier en pays sahélien*. Ministère de la Coopération et du Développement et la Fondation de la Maison des Sciences de l'Homme, Paris, 237 pp.

Breman, H., & Kessler, J. -J. (1995). *Woody plants in agro-ecosystems of semi-arid regions–with an emphasis on the Sahelian countries*. Advanced Series in Agricultural Science 23. Berlin: Springer, 340 pp.

Claude, J., Grouzis, M., & Milleville, P. (1991). *Un espace Sahélien, la mare d'Oursi, Burkina Faso*. ORSTOM: Paris.

Gakou, M., Force, J. E., & McLaughlin, W. J. (1994). Non-timber forest products in rural Mali: a study of villager use. *Agroforestry Systems, 28*, 213–226.

Ganaba, S., Ouadba, J. -M., & Bognounou, O. (1998). Les ligneux à usage de bois d'énergie en région sahélienne du Burkina Faso: préférence des groupes ethniques. *Sécheresse, 9*, 261–268.

Gonzalez, P. (2001). Desertification and a shift of forest species in the West African Sahel. *Climate Research, 17*, 217–228.

Guinko, S., & Pasgo, L. J. (1992). Harvesting and marketing of edible products from local woody species in Zitenga, Burkina Faso. *Unasylva, 43*(168), 16–19.

Hahn-Hadjali, K., & Thiombiano, A. (2000). Perception des espèces en voie de disparition en milieu gourmantché: causes et solutions. Berichte des Sonderforschungsbereichs 268, Bd. 14, (pp. 285–297). Frankfurt, Germany.

Hôte, Y., Mahé, G., Somé, B., & Triboulet, J. P. (2002). Analysis of a Sahelian annual rainfall index from 1896 to 2000; the drought continues. *Hydrological Science Journal, 47*(4), 563–572.

Hulme, M. (2001). Climatic perspectives on Sahelian desiccation: 1973–1998. *Global Environmental Change, 11*, 19–29.

IEMVT (1977). *Pâturage des l'O.R.D. du Sahel et de la zone de délestage au nord-est de Fada N'Gourma*, Vol. 1–3. IEMVT, Maison Alfort.

IPNI (2004). *International Plant Name Index*, http://www.ipni.org/index.html, (accessed Aug. 2004).

Joet, A., Jouve, P., & Banoin, M. (1998). Le défrichement amélioré au Sahel. Une pratique agroforestière adoptée par les paysans. *Bois et Forêts des Tropiques, 255*(1), 31–44.

Kéré, U. (1998). Vegetation und Wildpflanzennutzung in der Region Tenkodogo (Burkina Faso). *Etudes sur la Flore et la Végétation du Burkina Faso et des Pays avoisinants, 4*, 3–55.

Knierim, A. (1991). Die Wahrnehmung von Umweltveränderungen bei den Rimaibe und den Fulbe – Fallstudie im Sahel von Burkina Faso. Unpublished master thesis. University of Hohenheim, Germany, 118 pp.

Kristensen, M., & Balslev, H. (2003). Perceptions, use and availability of woody plants among the Gourounsi in Burkina Faso. *Biodiversity and Conservation, 12*, 1715–1739.

LeHouérou, H.N. (2002). Man-made deserts: desertization processes and threats. *Arid Land Research and Management, 16*, 1–36.

Lezine, A. M. (1989). Le Sahel: 20 000 ans d'histoire de la végétation – reliques végétales, zonation de la végétation, paléoclimats. *Bulletin de la Société Géologique de France, 5*(1), 35–42.
Lykke, A. M., Fog, B., & Madsen, J. E. (1999). Woody vegetation changes in the Sahel of Burkina Faso assessed by means of local knowledge, aerial photos, and botanical investigations. *Danish Journal of Geography Special Issue, 2*, 57–68.
Lykke, A. M., Kristensen, M. K., & Ganaba S. (2004). Valuation of local use and dynamics of 56 woody species in the Sahel. *Biodiversity and Conservation, 13*, 1961–1990.
Lykke, A. M., Mertz, O., & Ganaba, S. (2002). Food consumption in rural Burkina Faso. *Ecology of Food and Nutrition, 41*, 119–153.
Müller, J., & Wittig, R. (2002). L'état actuel du peuplement ligneux et la perception de sa dynamique par la population dans le Sahel burkinabé – présenté à l'exemple de Tintaboora et de Kollangal Alyaakum. *Etudes sur la Flore et la Végétation du Burkina Faso et des Pays avoisinants, 6*, 19–30.
Neef, A. (1999). *Auswirkungen von Bodenrechtswandel auf Ressourcennutzung und wirtschaftliches Verhalten von Kleinbauern in Niger und Benin*. Peter Lang, Europäischer Verlag der Wissenschaften, Frankfurt, 290 pp.
Nicholson, S. E., Tucker, C. J., & Ba, M. B. (1998). Desertification, drought, and surface vegetation: an example from the West African Sahel. *Bulletin of the American Meteorological Society, 79*(5), 815–829.
Rinaudo, T. (1996). Tailoring wind erosion control methods to farmers' specific needs'. In: B. Buerkert, B. E. Allison, & M. von Oppen (Eds.), *Wind erosion in Niger. The problem and its control*. Proceedings of the International Symposium University of Hohenheim, Germany, 5–7 December 1994, pp. 161–171.
Sadio, S., Dione, M., & Ngom, M.S. (2000). Région de Diourbel: Gestion des ressources forestière et de l'arbre. Drylands Research Working Paper 17, Drylands Research, Somerset, Great Britain, 34 pp.
Sambou, B., Lykke, A. M., & Goudiaby, A. (2003). La problematique de l'implication des collectivites laocales dans la gestion des reserves forestieres au senegal. SEREIN-PETREA Workshop 2003. *Serein Occasional Paper*, Vo1. 16, pp. 125–136.
SEPASAL (2005). Survey for economic plants for arid and semi-arid lands. Royal Botanic Gardens, Kew. http://www.rbgkew.org.uk/ceb/sepasal/index.html. Accessed June 2005.
Taylor, G. F. II, & Rands, B. C. (1992) Trees and forests in the management of rural areas in the West African Sahel: Farmer managed natural regeneration. *Desertification Control Bulletin, 21*, 49–51.
Tucker, C. J., Dregne, H. E., & Newcomb, W. W. (1991). Expansion and contraction of the Sahara Desert from 1980 to 1990. *Science, 253*, 299–301.
von Maydell, H. -J. (1992). *Trees and shrubs of the Sahel: their characteristics and uses*. Weikersheim: Margraf Verlag.
Wezel, A. (2004). Local knowledge of vegetation changes in Sahelian Africa – implications for local resource management. Proceeding of the 16th Danish Sahel Workshop, 5–6 Jan. 2004, Aarhus, Denmark. *SEREIN Occasional Paper*, Vol. 17, pp. 37–52.
Wezel, A., & Haigis, J. (2000) Farmers' perception of vegetation changes in semi-arid Niger. *Land Degradation and Development, 11*, 523–534.
Wezel, A., & Rath, T. (2002) Resource conservation strategies in agro-ecosystems of semi-arid West Africa. *Journal of Arid Environments, 51*(3), 383–400.