The socio-economic importance of non-timber forest products for rural livelihoods in West African savanna ecosystems: current status and future trends

Dissertation

zur Erlangung des Doktorgrades

der Naturwissenschaften

vorgelegt beim Fachbereich Biowissenschaften

der Johann Wolfgang Goethe-Universität

in Frankfurt am Main

von

Katja Heubach

aus Apolda

Frankfurt am Main, 2011

(D30)

vom Fachbereich Biowissenschaften der

Johann Wolfgang Goethe-Universität als Dissertation angenommen.

Dekanin: Prof. Dr. Anna Starzinski-Powitz

Gutachter: Prof. Dr. Rüdiger Wittig

Gutachter: Prof. Dr. Ernst-August Nuppenau

Datum der Disputation: 11.04.2012

Contents

CHAPTER 1 1

General Introduction 1

CHAPTER 2 13

The Economic Importance of Non-Timber Forest Products (NTFPs) to Livelihood Maintenance of Rural West African Communities: A Case Study from Northern Benin

CHAPTER 3 43

Social Differentiation as an Important Source for Improving Conservation Measures: The Impact of Ethnic Affiliation on the Valuation of NTFP-providing Woody Species in Northern Benin, West Africa

CHAPTER 4 81

Impact of future climate and land use change on Non-Timber Forest Product provision in Benin, West Africa: Linking niche-based modelling with ecosystem service values

CHAPTER 5 101

Synthesis

SUMMARY 107

ZUSAMMENFASSUNG 111

REFERENCES 117

ACKNOWLEDGEMENTS 137

CURRICULUM VITAE 139

ERKLÄRUNG 143

CAPTION OF TABLES

Table 1
Household characteristics of studied ethnic groups (Fulani, Ditammarie, Yom, Bariba, Kabiyé);

Table 2
Total and mean income (in Euro) and income shares by income source and year

Table 3
Regression of relative NTFP income against socio-economic variables (estimation of NTFP dependency model).

Table 4
Mean household income per aeu (in Euro) and income shares by income source and ethnic group.

Table 5
Comparison between NTFP income shares by use category and ethnic group.

Table 6
Total and mean household income (in Euro) and income shares by income source and income group.

Table 7
Comparison of Gini coefficients of total household income without and with NTFP income.

Table 8
Household characteristics of studied ethnic groups (Fulani, Ditammarie, Yom, Bariba, Kabiyé).

Table 9
Wood uses: List of species covering the five most important tree species used for construction wood (A), tool wood (B) and firewood (C) by ethnic group.

Table 10
Construction material: List of species covering the five most important tree species used for making cord (A) and mats (B) by ethnic group.

Table 11
Wild foods: List of species covering the five most important tree species harvested for edible fruits (A) and edible leaves (B) by ethnic group.

Table 12
Health care: List of species covering the five most important tree species used as medicinal plants (A) and for dental care (B) by ethnic group.

Table 13
Decoration: list of species covering the five most important tree species harvested for colouring matter (decoration) by ethnic group. Species were ordered according to their importance within the use category (UVSC). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

Table 14
Commercial use: List of species covering the five most important tree species harvested for commercial use by ethnic group.

Table 15
The thirty most important woody plant species according to overall use-values (UVS).

Appendix 1
Full list of plant species mentioned as useful by respondents

Appendix 2
Ordination plots for each of the eleven use categories.

Appendix 3
Results of regressions, testing whether residence (village) and ethnic affiliation are affecting informants' choices for plant species used in the eleven investigated use categories.

Appendix 4
Cash income: List of species covering the five most important tree species generating cash income by ethnic group.

CAPTION OF FIGURES

Figure 1
The MA classification of ecosystem services and the links between Ecosystem Services and Human Well-being (MA, 2005).

Figure 2
The anthropocentric concept of ecosystem services: a cascade from biophysical structures / processes to ecosystem functions and ecosystem services generating benefits obtained and valued by humans (adapted from Haines-Young and Potschin (2010) and de Groot (2010).

Figure 3
Climatological Zones in West Africa (FAO, 2006: www.fao.org/docrep/009/J7948e/eSah-cl.gif)

Figure 4

Map of the study area (Department of Atakora) with the two studied villages Papatia and Chabi-Couma.

Figure 5
Comparison of NTFP income shares (in Euro) by use category and ethnic groups.

Figure 6
Comparison of NTFP income (in Euro) between income groups by use category

Figure 7
Map of the study area (Department of Atakora) with the two studied villages Papatia and Chabi-Couma.

Figure 8
Comparison of annual mean per household cash income (in Euro) generated by the sale of fruits of the five most important fruit trees by ethnic group.

Figure 9
Schematic of generating monetary ecosystem service values from NTFPs (left), the niche-based modeling procedure (right) and the linkage of both parts, in order to generate future (2050) monetary gain/loss (bottom).

Figure 10
Economic value map (US$/yr) of three savanna species in Northern Benin at a 0.1° resolution (~10×10 km): (a) *Adansonia digitata*, (b) *Parkia biglobosa*, (c) *Vitellaria paradoxa.*

Figure 11
Projected future monetary gain and loss (%) for 2050 in Northern Benin, considering three savanna species: (a) *Adansonia digitata*, (b) *Parkia biglobosa*, and (c) *Vitellaria paradoxa*.

Chapter 1

General Introduction

1. The socio-economic notion of 'natural capital'

Societal dependence on nature's services, their destruction and the realignment of traditional nature conservation

Mankind's existence is intrinsically tied to nature's services (Costanza and Daly, 1992; Costanza et al., 1997; Myers and Reichert, 1997). Not alone is natural capital the basis of life (e.g. primary production, habitat, evolutionary processes) and the guarantee for an ecological equilibrium to survive in, it is a major input factor to human (industrial) production cycles and well-being (e.g. arable land, water, wood, fisheries, recreation, spiritualism), i.e. there is an infusible societal dependence on ecological life support systems world-wide (Daily, 1997; de Groot et al., 2002; MA, 2005; Wittig et al., 2000; Figure 1).

Albeit having been acknowledged as a fundamental truth since probably the dawn of conscious civilization (Mooney and Ehrlich, 1997), and, at the latest, having experienced it by being regularly exposed to the severe consequences of nature's destruction, this notion so far did not succeed in preserving viable ecosystems. Despite having resulted in a powerful conservation movement dating back to the beginning of the last century (Armsworth et al., 2007), still, world-wide biodiversity loss remains undiminished (Butchart et al., 2010) and ecological life-support systems are constantly depleted due to society's ever-mounting demand for natural capital (Krausmann et al., 2009; MA, 2005). The era in which the level of human impact on the environment has been driving ecosystems far beyond stable conditions, i.e. the last 200 years, was even assigned a representative name: the Anthropocene (Steffen et al., 2011). Having defined planetary boundaries ("safe-operating space" for humanity) for nine core areas (climate change, biodiversity loss, excess nitrogen and phosphorus production, stratospheric ozone depletion, ocean acidification, global consumption of freshwater, change in land use for agriculture, air pollution, and chemical pollution), the authors state that for climate change, biodiversity loss, and nitrogen production humanity has already exceeded these boundaries (Steffen et al., 2011).

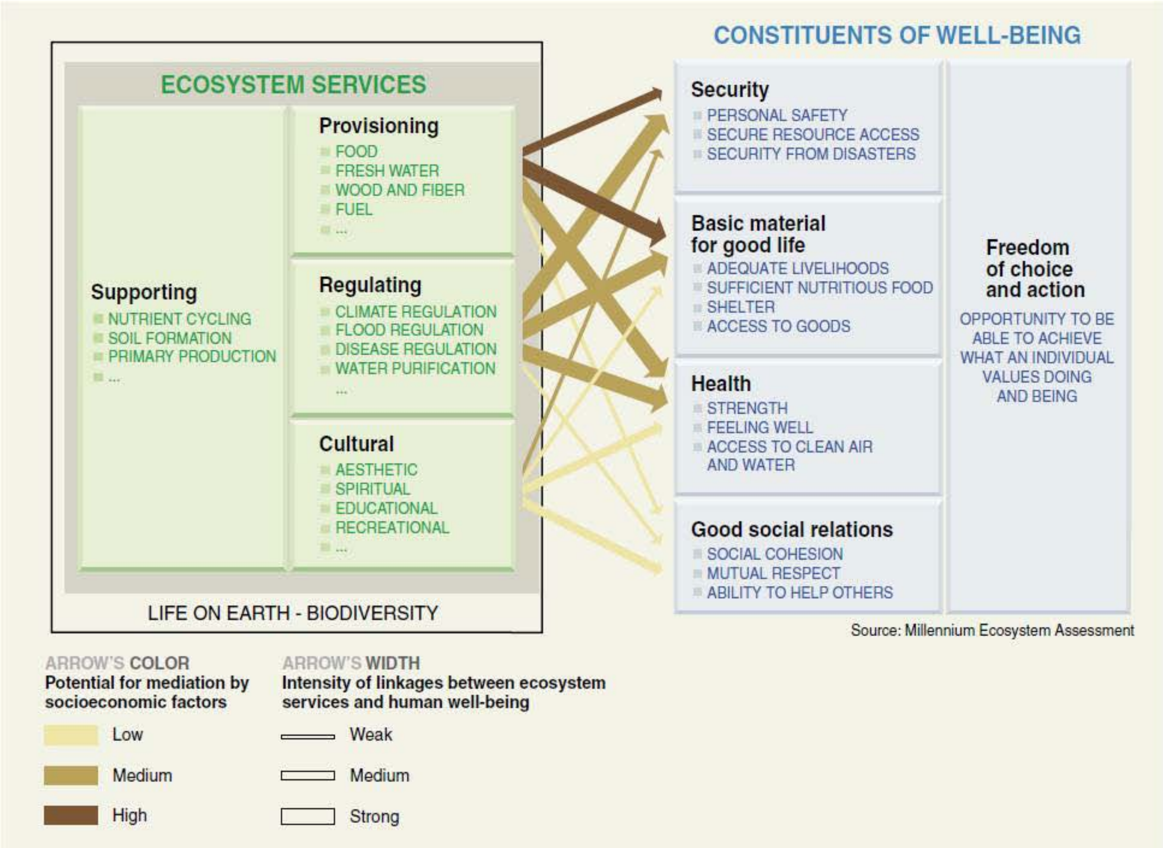


Fig. 1 The MA classification of ecosystem services, and the links between Ecosystem Services and Human Well-being (MA, 2005).

Traditional nature conservation has been securing critical thresholds of species and ecosystem functions (Clark et al., 2008; WWF, 2004) primarily via the establishment of protected areas (Adams and Hutton, 2007) and target-based conservation, introduced in the 1980s (Tear et al., 2005) to facilitate priorization in conservation planning and becoming a key component in international conservation policies (Convention on Biological Diversity, 2006; IUCN, 2003). Nevertheless, the confrontation with the still disastrous status quo of ecosystems has been triggering intensive search for new pathways towards their maintenance. Particularly, the rising recognition of social, economic and political factors being major drivers of ecosystem changes as well as the perception that people are an integral part of nature tremendously shaping it (Armsworth et al., 2007; Opschoor, 2003; Steffen et al., 2004), paved the way for the adoption of a socio-economic perspective to nature conservation. As early as in the middle of the 1980s, the interdisciplinary research area of 'ecological economics' emerged, shifting the human-excluding 'conservation versus development' to a more holistic 'conservation for development'-notion (Folke, 2006).

Ecological economics, the ecosystem services approach and the economic valuation of ecosystem services

Based on the rationale that natural capital is not fully substitutable by manufactured capital (concept of 'strong sustainability' (Neumayer, 1999)), ecological economics aims at unifying the notions of ecology and economics in order to achieve ways of living which are socially acceptable and compatible with nature (Costanza and Daly, 1992).

In the sequel, the concept of ecosystem services as an anthropocentric approach towards conservation gained increasing public and political attention (Gómez-Baggethun et al., 2009). Firstly introduced in 1981 (Ehrlich and Ehrlich, 1981), it was elaborated for a much greater public finally by the reports of the Millennium Ecosystem Assessment launched in 2005 (MA). The economic framing of ecosystem functions as ecosystem services, i.e. the benefits people obtain from ecosystems (Daily, 1997; Figure 2), at last enabled to label and quantify these benefits and, vice versa, the impacts on human well-being in case of their destruction, particularly through human land use activities and industrial production, i.e. externalities (Toman, 1998)).

Taking the next step, the economic valuation of ecosystem services subsequently allowed for translating values of nature which hitherto merely came across as intrinsic values of nature or moral obligations to protect non-human species (WBGU, 1999), into such that could be easily tracked also by non-conservationists and decision-makers whose first thought in general was not directed at conservation, but at saving costs. The estimation of the "value of the world's ecosystem services and natural capital" published by Costanza et al. in 1997 was a landmark in the mainstreaming of the ecosystem services concept stimulating a fruitful and critical discourse about and development in the field of ecological economics (Costanza et al., 1997). Prior, ecosystem use values had been constantly understated due to a lack of economic figures compatible to put in common cost-benefit-analysis and, thus, had not been adequately reflected in either market transactions (Costanza and Daly, 1992; Costanza et al., 1997; Emerton, 2003; Gómez-Baggethun and Ruiz-Pérez, 2011) or national accounting (Baumgärtner, 2002; Hassan et al., 2002; Mkanta and Chimtembo, 2002; TEEB, 2008, 2010). Economic valuation can significantly contribute to overcome this market failure (Toman, 1998; Troy and Wilson, 2007; WRI, 1998). Next to uncovering the hidden value of and due to destruction gone benefits from ecosystem services, respectively, valuation enabled to calculate the expenses for ecosystem service restoration (replacement cost approach) and such costs to be likely avoided by appropriate conservation measures (avoided costs approach).

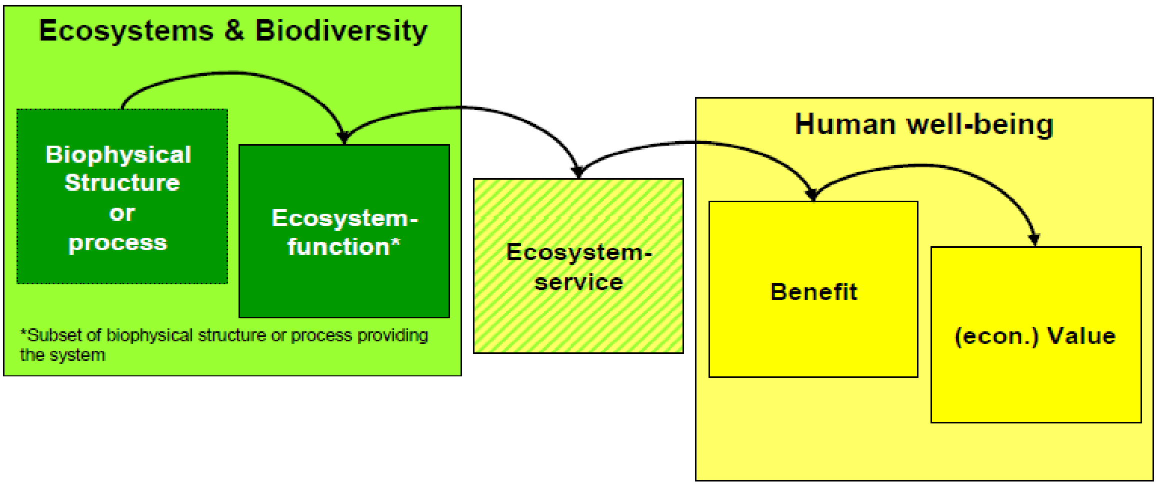


Fig. 2 The anthropocentric concept of ecosystem services: a cascade from biophysical structures / processes to ecosystem functions and ecosystem services generating benefits obtained and valued by humans (adapted from Haines-Young and Potschin (2010) and de Groot (2010).

In this context, the study "The Economics of Ecosystems and Biodiversity" (TEEB, 2008, 2010), which was launched by the German Federal Government in 2008 (interim report) and 2010 (final report), reviewed existing literature about ecological economics and set a common baseline for the valuation of natural capital. The major objective was to communicate the costs that are generated by the biodiversity loss-induced decrease of ecosystem services to decision-makers and the public to emphasize the inherent economic aspect. Out of a remarkable spectrum of studies considered for the report, one of the major issues emerging were pollinator services provided by wild bees. For instance, in Costa Rica, this regulating ecosystem service was estimated at US$ 395 per hectare per year, accounting for 7 % of total farm income (Ricketts et al., 2004). In Western Kenya, it represented even 40 % of annual revenue from crop production (Kasina et al., 2009). The total economic value of insect pollination globally is quoted as € 153 billion equalling 9.5 % of worldwide agricultural production (Gallai et al., 2009). Bearing in mind the tremendous global pollinator losses in 2011 these data clearly highlight the significance of this ecosystem service to human welfare (UNEP, 2010).

Another issue on ecosystem service valuation concerns the benefits that residents, and especially the fishery industry, obtain by healthy and sustainably fished marine ecosystems: The current combination of enormously subsidized industrial fishing and weak institutions has led to a decrease in income from global marine fisheries calculated at US$ 50 billion per year (World Bank and FAO, 2009).

Bespeaking costs occurring through technical solutions in order to restore ecosystem function, a key point is the 'avoided cost approach'. By way of example in New York City, landowners were paid for avoiding pollution of down-stream waters (run-off waste and nutrients) in avoidance of having to build costly new water treatment facilities in town. Taking this option saved New York City approximately between US$ 4.5 and 7 billion (Elliman and Berry, 2007).

In a nutshell, ecosystem services valuation can provide highly treasurable insights into ecosystems' economic performances and their relevance in human production cycles (Costanza et al., 1997). If adopted appropriately, i.e. having correctly considered the characteristics of the ecosystem service in question, having involved the adequate stakeholders, and having applied the apposite valuation method (market-based valuation or stated preference methods like contingent valuation), the economic framing and valuation of ecosystem services can serve as a promising tool for conservationists to bring their environmental concerns on to the political scene, underpinning the economic momentousness of natural capital for human well-being (WRI, 1998). As Goméz-Baggethun and Ruiz-Pérez (2011) have put it: "From the ecosystem services approach the conservation of ecological systems stands out as a necessary prerequisite for long-term economic sustainability." p. 615. The ecosystem service approach considerably changed the rationale of the discourse about effective and target-based nature conservation, natural resource management, and related issues of public policy (de Groot et al., 2010;

WRI, 1998). Increasingly, market-based approaches such as 'payments for ecosystem services' enter the area of nature conservation (Gómez-Baggethun et al., 2009) complementing traditional conservation concepts.

2. Non-timber forest products (NTFPs) as provisioning ecosystem services of West African savannas

NTPFs' contribution to rural livelihood maintenance in West Africa

For millennia, wild native plant and animal species have been forming an inherent part of the livelihoods of rural communities living in West African savannas (Boffa, 2000). They have been key to satisfying household subsistence needs in terms of nutrition, medical care, energy demand, and construction purposes, amongst others, as well as to their cultural self-conception and traditional belief-systems (Kristensen and Lykke, 2003; Lykke et al., 2004; Schumann et al., 2011, Sieglstetter et al., 2011). The variety of products extracted from these species in forests or deduced land use formations (e.g., parklands in agroforestry systems) are subsumed as non-timber forest products (NTFPs) comprising all biological matters except sawn timber (CIFOR, 2011). Typical NTFPs are fruits, seeds, bulbs, bark, fibres, roots, leaves, fish, game as well as small wooden poles and firewood, amongst others (Cunningham, 1996; Peters, 1994). Under the Millennium Ecosystem Assessment they are classified as provisioning ecosystem services (MA, 2005; Figure 1).

Next to fulfilling subsistence needs, NTFPs provide a valuable source of cash income contributing to meet domestic expenditures (Cavendish, 2002; Kristensen and Balslev, 2003; Lykke et al., 2004) and holding an important insurance function in times of crisis, e.g., lean times caused by crop failure (Angelsen and Wunder, 2003; Arnold and Pérez, 2001; Shackleton and Shackleton, 2004).

The extraction of NTFPs particularly attracts the African rural poor, since their collection does not require professional skills or equipment and harvest sites are commonly characterized by open or semi-open access. Beyond, despite being a low-return activity at high amounts of work, NTFP extraction still displays low opportunity costs given extremely thin labour markets in rural areas. Thus, it well complements other common basic income sources in sub-Saharan Africa as there are tillage and animal husbandry.

Threats and challenges to NTFP provision: major drivers of change

However, due to climate and land use changes impacting on West African savanna ecosystems (Hahn-Hadjali and Thiombiano, 2000; IPCC, 2007; Sala et al., 2000; Wittig et al., 2007) the availability and sustainable use of these ecosystem services are soaringly jeopardized, and consequently, the safe-guarding of dependent rural livelihoods.

Regarding the expected high levels of economic and population growth in Africa, land use change has been playing a key role concerning this matter (Jetz et al., 2007; Sala et al., 2000). The conversion of savanna area into cultivated land for subsistence farming has steadily increased in West Africa over the last decades (Brink and Eva, 2009; EarthTrends, 2003) with simultaneously shortened fallow periods reducing the time necessary for soil recovery (Wittig et al., 2007). In addition, the progressive promotion of cash crops (e.g., cotton, cashew nuts) in the region has resulted in shifts in traditional land management and cultivation techniques, e.g. fertilizer, technical engineering with clear-cutting of tree savanna, and introduction of alien species (Ræbild et al., 2007; Schreckenberg, 1999; Schumann et al., 2010; Taita, 2003; Wezel and Lykke, 2006). That is, resource and particularly land management in savanna ecosystems has to cope with articulate trade-offs concerning the concurrent satisfaction of subsistence and cash needs. In interaction with unsuitable law regulations and land tenure (Yatich et al., 2008), these developments have substantial effects on the ecological functions of savanna ecosystems and derived ecosystem services like NTFPs and, likewise, water purification, primary production, carbon storage and sequestration, amongst others (Brink and Eva, 2009; Ouédraogo et al., 2010; Polasky et al., 2011; Wittig et al., 2000). Hence, local communities are facing increasing vulnerability in terms of maintaining life-supporting systems (Fisher et al., 2010; Thomas, 2008).

Traditional conservation in West Africa and the capacity of economic valuation

Like elsewhere, conservation in West Africa first of all meant the establishment of protected areas strictly excluding human activities (Adams and Hutton, 2007). However, especially in developing countries, this concept of ‘conservation versus development’ (Folke, 2006) turned out to be a pitfall since local communities living in and adjacent to protected areas are heavily dependent on the utilization of natural capital, while coevally facing very low elasticity to substitute products and economic returns when cut off from natural areas (Adams and Hutton, 2007; Angelsen and Wunder, 2003; FAO, 1999a). The number of forest-dependent people was estimated at some 1.6 billion people globally (World Bank, 2001; renewed 2004) and the contribution of ecosystem services and non-marketed ecosystem goods to the so-called 'GDP of the poor' (i.e. the total source of livelihoods of forest-dwelling poor households) calculated as between 47 % and 89 % (TEEB, 2010). Subsequently, protected areas' unavoidably must have act opponent to developmental endeavours aiming at sustaining livelihoods: Restricting access to NTFPs was a likely source for increasing poverty (Sunderlin et al., 2005; Vedeld et al., 2007). In the sequel, policy-makers from both the conservation and the development sector had to think about how to jointly design appropriate measures which, on the one hand, securing biodiversity and ecosystems, while, on the other hand, not reducing human welfare (Ellenberg, 1993; Sunderlin et al., 2005).

In this context, economic valuation notably can facilitate this process and reconcile diverging objectives by setting economic incentives. On the one hand, for sustainable NTFP extraction on the user's part (Angelsen and Wunder, 2003) and, on the other hand, for reasonable cost-benefit analysis on the part of the decision-makers, i.e., considering the protection of forest as viable land-use option among others like for instance cash crops (Farber et al., 2002; TEEB, 2008; Troy and Wilson, 2007).

Thus, in order to support this positive development, it is crucial to provide figures about the economic relevance of NTFPs for livelihood maintenance in rural Africa. As reported in very few lately published studies, the contribution of NTFPs to total household income was approximately 15 % in Malawi (Kamanga et al., 2009), 27 % in Northern Ethiopia (Babulo et al., 2009) and 35 % in Zimbabwe (Cavendish, 2000). However, comparability of these studies is challenging due to different data sets and socio-economic contexts. Moreover, respective studies for the semi-arid tropics in West Africa are largely missing (TEEB, 2008). A first effort to enhance respective existing knowledge was carried out by Faye et al. (2010) who found NTFPs to make up 40 % of annual income in Mali which belongs to the Sudano-Sahelian zone. For the Sudanian zone further southwards, there is no such data available leading to a lack of understanding of the relevance of savanna products for the livelihood strategies of rural communities in that region. There is virtually no information about either the economic importance of different NTFP use categories, products and single plant species, or differences in terms of NTFP dependency between diverse socio-economic groups (local ethnic groups, income groups). Furthermore, in the light of prospected environmental changes it is crucial to assess their impacts on the future provision of theses ecosystem services. In accordance to that, the thesis at hand delivers precious information filling in this data gaps by taking the example of Northern Benin.

3. Aims and outline of this thesis

The major objective of this thesis was to analyse the economic importance of NTFPs in rural household economy in the Sudanian zone of West African savannas, aiming at understanding the current role of these ecosystem services within livelihood strategies of different socio-economic groups and assess their future availability with regard to severe environmental changes.

Description of the study area: biophysical and socio-economic characteristics

The research was conducted in Benin, a sub-Saharan country in the West African Sudanian zone. With a land area of approximately 113,000 km² the country hosts roughly 8 million people, as was estimated in 2008 (Przyrembel, 2011). The population is estimated to increase about 20-30 % by 2030 (Vodounou, 2008). Benin is one of the poorest developing countries in the world, listed on rank 134 (out of 169 countries) in the Human Development Index, i.e. Benin displays both low life expectancy (56 years) and education index (0.365). For comparison, Germany is assigned HDI-rank 9 with a life expectancy of 80 years and its education index is 0.928. However, Benin ranks in the upper level of the sub-Saharan African states (UNDP, 2010). The majority of dwellers live rural, only 40 % of the population lives in cities. The country is home to a great cultural variety and hosts more than 60 different ethnic groups (www.arbre-de-vie.org).

The study area belongs to the southern Sudanian zone which is characterized by a tropical climate with annual change of dry and wet seasons, the latter from May to November (annual rainfall ca. 1300 mm/m²; Figure 3). The mean annual temperature is 27°C. Vegetation types in the savanna ecosystem range from tree, shrub and grass savanna to woodlands (Krohmer, 2004, Sieglstetter, 2002). The area under study is covered with deciduous shrublands.

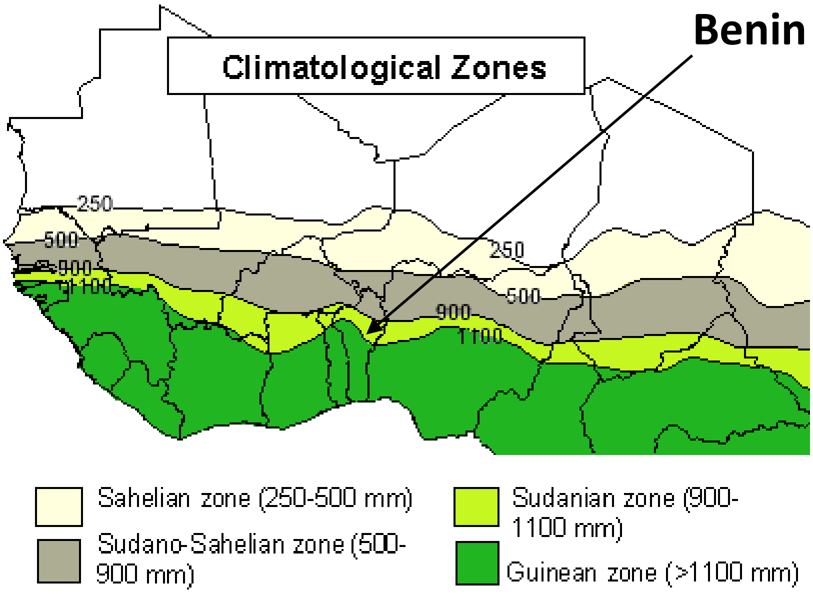


Fig. 3 Climatological Zones in West Africa (FAO, 2006: www.fao.org/docrep/009/J7948e/eSah-cl.gif)

The villages and adjacent areas studied are located in the north-western Atacora District (Papatia, Chabi-Couma and Niangou) and the Alibori District (Sampéto) further north-east. In 2008, roughly 62 % of the districts' inhabitants lived in rural areas and more than 70 % were classified as poor. Rural livelihoods are preponderantly based on rain-fed crop production in traditional shifting cultivation systems. After a multiannual tillage the cleared fields lie fallow between 6 and 15 years leading, by reason of habitual small-scale land use, to a typical mosaic pattern of cultivated areas and fallows. Crops grown for the local diet encompass sorghum, millet, maize, legumes, yams and manioc, amongst others. While clearing an area for cultivation particular socio-economically important trees are spared from felling (Boffa, 1999; Glèlè Kakaï et al., 2011). This type of agroforestry system, resulting in so-called parkland, includes cultivation and conserving of NTFP-providing tree species, thereby forming an inherent aspect of the savanna landscape (Schreckenberg et al., 2006). Typical trees exempted from felling are *Vitellaria paradoxa* (subspecies *paradoxa*, Shea Tree or karité), *Parkia biglobosa* (African Locust Bean Tree or néré) and *Adansonia digitata* (African Baobab). Animal husbandry is only a minor income activity. Livestock kept in the region ranges from cattle over medium-sized livestock (goats, sheep, and hogs) to poultry (chicken, guinea fowls).

The ethnic groups investigated represent the major ethnicities in the study area (Fulani, Ditammarie, Yom, Bariba and Kabiyé). Autochthon to the region is the people of the Bariba, the other ethnic groups immigrated from various areas. Four of the five groups are traditional tiller societies (Ditammarie, Bariba, Yom and Kabiyé) while the Fulani are originally nomadic pastoralists herding cattle on fixed annual feeding routes (transhumance). However, due to ongoing land use changes in terms of increasing pressure for agricultural land and severe drought events many Fulani people in the region quitted transhumance and started to settle and adapt farming as major livelihood activity (de Bruijn and Dijk 1994; Bolwig and Paarup-Laursen 1999); merely a minor proportion of new settlers maintain animal husbandry as a major income source.

Structure of the thesis

The thesis at hand comprises of three major parts: The first study addresses the economic contribution of NTFPs to a local household's livelihood. Based on a household survey comprising of 230 rural households I gathered information about collected quantities of and revenues gained from extracted NTFPs. Comparing them to income generated by other livelihood activities (e.g. crop cultivation, animal husbandry, off-farm income) enabled me to determine the economic relevance of NTFPs in the investigated households, i.e. in view of total household income. Furthermore, I investigated differences between five ethnic groups as well as three different income groups in order to assess whether patterns of NTFP dependency exist. I tested the hypothesis, that poorer households are comparatively higher dependent on income from NTFPs than wealthier households. The findings of this study help to gain clarity about the economic relevance of NTFPs for rural livelihoods.

The second study analyses the impact of social differentiation (ethnicity, residence) on the valuation of local species. I studied differences in use preferences for native woody species between five local ethnic groups in two villages (230 households), examining eleven NTFP use categories (e.g. nutrition, health care, energy supply, construction purposes). Specifically, I sought to identify which tree species are the economically most important for rural households and if their economic relevance changes due to their ethnic affiliation. The results serve to show if social differentiation shapes peoples' preferences for local woody species, delivering valuable information for local policy-makers aiming at adjusting existent conservation measures to peoples' real needs.

The third study was conducted in collaboration with my colleague Jonathan Heubes. We aimed at developing a novel approach to assess the impacts of climate and land use change on the economic benefits derived from NTFPs. The objective of the study was to generate a map displaying regional threats of loosing well-being due to climate and land use change. In particular, with regard to both the local importance and the growing international relevance of several NTFPs, an improved understanding of current and future NTFP availability and, thus, benefits is crucial for decision-makers in order to design appropriate management strategies. We performed 60 household interviews in Northern Benin to gather data on annual quantities and revenues of collected NTFPs from the three most important savanna tree species: *Adansonia digitata*, *Parkia biglobosa* and *Vitellaria paradoxa*. The species' current and future (2050) occurrence probabilities were appraised by calibrating niche-based models with climate and land use data at a 0.1° resolution. To assess future economic gains and losses, respectively, we linked the modelled species occurrence probabilities with the spatial monetary values. With our results we provide a first benchmark for local policy-makers to economically compare different land-use options today and adjust existing management strategies for the three species for the near future.

The last part of this thesis provides an encompassing synthesis of the major findings of the three studies aiming at drawing a comprehensive picture of the socio-economics of NTFP-extraction in Beninese savanna ecosystems today and in the near future. Beyond, I will give possible policy recommendations dealing with trade-offs concerning land use decisions in Benin.

Chapter 2

The Economic Importance of Non-Timber Forest Products (NTFPs) to Livelihood Maintenance of Rural West African Communities: A Case Study from Northern Benin

with Rüdiger Wittig, Ernst-August Nuppenau and Karen Hahn
published in *Ecological Economics* 70 (2011): 1991-2001.

ABSTRACT

Non-Timber Forest Products (NTFPs) contribute significantly to a rural household's livelihood in the African semi-arid tropics. This study examines the income from NTFPs and the dependency on these of different socio-economic groups in Northern Benin. Using survey data from 230 households of two villages, we firstly compared incomes of five different ethnic groups being differentiated by their traditional source of livelihood and regional provenance. Secondly, we investigated disparities between three income groups. On average, income from NTFPs accounted for 39 % of total household income and had a strong equalizing effect on it. However, the economic relevance of NTFPs differs between households: Poorer households are relatively more dependent on NTFPs in order to fulfil basic needs than wealthier households. However, the latter extract more NTFPs in quantitative terms and have significantly higher cash returns than poorer ones. This is mainly due to a significant greater land holding. Moreover, our study revealed that net income from NTFPs reflects traditional sources of livelihoods of different ethnic groups. In conclusion, both conservation and development strategies should take into consideration the socio-economic context of different beneficiaries of savanna woodland resources in order to apply appropriate measures to poverty reduction.

1. Introduction

1.1. NTFPs as important provisioning ecosystem service

There is growing evidence that Non-Timber-Forest-Products (NTFPs) contribute significantly to maintain livelihoods in rural Africa, Asia and elsewhere in developing countries (Cavendish, 2000; Campbell and Luckert, 2002; Shackleton and Shackleton, 2004; Viet Quang and Nam Anh, 2006; Cocks et al., 2008). NTFPs embody all biological matter of wild plants and animals other than timber extracted from forests and woodlands, e.g. fruits, nuts, vegetables, game, medicinal plants, resins, bark, fibres, palms, grasses as well as small wood products and firewood, amongst others (CIFOR, 2011). NTFPs have three main functions in the household economy of rural communities living in or adjacent to the forest. Firstly, they help to fulfil households' subsistence and consumption needs in terms of e.g. energy and nutrition as well as medical and construction purposes. Secondly, they serve as a safety-net in times of crises (e.g. income shortages from other income sources, e.g. crop failure) and thirdly, some NTFPs provide regular cash income (Cavendish, 2002; Angelsen and Wunder, 2003; Chileshe, 2005; Shackleton et al., 2007). While the extraction of NTFPs is work-intensive and yields comparatively low returns to labour, coevally, it only requires few skills and technology and extraction sites mostly are categorized by open or semi-open access (Angelsen and Wunder, 2003). These characteristics of NTFP extraction make it an attractive and important income opportunity to the rural poor. However, since the demand for conversion of land for cultivation purposes increases with growing populations in developing countries (Barbier and Burgess, 2001) the opportunity costs of the preservation of forests and woodlands are high (Shone and Caviglia-Harris, 2006; Illukpitiya and Yanagida, 2010) threatening the availability of NTFPs.

Recent case studies from Africa found NTFPs to be an essential income source in total household economy. In Malawi, wild and planted fruit trees on common land make up to 15 % of total income (subsistence and cash income) (Kamanga et al., 2009). In the Republic of Congo, wild plants contribute 10 % to households' total food consumption (de Merode et al., 2004) and Babulo et al. (2009) calculated that the provision of consumptive forest environmental products (i.e. fuel wood, farm implements, construction materials, wild food items, herbs, medicines) constitutes 27 % of the income in northern Ethiopia. A very comprehensive study of forest environmental income in Zimbabwe conducted by Cavendish (2000) found wild foods (plants and animals), medicinal plants, various wood and grass uses, forage plants as well as soil and termite uses even to account for 35 % of the average rural income. Despite that the comparability of these studies is difficult since most of them merely investigated a certain set of forest products, they throughout underpin the economic relevance of NTFPs. However, respective studies of the semi-arid tropics in western Africa are largely missing. Contemporary research only focused on access to NTFPs in Burkina Faso (Coulibaly-Lingani et al., 2009) as well as on their local values to rural dwellers (Vodouhê et al., 2009) and on their location and procurement in Benin (Schreckenberg, 1999). Others studied single species and their trade in Benin (e.g. Avocèvou-Ayisso et al., 2009). Thus, our study, which aims at investigating the link between income from NTFPs and rural household characteristics in Northern Benin, enhances existing knowledge of West African settings. This is in accordance with the TEEB-study that identified a lack of respective studies from several African developing regions (TEEB, 2008).

1.2. Household characteristics and external factors determining dependency on NTFPs

The economic importance of NTFPs in Benin is not well documented, leading to a lack of understanding of their relevance within the livelihood strategies of rural communities. Rural livelihoods are linked to socio-economic characteristics of households, e.g. household wealth, household composition (e.g. share of women) and percentage of adults with formal education as well as external factors like access to forests, markets and infrastructure, amongst others (Kamanga et al., 2009, Timko et al., 2010).

In general, wealthier households in rural African communities are characterized by greater levels of food-sufficiency and diverse income-earning opportunities due to e.g. better education and greater access to farmland (Emerton, 2005). That is, compared to poorer households, their differentiation in terms of income sources and livelihood strategies is augmented and so are their opportunities to cope with social, financial and environmental changes. Subsequently, their dependency on low-return activities like NTFP extraction, measured as the share of income from NTFPs in total household income, is likely to be smaller than with poorer households. However, since wealthier households are, in general, better endowed in terms of harvesting equipment and storage opportunities, have greater access to markets and are better connected to trade infrastructure (Arnold and Pérez, 2001; Angelsen and Wunder, 2003) than poorer households, they might be more engaged in NTFP extraction in quantitative terms.

Another important factor influencing the usage and importance of NTFPs to households is their ethnic affiliation: Ethnic groups differ by their social and cultural backgrounds, regional provenance and history as well as their traditional source of livelihood (agricultural or pastoral societies). Moreover, they show certain use patterns of plant resources regarding alimentation, energy supply and medicine, amongst others (Bussmann, 2006; Bussmann et al., 2006). Thus, different NTFP use patterns might also result in differences in the economic importance of NTFPs between ethnic groups. Additionally, African communities are constantly in motion in terms of migration due to demographic and / or ecological aspects leading to the necessity to adapt to new natural, social and political surroundings. The latter for instance also comprises access to resources and assets. Coulibaly-Lingani et al. (2009) could recently show that ethnic affiliation is determining access to NTFPs in Burkina Faso. Yet, until now, very few studies have focussed on the ethnic perspective of natural resource valuation. The present study sheds light on that issue.

In this study, we test the hypothesis, that poorer households are comparatively higher dependent on income from NTFPs than wealthier households and analyse further, if the affiliation to an ethnic group influences NTFP dependency. The overall objective is to investigate the economic contribution of NTFPs to the annual income of a rural household in Northern Benin, West Africa. We seek to answer the following specific questions: What is the average share of NTFP income in total income of a rural household and what are the socio-economic factors determining this mean share, i.e. NTFP dependency? Furthermore, does the economic contribution of NTFPs to total income change with the affiliation to i) an ethnic group or ii) an income group? And lastly, we investigate, if income from NTFPs reduces inequality between households.

The paper is organized as follows: In section 2 we describe and define the key terms used in this article followed by features of the study area (biophysical environment and socio-economic setting, land tenure and access to woodland resources, ethnic groups). In section 3 we delineate the study design as well as the data collection and analysis. Section 4 contains the results of the analysis of the economic contribution of

NTFPs to rural household economy a) on an average, b) comparing three income groups and c) comparing five ethnic groups. Furthermore, we address the issue of NTFP income having an equalizing effect on household inequality. Lastly, section 5 closes with some conclusions and policy recommendations.

2. Study context

2.1. Definition of key terms

2.1.1. Non-Timber Forest Products

Even though the issue whether a forest product is comprised by the term 'non-timber forest product' (NTFP) or not, has been discussed for more than 20 years now (de Beer and McDermott first used the term in 1989), a distinct terminology and, subsequently, a clear definition of the term NTFPs is still lacking. The Centre for International Forestry Research (CIFOR) defines NTFPs as "[..] any product or service other than timber that is produced in forests. They include fruits and nuts, vegetables, fish and game, medicinal plants, resins, essences and a range of barks and fibres such as bamboo, rattans, and a host of other palms and grasses". They also include "[..] wood products, such as those used for woodcarving or fuel" (CIFOR, 2011).

In 1995, the Food and Agriculture Organization of the United Nations (FAO) raised the term 'non-wood forest products' (NWFPs) in order to distinguish between wood products, non-wood forest products and forest services. To date, there is still only a working definition of NWFPs the FAO operates on (revised in 1999): "Non-wood forest products consist of goods of biological origin other than wood, derived from forests, other wooded land and trees outside the forest." (FAO, 1999a). That definition implies both products from animals and plants and the species itself, but excludes strictly all woody raw materials (small poles, stems, firewood). Referring to de Beer and McDermott (1989) timber and non-timber materials are distinguished by the level of their industrial extraction, i.e. non-timber wooden materials can be easily harvested by rural dwellers without high skills and technology requirements. Furthermore, it is unclear whether to include cultivated products (Belcher, 2003). From a conservationist's point of view the cultivation of plant species is considered rivalling to wild plants, while, regarding development concerns, plantations are seen as a potential factor to reduce access to resources for poorer people (Dove, 1994).

In this article, we use the term 'NTFPs' for plant products only, as they were the main products reported to be extracted from the forest. Our definition of NTFPs includes all biological matter of wild plants, i.e. fruits and seeds, vegetative textures (bulbs, leaves, bark, roots) as well as various small stems, twigs as well as firewood (Cunningham, 1996) extracted from savanna woodlands. Furthermore, we specifically exclude products from non-native, cultivated fruit trees due to them being private to its cultivators and, thus, are not equally accessible for rural dwellers. Hence, we consider these plants rather as 'crops' cultivated privately outside open / semi-open access savanna woodlands.

2.1.2. NTFP dependency

In 2001 the World Bank assessed the number of forest-dependent people globally, attaining a figure of some 1.6 billion people (World Bank, 2001; renewed 2004). This number was criticized due to its lack of a reasonable scientific rationale since the degree of peoples' dependency remained unclear: Being conditional upon the specific group of beneficiaries of forest goods rural people belong to (e.g. forest dwellers, farmers living adjacent to forests, commercial users and consumers of forest products), they can depend on forests either as a primary or a supplementary source of livelihood fulfilling subsistence and / or cash needs or serve as safety-nets in times of crisis (Angelsen and Wunder, 2003). That is, the nature of forest dependency is highly variable (Byron and Arnold, 1999). Thus, still lacking a proper definition of forest dependency, some authors e.g. adapted a concept which comprises certain forest products which serve as dependency indicators being hardly substitutable by alternative non-forest goods without inducing additional costs to the users (Calibre consultants and the Statistical Services Centre, 2000).

Others refer to a concept of forest dependency that is based on how strong a specific forest-based livelihood is concentrated in the investigated area (Illukpitiya and Yanagida, 2008). Forest dependency is then measured by setting a certain dependency threshold which, if exceeded, indicates higher dependency. This is e.g. the share of income derived from forest-based activities like NTFP extraction used by Fisher (2004), Dewi et al. (2005), Das and Sarker (2008) and Babulo et al. (2008), amongst others.

In this study, we measured forest dependency as the share of income from NTFPs in total household income (relative NTFP income) in order to compare different income groups. In the following we will use the term 'NTFP dependency' to express forest dependency.

2.2. General aspects of the biophysical environment and socio-economic setting of the studied region

We conducted our study in two West African villages in Northern Benin (Papatia and Chabi-Couma, 30 km apart), both belonging to the Department of Atakora (capital Natitingou; Figure 4). In 2008, the districts' population size was estimated with 667,500 inhabitants whereof 62.3 % lived in rural areas and 70.3 % were classified poor.

The region belongs to the southern Sudanian zone characterized by a tropical climate with annual change of dry and wet seasons, the latter from May to November (annual rainfall ca. 1300 mm/m²); mean annual temperature is 27 °C. Vegetation types in the savanna ecosystem range from tree, shrub and grass savanna to woodlands (see Krohmer, 2004, Sieglstetter, 2002). In 2003, Benin's total forest area was 2,650,000 hectare (covering 24 % of total land area) of which 93 % are savannas and shrublands (EarthTrends, 2003). The area under study is covered with deciduous shrublands (Figure 4).

The studied region's dominant livelihood activity is rain-fed crop production (shifting cultivation) with the main cultures being sorghum, millet, maize, rice, yams and manioc.

Livestock kept in the region ranges from cattle over medium-sized livestock (goats, sheep, and hogs) to poultry (chicken, guinea fowls). Cattle are generally scarce. Note further, that in the case of the two studied villages, the entire livestock population dropped dramatically in 2008 - the year under investigation - due to a severe disease that affected all types of livestock.

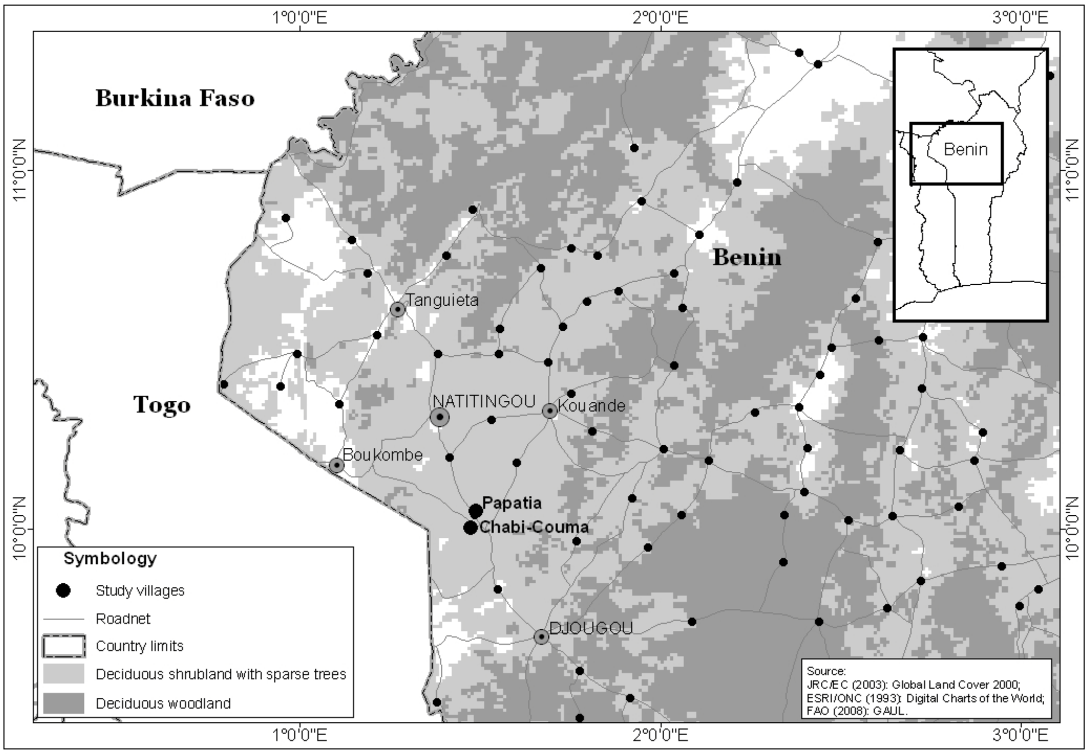


Fig. 4 Map of the study area (Department of Atakora) with the two studied villages Papatia and Chabi-Couma. Large black dots (labelled) represent the two study villages; other smaller black dots (unlabelled) are displayed in order to represent the density of villages located within the savanna ecosystem.

2.3. Traditional land tenure system and access to woodland resources

The right to distribute land to new settlers is traditionally exclusively held by the autochthonous people in the village, i.e. the *roi du terre* (the 'earth king'). He decides whether to comply with a land request or to refuse it. Land owners do not obtain land titles, but lifelong usufruct for the distributed land that is usually transferred along kin lines (Schreckenberg, 1999). Sale of land is prohibited, but land holders are entitled to pass the land to others for cultivation ('land borrowers') while keeping the right to reclaim it.

Within this traditional land tenure system, immigrants are mostly land borrowers who are endowed with fewer rights than land holders (usually autochthon villagers). For instance, extracting NTFPs from useful trees remaining on fields which were spared from felling (e.g. Sheabutter, *Vitellaria paradoxa*) is exclusive for land owners – they even remain 'private' when the land is cultivated by others. That is, land borrowers (immigrants) have no or limited access to NTFPs on fields despite cultivating the respective land (Schreckenberg, 1999).

Consequently, the greater the land holding, the likely greater the possibility to gather fruits from 'private' trees without competing with other collectors. The same applies to the accessibility to other plant resources, e.g. wood for construction purposes or firewood. Conversely, households with borrowed land have to rely stronger on common woodland resources to meet their needs while rivalling with other potential users. Common woodland within the village area is divided into distinct areas allocated to the different residing ethnic groups. Beyond the village boundary, access to woodland resources is open to everyone.

2.4. Ethnic groups of the studied area

The Department of Atakora hosts a great variety of different ethnic groups. In our studied villages, the most important ones are the Ditammarie, the Bariba, the Fulani, the Yom (Pila-Pila) and the Kabiyé (Lokpa). The Bariba are the autochthon people in the catchment, whereas the other groups migrated into the area: the Fulani came from their residential area in the east of the Atakora chain (Kouandé), the Ditammarie and the Kabiyé migrated from Togo and the Yom are originally from the Department of Bassila to the south of the study area.

While the aboriginal social system of the Ditammarie, the Bariba, the Yom and the Kabiyé is based on crop production, the Fulani are originally nomadic pastoralists herding cattle on fixed annual feeding routes (transhumance). A main part of Fulani people in the region quitted transhumance and started to settle, adapting crop farming as major livelihood activity, notably already some decades ago (de Bruijn and Dijk, 1994). Merely a minor proportion of settlers maintained recognizable herds of cattle.

Regarding the socio-economic characteristics of households, ethnic groups do not show significant differences, e.g. concerning household size, age and education of head (Table 1). However, the traditional lifestyle of the ethnic groups (pastoralist, tiller) is reflected in the figures; the Fulani are the only group owning cattle and being engaged in animal husbandry as a main employment. They are furthermore comparatively stronger engaged in healing activities, followed by the Ditammarie and the Bariba. The Fulani also display the greatest share of polygamous households. By contrast, the four tiller societies are quite similar in terms of household characteristics and assets.

Table 1 Household characteristics of studied ethnic groups (Fulani, Ditammarie, Yom, Bariba, Kabiyé); Hh(s) = households; sec = secondary

	Fulani		**Ditammarie**		**Yom**		**Bariba**		**Kabiyé**	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Socio-economic attributes of households										
Hh size (head count)	9.1	0.9	8.7	0.6	11.8	1.5	7.5	0.8	10.0	1.0
Major age group of hh head (years)	36-45		36-45		36-45		36-45		36-45	
Education of hh head (years)	0.7	0.4	2.2	0.6	1.2	0.5	0.2	0.1	0.2	0.2
Hh with polygamy (%)	64.3		37.0		41.3		11.9		23.8	
Main employment: tiller (%)	92.9		95.7		100		97.6		100	
Main employment: livestock breeder (%)	4.8		-		-		-		-	
Hhs with secondary employment (%)	38.1		80.4		60.9		61.9		78.6	
Hhs with tertiary employment (%)	14.3		4.3		0.0		16.7		4.8	
Sec. employment: retail dealer (%)	11.9		60.9		50.0		31.0		66.7	
Sec. employment: traditional healer (%)	16.7		6.7		0.0		4.8		0.0	
Total hh income (in Euro)	704	65	694	47	690	29	731	61	644	36
Index of diversification	1.90	0.09	2.02	0.05	2.03	0.04	2.05	0.07	2.03	0.04
Household assets										
Farmland size (ha/hh)	3.0	0.2	4.4	0.3	4.2	0.2	3.6	0.3	3.7	0.2
Cattle per hh	8.4	2.0	-		-		-		-	

3. Methods

3.1. Selection of villages to study

The study villages, Papatia and Chabi-Couma, were chosen, firstly, because both host a similar variety of ethnic groups and therefore analogous cultural and social structure prevails. Secondly, the villages show similar characteristics in terms of location to the next urban centre (Natitingou, ca. 35 km), availability of piped water and schooling. Electricity is rudimental (some private connections); energy demand is primarily covered through firewood. Thirdly, on the village level all surveyed households are led by males between 36 and 45 years old, have no or limited education and more than 95 % (Papatia) and 99 % (Chabi-Couma) are tillers. Due to the bigger and therefore economically more relevant market in Chabi-Couma a greater percentage of resident household members additionally work as retail dealers (71.2 %; only 16.8 % in Papatia). In Papatia the majority of secondary occupation are traditional healers (11.2 %) and livestock breeders (1.9 %) who are only located here. Around one third of households in both villages live polygamously.

3.2. Study design and data collection

We conducted a structured household survey containing closed and open questions. Questionnaire testing and adjusting was conducted prior to the survey among five randomly selected households in Papatia. The survey yielded a total of 230 households representing 26 % and 13 % of the population of Papatia and Chabi-Couma, respectively. Households were selected randomly, but by means of their ethnic affiliation (Bariba, Kabiyé, Fulani, Ditammarie and Yom). Of each ethnic group, 46 households (23 in each village) were interviewed between May and July 2009 to recall the income data of the previous year (one-year recall).

Due to determined gender roles in traditional West African rural societies, the questionnaire was split into two parts: Women gave information about the collection of wild foods, firewood consumption, medical use of plants as well as for decoration and cosmetic purposes. Men gave information about the households' composition and assets, sources of income as well as agricultural production including animal husbandry. All respondents were asked to recall quantities harvested / produced / gathered from cropping and the savanna woodland, and the respective amounts consumed / sold / bartered or given away as a gift. To assist with field work and translate the French questionnaires to the respondents we worked closely together with local interviewers who had in-depth knowledge about useful plants and were confident with all five ethnic languages.

Careful enumeration and data cleaning secured a response rate of usable questionnaires of 95 %. Despite, data collection itself is still fault-prone, since people might have had difficulties in recalling exact quantities of the product in question, when e.g. the season of harvest is dated back considerably. Moreover, they might not remember quantities of minor or rarely used woodland products (telescoping). This memory recall bias (systematic bias) might have led to underreporting of certain NTFPs while coevally highlighting those which are of higher importance both in terms of harvested quantities and economic relevance. However, since the species reported to be collected differ between households there is no particular 'set' of underreported NTFPs –

underestimation in this regard is rather random. Furthermore, given that people are heavily reliant upon NTFPs and collect them on a regular annual, mostly lifelong basis we can assume that respondents are highly aware of the quantities harvested and the returns, respectively.

In order to identify the plant species mentioned by the households, we conducted intensive field work with local healers from all five ethnic groups. Information about general aspects of the two villages (population size, land tenure, access etc.) was gathered through both key informant interviews (e.g. administrative chiefs) and informal participatory discussions with dwellers and interrogators assisting with the scientific work.

3.3. Income accounting

In accordance with Cavendish (2002) we defined a household's total income as the sum of cash income generated from various activities (e.g. crop and livestock production, collection of wild foods, small-scale activities) and the monetary equivalent of a household's subsistence use of the output of these activities. Total household income is accounted on annual basis; it reflects the net income generated by the population sample under investigation in 2008. That is the total value of output deducted by the total value of input (e.g. fertilizer for agricultural production, veterinary supplies) during the accounted period. Note that net income includes own-labour costs due to absent or thin labour markets in rural African settlements.

To calculate income we used means of local market prices (observed monthly at the two markets of Papatia and Chabi-Couma during the study period) and households' own-reported values given the local units of measure (*sac à 100 / 50 kilogramme*, *aguwe, bassine, lasoytatiya* etc.) of marketed products. Both market prices and own-reported values were found to be strongly consistent for both agricultural (crops, fruits and livestock) and woodland products which proves the relevance in income. Furthermore, taking the means of prices based on an observation of a full year corresponds with reported inflation of local market prices due to seasonality and thus differences in abundance of products. Where products had no market price, the values of close substitutes were imputed. In principle, the study revealed five different sources of income of which a household's total income is composed. These are: Income from crop farming, income from planted fruit trees, income from livestock keeping, off-farm income and NTFP income.

Net crop income equals the value derived from annual total crop output reduced by its production costs (e.g. fertilizer, wages for farm workers). The same accounts for the income from purchase and consumption of planted non-native fruit trees (that is *Anacardium oxidentale*, *Carica papaya*, *Citrus aurantifolia*, *C. limon*, *C. sinensis*, *Mangifera indica* and *Musa spec.*).

Net livestock income contains income from sale as well as household consumption of livestock and livestock produce corrected by costs applied to production units (e.g. veterinary supplies). As fodder is taken freely from the savanna ecosystem, we accounted it for NTFP income following Cavendish (1997).

The income generated by small-scale activities as well as wages earned from skilled and unskilled labour (e.g. retail dealer, hair dresser, teacher) are accounted for as off-farm income meaning income from non-agricultural and non-woodland activities. Off-farm income equals self-reported outcomes of these activities for the respective year.

Income from NTFPs (from both ‘private’ and common woodlands) sums up to annual income from various subsistence and commercial uses of NTFPs. It contains firewood, tooth-twigs, wild foods (only plant material, see chapter 2.1.2), fodder for animal husbandry and medicinal plants. Calculation was done using market prices, own-reported values or imputed prices from close substitutes (e.g. imported tooth-sticks of the same quality). Annual firewood and tooth-stick values were projected on the basis of daily consumption reported by the respondents. The income from wild foods was deduced from the recall data.

In order to calculate the annual amount and value of fodder for animal husbandry, we adopted an estimation procedure introduced by Cavendish (1997). He proposed to calculate the year’s income stream (y_0) from livestock assuming the current market price of a unit of livestock to reflect the net present value of its whole prospective income stream to the household. Then, further regarding the animal solely converting fodder into biomass without value added, he concluded, the year’s income stream over time from that particular unit of livestock will equal the value of all fodder inputs.

The equation is given as follows:

$$y_0 = P_0\left(\frac{r}{r-\left(\frac{1}{1+r}\right)^T+1}\right) \qquad (1)$$

where T is the lifespan of the livestock unit measured from the current date, r is the discount rate (expressed as proportion: 10 %) and P_0 is the actual price of the livestock unit (observed market price or own-reported value). Emerton and Mogaka (1996) used a similar calculation method for valuing the annual income from forest resources in Kenya.
The valuation of medicinal plants was difficult due to the fact that sound medical knowledge, in general, is a privilege of traditional healers by inheritance; other respondents had merely little medicinal plant knowledge. Therefore, we use the income gained by local healers as a monetary proxy to estimate the value of medicinal plants. Note, returns from healing activities are only assigned to those households actually generating income by these activities (i.e. we did not assign a mean value to all households equally).

If households were polygamous, we interviewed one woman of the household representatively and, subsequently, assigned each of the remaining women in the household the mean income from wild foods derived from the full sample. Thus, total income is the sum of the interviewed woman's reported income (n_1) and the full sample mean wild food income (x) multiplied by the number (n) of remaining women ($n_1 + x\ (n - 1)$). This estimation procedure might under- or overestimate real incomes derived by those women who were not interviewed. However, since the sample size is statistically representative and only 14 % of polygamous households have more than two women, we consider our data to be reasonable.

3.4. Income adjusting

In our study, the composition of households varies strongly regarding the number and sex of adults and children. This leads to different needs of households in terms of economies of scale which have to be taken into consideration while aiming at comparing income between households. We applied a combination of the OECD-modified equivalence scale due to type of household member (Hagenaars et al., 1994) and used an economy-of-scale coefficient resulting in household size as the determinant of needs suggested by Deaton (1982). The adjusted income (all income sources) then equals income per adult equivalent units (aeu).

3.5. Measurement of income diversification (index of diversification)

In general, rural households with more diversified income sources are more likely to cope with unpredictable changes of income sources, i.e. the higher diversification in terms of livelihood strategies (= different income activities), the easier to cope with income shortages from a single income activity e.g. crop production or unfavourable market conditions (Valdivia et al., 1996; Illukpitiya and Yanagida, 2008). Diversification also allows to make use of all available sources (Ellis, 1998). In our study, we calculated diversification levels of income by using the inverse Simpson index of diversity (Hill, 1973) as applied in Valdivia et al. (1996) and Illukpitiya and Yanagida (2010):

$$Index\ of\ diversity = 1/\sum_{i=1}^{N} P_i^2 \qquad (2)$$

In the survey people recorded a number of different income sources *N* from which they generated income P_i.

$$\sum_{i=1}^{N} P_i^2 = \left(\frac{I_1}{I_T}\right)^2 + \left(\frac{I_2}{I_T}\right)^2 + \left(\frac{I_3}{I_T}\right)^2 + \left(\frac{I_4}{I_T}\right)^2 + \left(\frac{I_5}{I_T}\right)^2 \qquad (3)$$

Total value (subsistence and cash) of products from crop production (I1), fruit trees (I2), animal husbandry (I3), off-farm activity (I4) and NTFP extraction (I5) then sums up to total household income (I_T).

3.6. Measurement of income inequality (Gini coefficient)

Additionally, we calculated Gini coefficients for total income inequality both exclusive and inclusive NTFP income referring to Deaton (1997) in order to analyse if NTFP income has an equalizing effect on total income distribution.

Deaton defined the Gini coefficient directly (instead of deriving it from the Lorenz curve):

$$\gamma = \frac{N+1}{N-1} - \frac{2}{N(N-1)\mu}\left(\sum_{i=1}^{n} PiXi\right) \qquad (4)$$

where *u* is the population's mean income and *Pi* is the income rank *P* of person *i* with income *X*. In this model the household with the highest income is accounted for rank 1 and the poorest household receives a rank of *N*. This effectively gives higher weight to poorer people in the income distribution helping to satisfy the transfer principle (i.e. the measured inequality should decrease, when shifting income from a higher to a lower income household given the original order of income ranks).

3.7. Measurement of NTFP dependency (= forest dependency model)

In this study, we measured NTFP dependency as the share of income from NTFPs in total household income (relative NTFP income). In order to test which socio-economic variables influence NTFP dependency we ran an ordinary least square (OLS) regression. We tested: village, ethnicity, age of household head, formal education of household head, female labour resources (proxy: number of women in the household), off-farm income, farmland size, number of cattle per household and index of diversification. We selected these variables on the following assumptions:

- Village: The villages under investigation showed similar characteristics e.g. regarding the distance to the next urban centre and the savanna woodland type surrounding them. However, the market in Chabi-Couma is considerably bigger and households in Chabi-Couma are comparatively stronger engaged in small-scale sale activities. Thus, we hypothesize, that respective households generate more income from non-woodland activities and, subsequently, location has an effect on NTFP dependency.
- Ethnicity is one of the key variables we focus on in our analysis. Since ethnic groups show different woodland resource use patterns due to their traditional source of livelihood (pastoralist vs. tiller) and regional provenance (autochthonous vs.

immigrated group), we expect ethnicity to have an influence also on NTFP dependency.

- Age of household head: Higher age of rural dwellers is assumed to be linked to greater knowledge of usable NTFPs and appropriate skills related to their extraction. Both knowledge and skills are spread within the family. Additionally, as elder people often are limited in their physical performance, they are more likely to be engaged in NTFP extraction, since this income activity requires comparatively low physical skills. Thus, we expect greater age of household to augment NTFP dependency (Fisher, 2004).

- Formal education of household head: Education is a focal point in order to create access to a greater diversity of income opportunities (Adhikari et al., 2004; Fisher, 2004). We hypothesize, that the higher formal education, the lower NTFP dependency.

- Female labour resources (= number of women in the household): Since most of the valued NTFPs are collected by women the availability of female labour resources is crucial to gather woodland products (Illukpitiya and Yanagida, 2008, Viet Quang and Nam Anh, 2006). Therefore, with increasing number of women, NTFP dependency is assumed to increase, too.

- Off-farm income: When occupied with profitable off-farm income activities, NTFP extraction will be lower (Adhikari et al., 2004; Fisher, 2004).

- Farmland size: Farmland size is determining the extent of crop production. If land size and, thus, crop production is rising, NTFP extraction is likely to decrease (Fisher, 2004; Vedeld et al., 2007

- Number of cattle: Since fodder forms a major part of NTFP income, the latter should be positively related to the number of cattle.

- Index of diversification: The greater the possibility to make use of different available income sources the likely lower the share of a particular income activity in total household economy. We hypothesize a negative relationship between the index of diversification and NTFP dependency.

In recent publications forest dependency was analysed in regression models either as total forest income of households (Fisher, 2004; Illukpitiya and Yanagida, 2008) or as relative forest income like proposed by Vedeld (Vedeld, Angelsen et al. 2004) and conducted by Kamanga (Kamanga, Vedeld et al. 2009) and Fisher as relative cash income (Fisher 2004). While total forest income shows the magnitude of forest utilization compared across households, forest dependency as an income ratio entitles to determine the individual economic contribution of forest products to overall household income and, thus, determine its relative importance among other income sources. However, since the relative forest income is conditioned by total household income, it will subsequently alter with changes in the former expressing a sigmoidal curve. Thus, it can cause alterations in regressors' responses when put into a regression analysis. Reasonable results are gathered if the majority of processed data lies within the linear section of the curve (i.e. between 0.2 and 0.8) which was the case in our study.

3.8. Comparison of income groups

In order to compare income groups regarding their NTFP dependency, we split the sample into three income terciles ("very poor", "medium poor" and less poor") of proximately the same size (73, 73 and 72). Mean total incomes per aeu between groups are significantly different (406 €, 669 € and 1017 €, respectively; ANOVA $p < 0.001$).

3.9. Comparison of ethnic groups

Aiming at analyzing differences between ethnic groups regarding NTFP dependency and usage, we compared the five ethnic groups from the full sample, the Fulani, the Ditammarie, the Yom, the Bariba and the Kabiyé (with each $N = 42$), each representing a particular combination of regional provenance (autochthon, migrated) and traditional source of livelihood (pastoralist, tiller).

4. Results and discussion

4.1. Economic importance of NTFPs in a rural household's economy in Northern Benin

All interviewed households recorded to be engaged in the collection of and more than 80 % in the sale of NTFPs. This high importance of NTFPs is reflected in the households' economies (Table 2): With an average income share of 39 % income from NTFPs accounted for the second largest share in total household income in 2008, next to income from crop production (44 %), fruit trees (7 %), off-farm income (7 %) and animal husbandry (3 %). Referring to the income studies cited in the introduction, which calculated income from the same NTFPs like us (firewood, fodder, wild food items, medicinal plants) our figure of 39 % NTFP income is comparatively high: Babulo et al. (2009) found the share of NTFP income in total income to be 27 % and Kamanga et al. (2009) calculated an 15 % income share. That might also be due to the pest-caused very low livestock income (Babulo (2009) found 16 % and Cavendish (2000) 15 % livestock income share).

Table 2 Total and mean income (in Euro) and income shares by income source and year

Income source	Total income by source	Mean income per aeu	SE	Income shares (%)
Crops	66,861	30.95	14.64	44
Fruit trees	10,423	5.04	4.93	7
Livestock	4,761	21.84	6.43	3
Off-farm	9,688	46.58	6.09	7
NTFPs	59,197	271.54	10.25	39
Total	150,930	699.86		

SE = Standard Error

4.2. NTFP dependency model

The most important factors (both in magnitude and significance) likely to reduce NTFP dependency of households are i) greater land holding, i.e. higher crop production and appropriate income (which is proved by a significant correlation between farmland size and crop income, $r = 0.372$, $p < 0.01$) and ii) profitable off-farm activities (Table 3). The latter is significantly positive correlated with the index of diversification ($r = 0.389$, $p < 0.01$). Albeit not significant and having merely a very small regression coefficient, this relationship is embodied in the direction of the coefficient of the diversification index indicating that greater diversification can lessen NTFP dependency.

Table 3 Regression of relative NTFP income against socio-economic variables (estimation of NTFP dependency model)

Term	Coefficient	SE	Beta (adjusted coefficient)	*t*-ratio
(Intercept)	(45.5453)	(7.4256)		(6.134***)
Village	2.4113	2.23763	.063	1.078
Ethnicity	-1.4898	0.83630	-.108	-1.781
Age of household head	1.9368	0.81428	.137	2.379*
Education of household head (years)	-0.1927	0.45692	-.024	-.422
Number of women in household	8.6322	1.01621	.516	8.494***
Farmland size	-4.3473	0.68609	-.394	-6.336***
Number of cattle in household	0.4084	0.17216	.142	2.372*
Off-farm income	-0.0001	0.00002	-.220	-3.642***
Index of diversification	-2.3081	2.93305	-.047	-.787

N = 218; R^2 = 0.506; R^2 adj = 0.479; F = 18.903;
*** p < 0.001; ** p < 0.01; * p < 0.05

Vice versa, the more women belong to a household and the older the households' head, the higher relative income from NTFPs, which is explained by very low opportunity costs of NTFP extraction activities and, for the case of age, by the experience concerning these activities. Additionally, since fodder forms an important NTFP income category, a greater amount of cattle is significantly reflected by a higher NTFP dependency. The importance of these three factors is displayed by comparatively high regression coefficients.

In contrast, location, ethnicity and education showed no significant effects on NTFP dependency, indicating that market size does not influence the extent of NTFP extraction activities, ethnic groups seem to generate similar income from NTFPs and formal education is not important regarding NTFP extraction activities.

4.3. Economic contribution of NTFPs to household income: Comparison between ethnic groups

The pastoralist society (Fulani) showed the highest income share from NTFPs among ethnic groups (53 %, Table 4). Coevally, NTFP income accounted for their largest income share, followed by crop production (30 %), livestock (9 %), off-farm (5 %) and fruit trees

(3 %). Conversely, for the original tiller societies (Ditammarie, Yom, Bariba and Kabiyé), income from crops was highest (48 %, 47 %, 52 % and 43 %, respectively), while the economic contribution of woodland products ranked second (34 %, 42 %, 30 % and 36 %, respectively). The income share from fruit trees and off-farm activities altered only little between tillers; income from livestock accounted for the lowest income share of all tiller societies. Since total household income between ethnic groups was similar this holds true for both income shares and factual mean income from each source.

When comparing pastoralists with tiller societies we find some general trends: Pastoralists have lower income from cultivation activities with concurrently higher livestock and NTFP income; no trend is revealed regarding off-farm income. Vice versa, tiller societies are stronger engaged in crop and fruit tree production, which is reflecting their traditional source of livelihood (tiller): Income from crop production is equivalent to their primary income source. In case of the Fulani, however, livestock did not account for the largest income share but NTFP income did. The underlying rationale is that the Fulani lost many cattle owing to the disease-caused decrease of livestock in 2008, hence leading to diminished income from livestock. One can assume that income from livestock would have been notably higher in “normal” years.

When comparing the autochthon (Bariba) and the migrated tillers (Ditammarie, Yom and Kabiyé), there are no significant differences found between autochthon and migrated tillers with regard to income shares and mean incomes. Furthermore, the Bariba do not have significantly greater land holdings than migrated ethnic groups indicating, that regional provenance in our study area is not necessarily leading to unequal land distribution and, subsequently, higher crop outputs and lower NTFP dependency (fulfil consumption and cash needs via cultivation rather than through NTFP extraction). Significant differences in farmland size are only measured between migrated groups (Fulani and Ditammarie and Fulani and Yom, respectively), which is in turn linked to the Fulani being livestock breeders requiring less land for cultivation. Furthermore, as NTFP income share is not linked to access to crop land, the significant higher income from NTFPs with the Fulani indicates that this is likely to be linked to their traditional source of livelihood, too.

Table 4 Mean household income per aeu (in Euro) and income shares by income source and ethnic group

	Fulani		**Ditammarie**		**Yom**		**Bariba**		**Kabiyé**	
	Mean income per aeu (SE)	Share (%)	Mean income per aeu (SE)	Share (%)	Mean income per aeu (SE)	Share (%)	Mean income per aeu (SE)	Share (%)	Mean income per aeu (SE)	Share (%)
Income source										
Crops	215 (27)	30	334 (34)	48	325 (28)	47	389 (43)	52	281 (24)	43
Fruit trees	20 (5)	3	61 (10)	9	41 (7)	6	52 (16)	7	77 (12)	12
Livestock	65 (32)	9	12 (4)	2	14 (3)	2	6 (2)	1	14 (4)	2
Off-farm	37 (11)	5	52 (16)	7	22 (4)	3	77 (17)	10	46 (16)	7
NTFPs	378 (39)	53	241 (12)	34	287 (14)	42	222 (18)	30	232 (15)	36
Total	714		699		689		747		651	

SE = Standard Error

4.3.1. Comparison of the composition of NTFP income in terms of use categories between ethnic groups

Against this background, a considerable and significant share of NTFP income can be found within the Fulani. It reveals, on the one hand, a shift in income shares of total household income: e.g. the decrease of livestock income presumably led to a corresponding increase of NTFP income. On the other hand, since income from woodland embodies income from fodder and the Fulani solely possess cattle, this should be reflected by the composition of their NTFP income. By dividing NTFP income into the use categories, the hypothesis is confirmed: Fodder accounted for the Fulanis' second largest NTFP use category share (33 %) being significantly greater than compared to the other ethnic groups (Table 5 and Figure 5). That is, the traditional livelihood source of the Fulani is reflected by their use of woodland resources. In that case, fodder is the means of production for their animal husbandry. Consequently, ethnicity plays a significant role determining natural resource use patterns and the economic relevance of different income sources. This relationship is confirmed by the regression results as mentioned in section 4.2.

Table 5 Comparison between NTFP income shares by use category and ethnic group

	Fulani	Ditammarie	Yom	Bariba	Kabiyé
Firewood (%)	19	29	30	27	32
Tooth-twigs (%)	6	9	9	8	10
Wild foods (%)	37	56	55	63	53
Fodder (%)	33	5	6	1	5
Medicinal plants (%)	5	0.3	0	0.5	0

Following that rationale and excluding fodder from the NTFP income calculation, however, underpins that all ethnic groups are in general equally engaged in harvesting NTFPs. This is supported by the finding that across all samples the major share of income was gained by collecting wild fruit trees for nutrition: Wild foods made up to 62 % of total income from woodland resources achieving an annual mean income between € 123 (Kabiyé) and € 158 (Yom) per aeu highlighting their importance for the local diet.

The second most important income component was firewood, being the primary source of energy. Income from firewood (and tooth-twigs) reflects daily consumption needs; annual consumption of firewood equalled an income between € 62 (Bariba) and € 85 (Yom) per aeu. Furthermore, albeit not significant, Fulani had highest income from medicinal plants (€ 21) which is due to the comparatively greater proportion of traditional healers found within the Fulani.

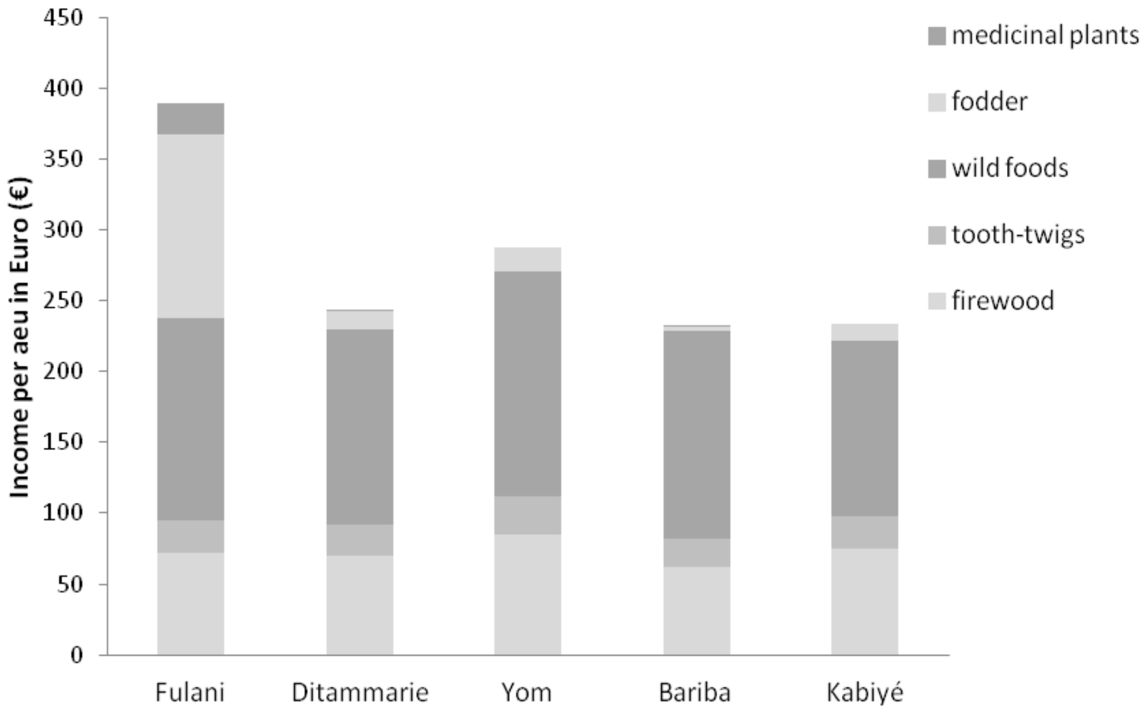


Fig. 5 Comparison of NTFP income shares (in Euro) by use category and ethnic groups

4.4. Economic contribution of NTFPs to household income: comparison between income groups

When linking NTFP income to income terciles, we found that with higher total household income the share of NTFPs decreased significantly (Table 6). The lowest income tercile ("very low income") generated 49 %, the medium tercile ("medium income") 44 % and the highest tercile ("above medium income") 33 % of its income through NTFPs. Conversely, income from crops increased significantly with total income (38 %, 41 % and 48 %, respectively) indicating that the higher the crop income the lower the NTFP income.

However, despite the lower income proportion the mean income from woodland products was higher in the second and third tercile. Thus, in quantitative terms households with higher income gathered more NTFPs than those with lower income, but the latter are relatively more dependent on NTFPs than medium and above medium income households. Dependency in this regard displays the need to fulfil basic diet needs through wild foods which is most appropriate with the poorest households. Recently conducted studies agree on the fact that wealthier households are more engaged in the extraction of NTFPs in quantitative terms (Cavendish, 2000; Emerton, 2005; Shackleton and Shackleton, 2006; Babulo et al., 2009), hypothesizing that they are better equipped to extract certain high-value resources, have greater access to markets and are better connected to trade infrastructure (Arnold and Pérez, 2001; Angelsen and Wunder, 2003) than poorer households.

Table 6 Total and mean household income (in Euro) and income shares by income source and income group

Income source	1. Tercile ("very low income")			2. Tercile ("medium income")			3. Tercile ("above medium income")		
	Mean income per aeu	SE	Income shares (%)	Mean income per aeu	SE	Income shares (%)	Mean income per aeu	SE	Income shares (%)
Crops	16	1	38	273	15	41	494	29	48
Fruit trees	26	5	6	47	1	7	75	11	7
Livestock	4	1	1	15	3	2	47	19	5
Off-farm	24	0	6	41	1	6	73	16	7
NTFP	203	10	49	293	1	44	342	30	33
Total	417			669			1031		

(SE) = Standard Error

These assumptions are approved in the findings, that households of the medium and upper income level are remarkably more engaged in the sale of NTFPs which is reflected by their significantly higher amount of cash income from NTFPs compared to the lowest income group (Figure 6). These findings on the stronger dependency on NTFPs with the least income groups are consistent with findings of Godoy and Bawa (1993), Neumann and Hirsch (2000), Kamanga et al. (2009), Illukpitiya (2010) and Cavendish (2000) while contrasting the results of Shackleton and Shackleton (2004) who found poorer households to generate more cash income from NTFPs than wealthier ones.

One key factor explaining the higher amounts of NTFPs collected by households with higher income is certainly that they own more farmland – supported by a significant correlation between total household income and farmland size ($p < 0.01$): While, on the one hand, explaining the higher returns from crop production, greater access to farmland, on the other hand, also offers an increased possibility to gather NTFPs from 'private' trees rather than competing with other extractors on common woodlands. Thus, households with greater land holding are more likely to fulfil their basic consumption needs via 'private' resources while households with insufficient farmland stronger rely on open or semi-open access woodlands. The latter, in addition, are mostly situated far outside the village, i.e. people with less land often face long walking distances to places where they can legally harvest, meaning that the opportunity costs of collecting are high (time and work consumptive activity). That is, households with greater nearby land holdings can more easily achieve harvesting levels above their consumption needs via 'private' resources enabling them to sell the remaining products. Vice versa, households lacking land primarily fulfil their basic needs and, facing higher opportunity costs, tend to collect less NTFPs.

That is, next to basic consumption needs, NTFP extraction primarily serves poorer people as a gap-filling activity or as a safety-net in times of crisis while remaining a low return activity. Since they have only minimal access to farmland either, they further have no chance to replace NTFP extraction by sufficient crop production. Beyond, if an NTFP would get more valuable, then it will be mostly the wealthier households who will be favoured to become engaged in extraction and, if applicable, the cultivation of the plants in question. This is due to them being endowed with appropriate land, capital, skills and political power (Angelsen and Wunder, 2003; Dewi et al., 2005). In conclusion, NTFP extraction helps to prevent further poverty and sustains current livelihoods, respectively, but might not help to lift people out of poverty (Campbell and Luckert, 2002; Angelsen and Wunder, 2003; Belcher, 2003; Dewi et al., 2005).

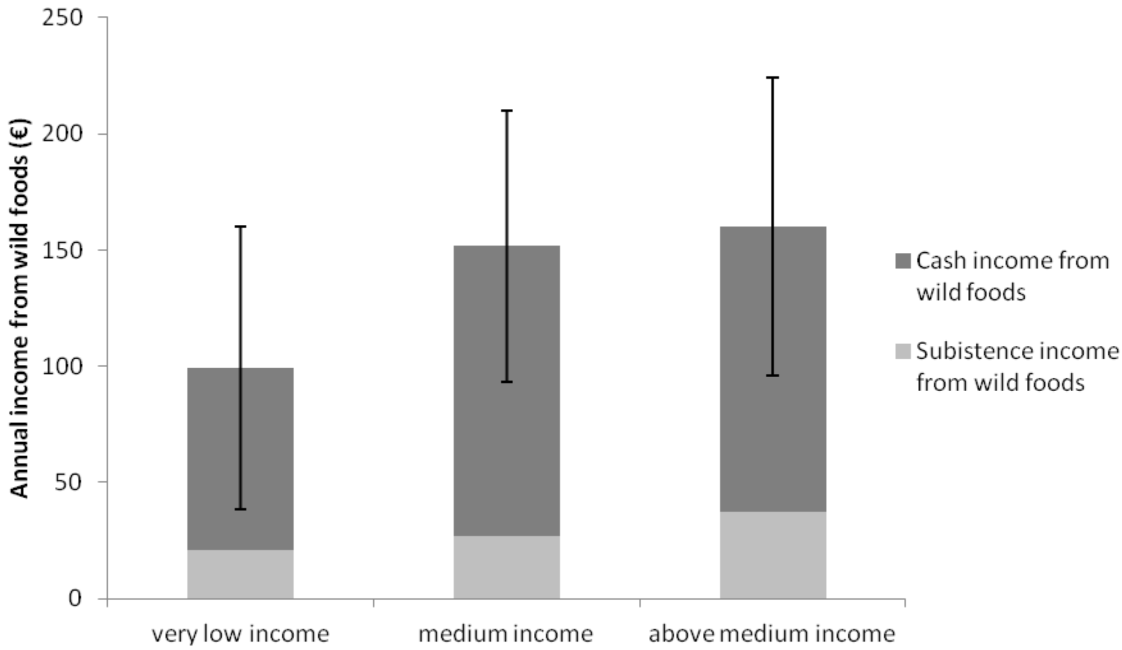


Fig. 6 Comparison of NTFP income (in Euro) between income groups by use category

4.5. NTFP income and inequality

The inclusion of NTFP income in total household income considerably reduced inequality between households from 0.61 to 0.23 (Table 7). (The Gini coefficient for sub-Saharan Africa equals 0.72 (Anderson et al., 2006)). This is concordant with other recent studies on the relation of poverty and environmental income (Babulo et al., 2009; Kamanga et al., 2009).

Table 7 Comparison of Gini coefficients of total household income without and with NTFP income

	G
Without NTFP income	0.23
With NTFP income	0.61
Change units	0.38
N = 218	

The unexpected strong reduction of the Gini coefficient (0.38 change units) might be explained by the even participation of households in NTFP collection. On the contrary, not all households had income from off-farm activities and livestock. Even if numbers overestimate the equalizing effect, it is proof that NTFPs help diminishing income disparities between rural dwellers.

5. Conclusions

Our study showed that woodland products make a significant contribution to rural dwellers' total income in Northern Benin while coevally reducing inequality between households. On average, 39 % of annual income is generated by diverse NTFPs. National statistics number the per capita income of a person in Benin to roughly 1.4 Euro a day (Auswärtiges Amt Berlin, 2010). However, this figure only represents a numerical quotient of national income divided by population which omits the economic contribution of savanna woodland products. Subsequently, this is an underestimation of rural income. Adding the monetary surplus of NTFPs as detected in our study increases daily income from the above mentioned 1.4 € to roughly 2 € per capita. This matches an enhancement of total income by approximately 30 %. Even if our result is an exaggeration, nevertheless, this calculation displays the essential gain by NTFP extraction obtained by people having limited income opportunities and coping with permanent natural and social insecurities.
Albeit a strongly dividing socio-economic factor, ethnicity in our study only has an effect on the net income from a single NTFP use category leading to a shift in NTFP income composition: Fulani reveal significantly higher income from fodder. In general, we found local dwellers to embrace their natural environment in a uniform manner autonomously of their ethnic affiliation.

However, the economic significance of NTFPs differs between households with regard to their annual household income: The lower the total household income, the higher the share of NTFP income, i.e. the higher the relative dependency on woodland products to meet basic consumption needs. Though, the amount of NTFPs extracted and the cash income gained through local sales generally increases with income status which is mainly due to greater access to farmland ('private' resources). In contrast, poorer households have to face higher opportunity costs in terms of extraction (remote extraction sites and rivalry with other users).

Due to increasing population sizes of West African rural societies, both the demand for NTFPs and the pressure for agricultural land are likely to increase. Thus, NTFP providing plants are highly prone to overexploitation and / or disappearance. However, in the light of the findings of this study, it would not be appropriate to restrict further access to woodlands in order to conserve woodland resources and biodiversity because it would be likely to increase poverty. Coevally, developmental action should consider that adopting the cultivation of NTFP providing species as a pro-poor strategy might not be suitable to lift people out of poverty since NTFP extraction remains a low-return activity. Therefore, lowering the opportunity costs of conserving woodlands, i.e. NTFP dependency, might be rather achieved by e.g. creating robust income opportunities independent of NTFP extraction or by increasing the efficiency of crop production systems in order to avoid lean times driving people to exploit more resources. These measures will coevally improve rural livelihoods and conserve woodland resources and biodiversity.

6. Acknowledgements

The present study was conducted at the Biodiversity and Climate Research Centre (BiK-F), Frankfurt am Main, Germany, and funded by the research funding programme "LOEWE – Landes-Offensive zur Entwicklung Wissenschaftlich-Ökonomischer Exzellenz" of Hesse's Ministry of Higher Education, Research, and the Arts. The authors are grateful to Gnanando Saidou and Laurent Akissatom who assisted in field work and especially all respondents who took part in the survey. Sincere thanks go further to Prof. Brice Sinsin (University of Abomey-Calavi, Benin) for scientific and logistic support. Furthermore, we would like to thank two anonymous reviewers for their constructive comments on this work.

Chapter 3

Social Differentiation as an Important Source for Improving Conservation Measures: The Impact of Ethnic Affiliation on the Valuation of NTFP-providing Woody Species in Northern Benin, West Africa

with Rüdiger Wittig, Ernst-August Nuppenau and Karen Hahn
submitted to *Human Ecology*.

ABSTRACT

Non-Timber Forest Products (NTFPs) contribute significantly to rural households' livelihoods in the West African savannas. This study investigates differences in use preferences for native woody species in eleven use categories and their economic returns between five local ethnic groups in northern Benin. Ethnobotanical survey data from 230 households in two villages were analysed with both ethnic affiliation and location having had significant effects on the valuation of species. A total of 90 ligneous species were mentioned by the informants as useful whereof 61 % were used for medicinal applications, 49 % in dental care, 41 % as firewood, 39 % for construction, and 32 % as wild foods. Whilst there was a certain set of plant species used jointly by all rural dwellers, others were exclusively used by particular ethnic groups. Vitellaria paradoxa, Parkia biglobosa and Adansonia digitata can be considered as cultural and economic key species for all groups. From our findings we conclude that conservation measures should consider multi-purpose trees that both i) fulfil subsistence needs and ii) have high commercial potential while giving iii) high consideration to culturally conditioned differences in use preferences on a small-scale basis.

1. Introduction

Products from native tree and shrub species have been forming an inherent part of people's livelihood and cultural tradition in West Africa for centuries. Knowledge about traditional uses of plant species for various household requirements, their cultural importance and involvement in spiritual applications and ceremonies as well as about their ecological relevance in complex ecosystems and their ecological status is prevalent among these rural communities being maintained by passing on via kin lines (Boffa 2000; Lykke 2000; Paré et al., 2010).

Furthermore, rural dwellers in sub-Saharan Africa are substantially dependent on Non-Timber Forest Products (NTFPs) provided by the surrounding ecosystems in terms of maintaining their livelihoods (Cavendish 2000; Campbell and Luckert 2002; Shackleton and Shackleton 2004; Vodouhê et al. 2009). That is, wild fruits, leaves, seeds, bark, grasses, wood, fish and game, amongst others, are, firstly, essential for meeting a household's subsistence and consumption needs with regard to e.g. daily diet, energy demand and medical treatment. Secondly, they present a safety-net helping to better overcome unfavourable situations like famine to arise by reason of crop failure or income shortage from other sources. And, thirdly, wild products allow for additional cash income contributing to total household income (Cavendish 2002; Angelsen and Wunder 2003; de Merode et al., 2004; Shackleton et al., 2007; Babulo et al., 2009; Kamanga et al., 2009).

Latest studies highlighted the economic importance of NTFPs for livelihood maintenance in sub-Saharan Africa, both in terms of subsistence and cash income. In Malawi, fruit trees on common land on average contributed 15 % to total household income (Kamanga et al., 2009), and in the Republic of Congo wild plants made up to 10 % of total food consumption (de Merode et al., 2004). For northern Ethiopia, Babulo (2009) found forest environmental products to constitute 27 % and, Cavendish (2000), for Zimbabwe, even 35 % of total income (inclusive animal and soil products). This figure corresponds with recent findings in northern Benin where the share of income from NTFPs accounted for approximately 39 % of the household income equating the second largest income share within total income (Heubach et al., 2011). Consistently, Faye (2010) reported that households in Mali obtained at least 40 % of their annual revenue from selling tree and shrub products.

However, recent scientific records led to growing concern that NTFP-providing trees have been undergoing a subtle decline due to newly introduced agricultural practices (Schreckenberg 1999), land-use intensification, introduction of alien species and overexploitation (Taita 2003; Augusseau et al., 2006; Wezel and Lykke 2006; Ræbild et al., 2007; Schumann et al., 2010), ecological changes, e.g. declining rainfall (Faye et al., 2010; Paré et al., 2010), as well as unsuitable law regulations and land tenure hampering proper and sustainable management of important NTFP-providing trees (Yatich et al., 2008). Consequently, the exigent call to design appropriate conservation strategies towards maintenance and sustainable use of these species was raised. Concerning this matter, there is emergent evidence that the inclusion of local use preferences and traditional knowledge into the development of these measures considerably contributes to jointly preserving socio-economically important species and such that play critical roles in maintaining ecosystem functions (Gadgil et al., 1993; Berkes et al., 2000; Taita 2003; Lykke et al., 2004; Ticktin 2004; Paré et al., 2010; Schumann et al., 2010). Unsurprisingly, since traditional conservation modes were established on long-term observations by rural communities (Berkes and Folke 2002) who have been using NTFP species extensively for hundreds of years (Ticktin et al., 2002) coping with complex environmental changes, local knowledge can be considered a “library of information” in terms of dynamic change management (Berkes et al., 2000).

Though, traditional knowledge and plant use can differ between groups of diverse local provenance and cultural background, as well as due to individual characteristics of users (gender, age, present place of domicile, amongst others) and contextual factors (institutional regulation, e.g. de facto access to plant resources, ecological conditions and abundance of species). In his recent review, Kepe (2008) highlighted that social differentiation is one of the key factors determining resource use in forest-based communities due to specific combinations of social affiliation to certain groups or networks (e.g. ethnic groups, user groups) and individual features which, in addition, may be subject to changes. Knowledge is differently exposed and transmitted within communities due to diverging preferences of users (Gaoue and Ticktin 2009) entailing heterogeneity in species valuation among members of the same and / or between different groups and leading to a cultural conditioned regulation of natural resource use (Belem et al., 2009; Vodouhê et al., 2009).

Recent studies in Benin and Burkina Faso, West Africa, showed that use values for particular woody plant species differed due to age, gender, access to farmland, ethnic affiliation and regional proximity of ethnic groups as well as marketability of species. De Caluwé (2009) found significant differences in use values and use patterns of baobab (*Adansonia digitata*) between Ottamari and Dendi in northern Benin. In the Sudanian zone of Burkina Faso, Schumann (2011) investigated baobab uses among the Gulimanceba people and identified differences between investigated villages. Fandohan (2010) presented differences between ethnic groups in northern Benin with regard to knowledge of *Tamarindus indica.* whereas for use patterns of *Sclerocarya birrea* products in the region Gouwakinnou (2011) detected varieties between separate locations. The latter, too, held true for the spread of ecological knowledge of forage uses of *Khaya senegalensis* among Fulani peoples from northern and central Benin (Gaoue and Ticktin 2009).

Rather than focussing on single primary important plant species, only few studies investigated the relative cultural importance of a wider set of multi-purpose species, partially for different ethnic groups (Schreckenberg 1999; Lykke et al., 2004; Vodouhê et al., 2009; Paré et al., 2010).

Considering this scarcity of appropriate investigations our study contributes to further close the knowledge gap with regards to the impact of social differentiation on local use preferences and valuation of local native woody plants like stressed by Kepe (2008) and Taita (2003). Additionally, by explicitly incorporating the economic aspect of NTFP-providing trees into our analysis we are complementing present scientific record substantially since such information are essential to design appropriate conservation measures.

We conducted a quantitative ethnobotanical survey among five different ethnic groups in two villages of the Sudanian zone of northern Benin, West Africa, to identify patterns of and differences between groups with regard to use and valuation of different native woody plant species and their delivered products (NTFPs). In particular, we sought to investigate species' use-values for their various subsistence uses and detect whether and to which extent they are also economically relevant for rural households.

We sought to answer the following specific questions: Firstly, do ethnic groups differ in terms of use preferences for woody species, and does it matter where they are located? Secondly, which are the economic most important plant species for rural households in terms of cash income in general and does their economic relevance change due to their ethnic affiliation? And, thirdly, we ask which are the thirty most important ligneous species for the entirety of the investigated sample and within which major use category(ies) are they most valued and for what reasons?

2. Study area and investigated ethnic groups

2.1. Biophysical environment and socio-economic setting

We conducted our study in two West African villages, Papatia and Chabi-Couma, in northern Benin, Department of Atakora (Figure 7). Villages are located about 33 km from the closest urban centre, Natitingou, and display similar socio-economic profiles: they are endowed with piped water, a local primary school and an own small market; electricity is largely missing and energy demand is primarily covered by firewood. Differences exist with regard to the number of households (Chabi-Couma hosts roughly 860 and Papatia 450 households), the market size (considerably larger in Chabi-Couma) and large plantations of non-native tree species to occur in Chabi-Couma only (e.g. *Tectona grandis*, *Mangifera indica, Musa spec*.). The majority of residing dwellers belong to one of the five major ethnic groups, i.e. Fulani, Ditammarie, Yom, Bariba and Kabiyé.

The study region belongs to the southern Sudanian zone which is characterized by a tropical climate with a rainy season lasting from May to November. Mean annual precipitation is about 1300 mm/m² and the temperature's yearly average is 27°C (Sieglstetter, 2002). According to the land cover map of the European Commission Joint Research Centre (Mayaux, 2003) the area under investigation is covered with deciduous shrublands with sparse trees (Figure 7). Vegetation types in the savanna landscape range from tree, shrub and grass savanna to dry forests being dominated by the woody species *Isoberlinia doka.* The herb layer is dominated by annual and perennial grasses reaching considerable heights (> 2 m; Krohmer, 2004; Sieglstetter, 2002).

The studied region's dominant livelihood activity is rain-fed crop production (sorghum, millet, maize, legumes, yams and manioc, groundnuts, amongst others) in traditional shifting cultivation systems (agroforestry systems), i.e. after a multiannual tillage the cleared fields lie fallow between five up to 15 years. Due to the small-scale land use a typical mosaic pattern of fields and fallows emerges. Additionally, by virtue of sparing particular useful tree species from felling while clearing areas for cultivation so-called parklands form supplementary aspect of the savanna landscape. Conserved tree species on fields are principally mature trees providing high valued NTFPs (Schreckenberg 1999), e.g. *Vitellaria paradoxa*, *Adansonia digitata* and *Parkia biglobosa*. Livestock kept in the region ranges from cattle over medium-sized livestock (goats, sheep, and hogs) to poultry (chicken, guinea fowls). Animal husbandry is no major income source in the investigated region (Heubach et al., 2011). Note further, that due to a severe livestock disease the entire livestock population dropped dramatically in 2008 – the year before the investigation.

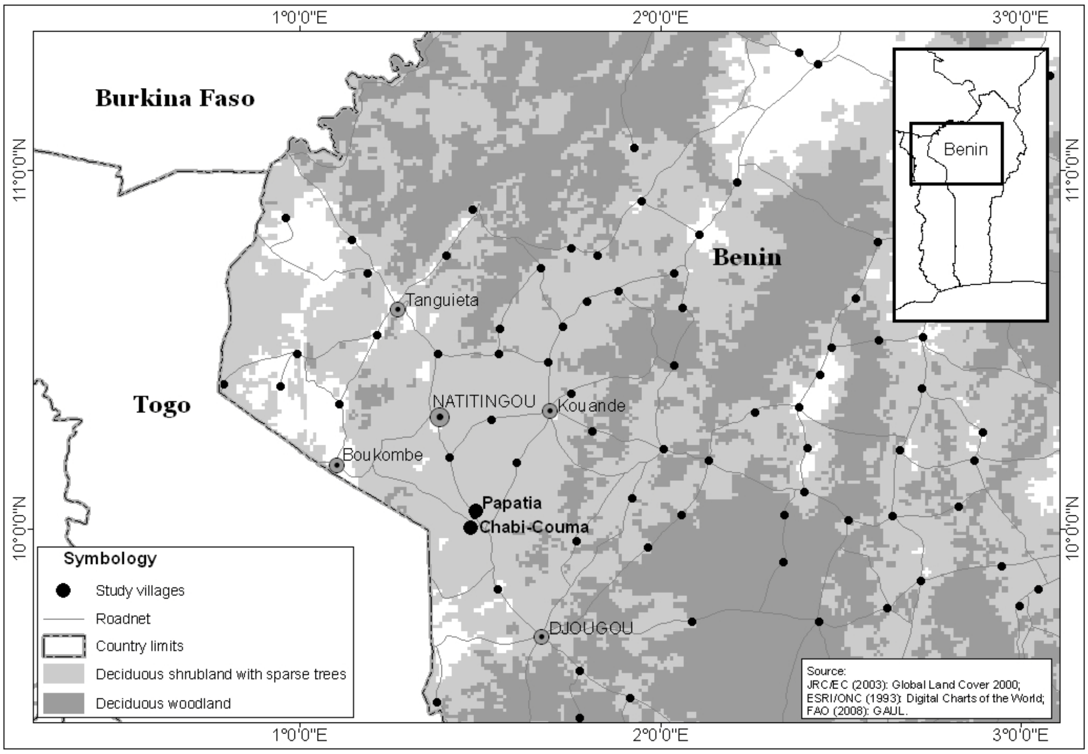


Fig. 7 Map of the study area (Department of Atakora) with the two studied villages Papatia and Chabi-Couma. Large black dots (labelled) represent the two study villages; other smaller black dots (unlabelled) are displayed in order to represent the density of villages located within the savanna ecosystem.

2.2. Key characteristics of the investigated ethnic groups

Historically, the Bariba people are the autochthon people in the study area, whereas the other groups migrated into the region: The Fulani came from their residential area in the east of the Beninese Atakora chain, the Ditammarie and the Kabiyé migrated from Togo and the Yom are originally from the Beninese Department of Bassila, to the south of the study area. Four of the five groups are traditional tiller societies (Ditammarie, Bariba, Yom and Kabiyé) while the Fulani are originally nomadic pastoralists herding cattle on fixed annual feeding routes (transhumance). However, due to ongoing land use changes in terms of increasing pressure for agricultural land and severe drought events many Fulani people in the region quitted transhumance and started to settle and adapt farming as major livelihood activity (de Bruijn and Dijk, 1994; Bolwig and Paarup-Laursen, 1999); merely a minor proportion of new settlers could maintain recognizable herds of cattle. Autonomous of ethnic affiliation all households were led by males and showed similar characteristics in terms of average household size, average formal education of head and farmland size. However, the Fulani were the only group owning cattle and being engaged in animal husbandry (Table 8).

Table 8 Household characteristics of studied ethnic groups (Fulani, Ditammarie, Yom, Bariba, Kabiyé).

	Fulani		**Ditammarie**		**Yom**		**Bariba**		**Kabiyé**	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Socio-economic attributes of households										
Household size (head count)	9.1	0.9	8.7	0.6	11.8	1.5	7.5	0.8	10.0	1.0
Major age group of household head (years)	36-45		36-45		36-45		36-45		36-45	
Education of household head (years)	0.7	0.4	2.2	0.6	1.2	0.5	0.2	0.1	0.2	0.2
Household with polygamy (%)	64.3		37.0		41.3		11.9		23.8	
Main employment: tiller (%)	92.9		95.7		100		97.6		100	
Main employment: livestock breeder (%)	4.8		-		-		-		-	
Households with secondary employment (%)	38.1		80.4		60.9		61.9		78.6	
Households with tertiary employment (%)	14.3		4.3		0.0		16.7		4.8	
Secondary employment: retail dealer (%)	11.9		60.9		50.0		31.0		66.7	
Secondary employment: traditional healer (%)	16.7		6.7		0.0		4.8		0.0	
Mean income per aeu (in Euro)	704	65	694	47	690	29	731	61	644	36
Index of diversification	1.90	0.09	2.02	0.05	2.03	0.04	2.05	0.07	2.03	0.1
Household assets										
Farmland size (ha/household)	3.0	0.2	4.4	0.3	4.2	0.2	3.6	0.3	3.7	0.2
Cattle per household	8.4	2.0	-		-		-		-	

Within the traditional land tenure system, immigrants are mostly land borrowers who are endowed with fewer rights than land holders (usually autochthon villagers). Extracting NTFPs from useful trees remaining on fields is exclusive for land owners even when the land is cultivated by others. That is, land borrowers (immigrants) have no or limited access to NTFPs on fields despite cultivating the respective land (Schreckenberg, 1999). Consequently, the greater the land holding, the likely greater is the possibility to gather NTFPs from 'private' trees without competing with other collectors. Conversely, households with borrowed land have to rely stronger on common woodland resources to meet their needs while rivalling with other potential users. Common woodland within the village area is divided into distinct areas allocated to the different residing ethnic groups. Beyond the village boundary, access to woodland resources is open to everyone.

3. Methods

3.1. Data collection

We conducted a structured household survey containing questions concerning, firstly, socio-economic profiles of the households (closed questions) and, secondly, use preferences for and knowledge about useful woody species (open questions). The survey yielded a total of 230 households representing 26 % and 13 % of the population of Papatia and Chabi-Couma, respectively. Households were selected randomly but by means of their ethnic affiliation (46 households of each ethnic group, i.e. 23 per village). The interviews took place between May and July as well as September and December 2009 and were carried out in the five ethnic languages. Plant species were recorded by their local names and later on identified through intensive field work with local healers complemented by specimen. Information about general aspects of the two villages (population size, land tenure, access etc.) were gathered through both formal key informant interviews (e.g. administrative chiefs) and informal participatory discussions with dwellers and interrogators assisting with the scientific work.

According to determined gender roles in traditional West African rural societies, of each household both the male household head (aged between 20 and 95) and his (first) wife (aged between 19 and 84) were interviewed individually for particular use categories of plant species. Women gave information about the species collected for nutrition, used or banned as firewood as well as for medical, cosmetic and decoration purposes. Additionally, they were asked to report quantities and prices of NTFPs sold on local markets. Men reported plant species used for construction material and tool wood and gave information about the household's socio-economic profile (number of household members, sources of income, levels of education etc.).

Careful enumeration and data cleaning secured a response rate of usable questionnaires of 99 % (N = 227). According to Borgatti and Halgin (2010), all species mentioned by at least two respondents were included in the analysis. Triangulation of data was performed by comprehensive key-informant interviews (e.g. with traditional healers, market-women, the eldest), market analysis of locally traded NTFPs and participatory observation.

In this article, we used the term 'NTFPs' for all biological matters of spontaneous, native plants extracted from savanna shrublands, i.e. seeds, fruits, vegetative textures (leaves, bark, bulbs etc.) as well as diverse small woody items (twigs, stems; Cunningham, 1996). We particularly excluded cultivated, alien tree species (e.g. *Anacardium oxidentale*, *Mangifera indica*) as they are planted in large plantations and therefore considered as cash crops.

3.2. Income accounting and adjusting

The survey contained questions concerning the amount of NTFPs harvested, their current market prices, as well as the income gained by the sale of these products in the respective year. In order to calculate both annual total household income (the sum of cash income and the monetary equivalent of a household's subsistence use of respective products) and cash income from NTFPs we used means of local market prices (observed monthly at the markets of Chabi-Couma and Papatia) and households' own-reported values given the local units of measure (e.g. '*lasoytatiya', 'aguwe', 'bassine'*) of marketed products (means corresponded with reported inflation of market prices due to seasonality and, subsequently, abundance of products). Where products had no market equivalent, we used imputed values from close substitutes, i.e. we calculated with the market price of a product displaying the same characteristics and being used for the same purpose as the non-marketed one (Campbell and Luckert 2002). Since opportunity costs of NTFP extraction are low (no labour alternatives, no high-capital equipment required), labour was not deducted from gross benefits, i.e. net benefits equal gross benefits.

Since investigated households differ considerably in terms of number and sex of adults and children, we adjusted our income calculations with regard to different economies of scale. According to Hagenaars (1994) we applied the OECD-modified equivalence scale using the economy-of-scale coefficient suggested by Deaton (1982) resulting in income per adult equivalent units (aeu), i.e. mean income displays the adjusted income per person in the respective household.

3.3. Data analysis

Aiming at assessing the cultural importance of woody plant species, we calculated their overall and categorial use-values displaying the appreciation of local users attributed to the respective species. According to Philipps and Gentry (1993) and simplified by Albuquerque et al. (2006) the overall use-value (UV_s) of each species was calculated as:

$$UV_s = \sum UV_{sc} = \sum U_i / N \quad (1)$$

where U_i is the sum of all use-reports mentioned for species *s* by each informant *i* and *N* is the total number of informants interviewed. Splitting UV_s into its use categories delivers the categorial use-values UV_{sc} for species *s*.

Additionally, we calculated the relative importance of a species within a particular use category as:

$$UV_{sc} = \sum UV_{sc} / N_{sc} \quad (2)$$

where UV_{sc} is divided by the total number of informants in the respective category.

Subsequently, use-reports (U_i) for each use category were analysed by means of a Principal Component Analysis (PCA) in order to assess differences and similarities of use patterns among informants. To detect which species explain most of the differences between respondents we correlated the set of species with the PCA-scores of the first two axes. All species showing a correlation coefficient of at least 0.6 (= marked degree of correlation) were referred to as explaining species. Furthermore, we ran a stepwise logistic regression of both axes-scores against socio-economic variables, i.e. village and ethnicity, to test whether the use patterns for these species differed between investigated groups. Statistical analyses were performed using PC-ORD 5.3.1 (McCune and Mefford 2006) and PASW Statistics 9.0.0. (SPSS, 2011).

For best clarity of the presented tables we do not show the entirety of plants used for each category but listed all the species needed to cover the five most important species by ethnic group (Tables 9 to 15). We ordered the species according to their overall use-value (UV_S; Table 2) and their importance within the use category (UV_{SC}; applies to Tables 2 to 8). In case multiple species obtained the same use-value (in terms of magnitude), we assigned them the same rank within the order, i.e. if, for instance, two species were ranked first place we proceeded with number 3 for the third species in order to keep the continuity of counting.

4. Results

4.1. Similarities and differences concerning use-values of woody species between investigated ethnic groups

4.1.1. Wood uses

Construction wood

Construction wood is needed for walls and roofs of traditional clay huts. Plant species valued for construction wood comprised 35 species (39 % of all species reported), whereof the 3 most important were *Oxynanthera abyssinica*, *Lophira lanceolata* and *Parinari curatellifolia* (Table 9). While the number of species mentioned by ethnic groups was similar (from 14 (Kabiyé) to 19 (Ditammarie)) the species' relevance differed. Fulani and Bariba people most often cited *O. abyssinica* as construction wood, Ditammarie mainly mentioned *L. lanceolata*, Yom *P. curatellifolia,* and Kabiyé *Khaya senegalensis. L. lanceolata* additionally was cited commonly second most by three ethnic groups: Fulani, Yom and Bariba. Other second places were given to *Hannoa undulata* (Fulani), *Anogeissus leiocarpus* and *Swartzia madagascariensis* (Ditammarie) as well as *P. curatellifolia* (Kabiyé).

The ordination plot (Appendix 2) did not show distinct patterns between ethnic groups with the exception of the Ditammarie people from Papatia which were slightly separated from all other informants along the first axis. The ordination's first axis highly correlated with *Afzelia africana*, *S. madagascariensis*, *Prosopis africana* and *Tamarindus indica,* the second axis with *Pericopsis laxiflora*. For these species, we found strong significant differences between both villages and ethnic groups (Appendix 3). That is, *S. madagascariensis*, *P. africana*, *T. indica* and *P. laxiflora* were solely mentioned by people from Papatia while *A. africana* was exclusively cited by Ditammarie in Papatia and Kabiyé in Chabi-Couma.

Tool wood

Tools crafted in the region include mortars, pestles, ladders, farm implements (billets, handles etc.) and wooden spoons, amongst others. There was a large overlap between species mentioned as feasible for tool wood (29 species) with those reported to be used for construction purposes (35 species, Table 9). The major difference concerned *V. paradoxa*, which is exclusively cited as tool wood and coevally most commonly treasured in this regard by four of the investigated ethnic groups, except by the Kabiyé people. While four ethnic groups reported to use a considerably great diversity of species for making tools (up to 16 species) the Yom people only cited *V. paradoxa* in just low frequency. Apart from *V. paradoxa*, there were obvious differences between ethnic groups concerning the favouritism of species for tool wood: For instance, the Fulani people mostly cited *S. madagascariensis*, whilst the interviewed Ditammarie people preferred *T. avicennioides* and the Bariba people *Dichrostachys cinerea*.

We neither found a distinct grouping of ethnic groups in the ordination plot nor plant species being highly correlated to socio-economic characteristics (results of correlation and regression not shown).

Firewood

Informants reported to use 37 species as firewood. Ethnic groups showed very similar patterns of firewood collection (Table 9). All ethnic groups ranked *V. paradoxa* first and *P. biglobosa* was assigned three times second rank across groups. Beyond, highly appreciated as firewood by at least four of five groups (exception: Kabiyé) were *Isoberlinia doka*, *I. tomentosa*, *Hymenocardia acida*, amongst others.

Table 9 Wood uses: List of species covering the five most important tree species used for construction wood (A), tool wood (B) and firewood (C) by ethnic group. Species were ordered according to their importance within the use category (UV_{SC}). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

A CONSTRUCTION WOOD (35 species mentioned in total)

			Fulani		Ditammarie		Yom		Bariba		Kabiyé	
R	**Species /** Species per cat.	UV_{SC}	16	Rank	19	Rank	16	Rank	18	Rank	14	Rank
1	*Oxynanthera abyssinica*	0.357	0.83	1	0.07		0.22	6	0.39	1	0.28	3
2	*Lophira lanceolata*	0.269	0.37	2	0.30	1	0.28	2	0.26	2	0.12	
3	*Parinari curatellifolia*	0.251	0.33	4	0.22		0.33	1	0.09		0.30	2
4	*Terminalia avicennioides*	0.216	0.30	5	0.28	2	0.09		0.17	5	0.23	5
5	*Anogeissus leiocarpus*	0.185	0.22		0.28	2	0.22		0.15		0.05	
6	*Hannoa undulata*	0.150	0.37	2	0.04		0.26	3	0.07		-	
7	*Monotes kerstingii*	0.145	0.26		-		0.24	5	0.20	3	-	
8	*Pterocarpus erinaceus*	0.128	0.09		0.07		0.15		0.09		0.26	4
9	*Diospyros mespiliformes*	0.119	-		0.15		0.26	3	0.11		0.07	
10	*Khaya senegalensis*	0.097	-		0.07		-		-		0.40	1
11	*Swartzia madagascariensis*	0.093	0.13		0.28	2	-		0.04		-	
14	*Afzelia africana*	0.066	-		0.26	5	-		-		0.07	
15	*Pericopsis laxiflora*	0.057	-		0.11		-		0.17	5	-	
18	*Hexalobus monopetalus*	0.040	-		-		-		0.20	3	-	

B TOOL WOOD (29 species mentioned in total)

R	**Species /** Species per cat.	UV_{SC}	16	Rank	11	Rank	1	Rank	16	Rank	9	Rank
1	*Vitellaria paradoxa*	0.374	0.52	1	0.59	1	0.07	1	0.50	1	0.14	2
2	*Terminalia avicennioides*	0.137	0.13		0.39	2	-		0.07		0.09	
3	*Pterocarpus erinaceus*	0.132	0.20	4	0.09	4	-		0.20	4	0.12	4
4	*Dichrostachys cinerea*	0.106	0.15		-		-		0.26	2	0.12	4
5	*Swartzia madagascariensis*	0.088	0.37	2	-		-		0.07		-	
6	*Khaya senegalensis*	0.075	0.17	5	0.04		-		-		0.07	
7	*Manilkara multinervis*	0.066	0.35	3	-		-		-		-	
9	*Pteleopsis suberosa*	0.062	0.07		-		-		0.09		0.16	1
10	*Erythrophleum africanum*	0.057	-		-		-		0.26	2	-	
11	*Afzelia africana*	0.048	-		0.15	3	-		-		0.05	
11	*Hannoa undulata*	0.048	0.04		0.09	4	-		0.11		-	
13	*Pericopsis laxiflora*	0.044	-		0.07		-		0.15	5	-	
16	*Diospyros mespiliformes*	0.035	-		0.09	4	-		-		-	
18	*Parinari curatellifolia*	0.022	-		-		-		-		0.14	2

B FIREWOOD (37 species mentioned in total)

R	**Species /** Species per cat.	UV_{SC}	25	Rank	19	Rank	23	Rank	17	Rank	11	Rank
1	*Vitellaria paradoxa*	0.846	0.85	1	0.89	1	0.65	1	0.89	1	0.95	1
2	*Parkia biglobosa*	0.599	0.59	4	0.61	2	0.48	3	0.65	2	0.67	2
3	*Isoberlinia tomentosa*	0.339	0.61	3	0.30	3	0.39	4	0.37	3	-	
4	*Isoberlinia doka*	0.326	0.28		0.30	3	0.52	2	0.13		-	
5	*Hymenocardia acida*	0.273	0.67	2	0.22	5	0.20		0.20	5	0.07	
6	*Pterocarpus erinaceus*	0.260	0.26		0.15		0.22		0.30	4	0.37	3
7	*Daniellia oliveri*	0.247	0.48	5	0.15		0.24	5	0.07		0.30	4
8	*Detarium microcarpum*	0.194	0.39		0.07		0.22		0.11		0.19	

The ordination plot (Appendix 2) did not show discrete patterns. We found strong correlations for *H. acida*, *I. doka* and *I. tomentosa* along the first axis (Appendix 3). Differences between informants were explained by village and ethnicity - all three species were mainly mentioned by villagers from Papatia belonging to the peoples of the Fulani and the Yom.

4.1.2. Construction material

Cord

Cord is needed to attach wooden poles for roofs, storage huts and fences as well as for handcraft and to leach livestock. In total, informants mentioned 19 species as useful for making cord, whereof two species were in particular valued: the bark fibres of *Piliostigma thonningii* (assigned first place by four ethnic groups) and *Hexalobus monopetalus* (most mentioned by the Fulani, Table 10). Moreover, the leaves of *Raphia sudanica* were highly appreciated by the Fulani and the Bariba whereas the fibres of *Adansonia digitata* (fibres of the inner bark are twisted into ropes) were especially valued by the Ditammarie. Beyond, the Yom described *Cochlospermum planchonii* and *Pteleopsis suberosa* as considerably useful for making cord; the latter was also frequently mentioned by the Kabiyé. Several species were solely mentioned by particular ethnic groups.

No distinct patterns were to be found within the ordination plot (Appendix 2). However, the first axis of the PCA highly correlated with *Entada africana* for which we found significant differences with regard to location and ethnicity (Appendix 3) – *E. Africana* was only mentioned by respondents from Papatia.

Mats

Mats are woven with leaves of palm trees of 4 species. Most suitable for three of the ethnic groups were the leaves of *Borassus aethiopum* (Fulani, Ditammarie and Bariba) while for the Yom the leaves of *Hyphaene thebaica* and for the Kabiyé the leaves of *Raphia sudanica* were the most important for making mats (Table 10). However, use preferences were rather consistent between groups: all ethnic groups cited all three species as providing useful mat material.

Along the first axis of the ordination plot (Appendix 2) informants were significantly separated by location for *B. aethiopum* and *H. thebaica* (Appendix3). Both species were harvested by all five ethnic groups in Papatia while in Chabi-Couma only Fulani and Bariba reported to use these species.

Table 10 Construction material: List of species covering the five most important tree species used for making cord (A) and mats (B) by ethnic group. Species were ordered according to their importance within the use category (UVSC). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

A **CORD** (19 species mentioned in total)

			Fulani		Ditammarie		Yom		Bariba		Kabiyé	
R	**Species /** Species per cat.	UV_{SC}	6	Rank	7	Rank	8	Rank	8	Rank	4	Rank
1	*Piliostigma thonningii*	0.485	0.59	2	0.43	1	0.59	1	0.50	1	0.30	1
2	*Hexalobus monopetalus*	0.278	0.83	1	0.22	3	0.09	4	0.24	4	-	
3	*Raphia sudanica*	0.225	0.52	3	0.17	4	-		0.41	2	-	
4	*Adansonia digitata*	0.119	0.26	4	0.24	2	0.07		-		-	
5	*Cochlospermum planchonii*	0.093	-		-		0.13	2	0.28	3	-	
6	*Pteleopsis suberosa*	0.066	-		0.04	5	0.13	2	-		0.14	2
7	*Lannea microcarpa*	0.031	-		0.04	5	-		0.11	5	-	
7	*Saba comorensis*	0.031	0.07	5	-		-		-		0.07	4
9	*Detarium microcarpum*	0.018	-		-		0.09	4	-		-	
9	*Elaeis guineensis*	0.018	-		-		-		-		0.09	3
11	*Lannea barteri*	0.013	0.07	5	-		-		-		-	
16	*Pseudocedrela kotschyii*	0.009	-		0.04	5	-		-		-	

B **MATS** (4 species mentioned in total)

R	**Species /** Species per cat.	UV_{SC}	3	Rank	3	Rank	4	Rank	3	Rank	3	Rank
1	*Borassus aethiopum*	0.339	0.52	1	0.28	1	0.13	2	0.59	1	0.16	2
2	*Hyphaene thebaica*	0.273	0.30	3	0.15	3	0.35	1	0.43	2	0.12	3
3	*Raphia sudanica*	0.238	0.35	2	0.24	2	0.13	2	0.04	3	0.44	1

4.1.3. Wild foods

Wild vegetable foods, i.e. edible fruits, seeds and leaves from woody species complement the daily diet of rural households both in terms of quality (vitamins, nutrients, minerals, micronutrients etc.) and quantity (e.g. in times of crop failure or lean seasons between crop production). In total, 29 species were mentioned as fruit providers. The by far most valued two species were *V. paradoxa* and *P. biglobosa* (Table 11) which both are typical field trees. For both species, respondents from all five ethnic groups showed consistent preferences: The seeds of *V. paradoxa*, were assigned first place and the seeds of *P. biglobosa* second. In addition, fruits of *Adansonia digitata* and *Blighia sapida* were mentioned frequently – both were cited two times third most commonly. The seeds of

B. sapida also refine sauces. Other generally harvested species are *D. mespiliformes*, *V. doniana* and *T. indica*. Ethnic groups treasure fruit species similarly; only few are mentioned by a single or two ethnic groups only.

Table 11 Wild foods: list of species covering the five most important tree species harvested for edible fruits (A) and edible leaves (B) by ethnic group. Species were ordered according to their importance within the use category (UVSC). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

A EDIBLE FRUITS (29 species mentioned in total)

			Fulani		Ditammarie		Yom		Bariba		Kabiyé	
R	**Species /** Species per cat.	UV_{SC}	13	Rank	11	Rank	15	Rank	11	Rank	8	Rank
1	*Vitellaria paradoxa*	0.877	0.83	1	0.98	1	1.00	1	0.80	1	0.77	1
2	*Parkia biglobosa*	0.863	0.76	2	0.96	2	0.91	2	0.78	2	0.74	2
3	*Adansonia digitata*	0.273	0.43	4	0.48	3	0.28	3	0.09		0.07	
4	*Blighia sapida*	0.216	0.46	3	0.15	5	0.11		0.26	3	0.09	4
5	*Diospyros mespiliformes*	0.145	0.26		0.11		0.07		0.22	4	0.07	
6	*Vitex doniana*	0.132	0.33	5	0.11		0.04		0.17	5	0.05	
7	*Tamarindus indica*	0.079	0.07		0.20	4	0.13	4	-		-	
9	*Ceiba pentandra*	0.044	-		-		0.13	4	-		-	
11	*Elaeis guineensis*	0.040	-		-		-		0.07		0.12	3
11	*Hyphaene thebaica*	0.040	-		-		0.09		-		0.09	4

A EDIBLE LEAVES (3 species mentioned in total)

R	**Species /** Species per cat.	UV_{SC}	2	Rank	3	Rank	2	Rank	3	Rank	2	Rank
1	*Adansonia digitata*	0.225	0.26	1	0.33	1	0.13	2	0.04	2	0.05	1
2	*Vitex doniana*	0.053	0.15	2	0.11	2	0.17	1	0.15	1	0.05	1
3	*Ceiba pentandra*	0.040	-		0.11	2	-		0.04	2	-	

We found significant differences between villages and ethnicity for *D. mespiliformes* and *V. doniana* along the first axis of the PCA (Appendix 3). Both were mainly consumed by Fulani and Bariba in both villages but with a focus on households in Papatia.

Like edible fruits, edible leaves are highly appreciated in daily cooking. Notably the leaves of *A. digitata*, *V. doniana* and *Ceiba pentandra* were valued equally across all ethnic groups (Table 11). While Fulani, Ditammarie and Kabiyé mentioned *A. digitata* most often, Yom and Bariba preferred the leaves of *V. doniana*.

In the PCA informants were separated along the first axis by location and ethnicity for all three leave-providing species (Appendix 3). That is, all interviewed dwellers in Papatia reported to harvest these trees for edible leaves but only two informants in Chabi-Couma mentioned *A. digitata* and only one mentioned *V. doniana* as important.

4.1.4. Health care

Medicinal plants

Roughly 61 % of the entirety of mentioned species was reported to be used in medical care (Table 12). Most important and used at large across households were *A. digitata* (e.g. against malaria, fever), *P. thonningii* (e.g. antiseptic, wounds) and *T. avicennioides* (e.g. antibacterial, wounds). However, overall, ethnic groups showed very different use patterns for medicinal plants. The Fulani valued *P. biglobosa* highest whereas the Ditammarie and the Kabiyé assigned *T. avicennioides*, the Yom *Monotes kerstingii* and the Bariba *Bombax costatum* and *Trichilia emetica* first priority.

Dental care (chew sticks)

Informants reported to use a great diversity of twigs for dental care: About 49 % of mentioned species were considered good chew sticks because they appear antibacterial and antiseptic. While for the Fulani and the Kabiyé *P. africana* is most important, the Yom and Bariba valued *T. aviciennioides* highest and the Ditammarie ordered *A. leiocarpa* on first place as chew sticks (Table 11). Beyond, high priority was given to *Bridelia ferruginea* and *Parinari curatellifolia* by the Kabiyé, *Pseudocedrela kotschyii* by the Bariba and Yom as well as *V. paradoxa* by the Ditammarie and the Fulani.

We found strong significant differences between informants' answers with regard to village and ethnicity along the first axis of the ordination plot for three species (Appendix 3): *Acacia spec.*, *Securinega virosa* and *Vernonia colorata* were mainly mentioned by informants from Papatia.

Table 12 Health care: list of species covering the five most important tree species used as medicinal plants (A) and for dental care (B) by ethnic group. Species were ordered according to their importance within the use category (UVSC). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

A MEDICINAL PLANTS (55 species mentioned in total)

			Fulani		**Ditammarie**		**Yom**		**Bariba**		**Kabiyé**	
R	**Species /** Species per cat.	UV_{SC}	23	Rank	11	Rank	19	Rank	13	Rank	19	Rank
1	*Parkia biglobosa*	0.088	0.24	1	-		0.11	2	-		0.09	
1	*Piliostigma thonningii*	0.088	0.09		0.07	3	0.11	2	-		0.16	2
3	*Terminalia avicennioides*	0.079	0.04		0.09	1	0.07		-		0.21	1
4	*Pteleopsis suberosa*	0.070	0.09		0.07	3	0.09		-		0.12	3
5	*Khaya senegalensis*	0.066	0.15	2	-		0.09		-		0.09	
5	*Vitellaria paradoxa*	0.066	0.11	4	0.07	3	0.09		0.07		-	
7	*Monotes kerstingii*	0.053	-		-		0.17	1	0.07		-	
8	*Gmelinia arborea*	0.048	-		-		0.07		0.07		0.12	3
8	*Pavetta crassipes*	0.048	0.07		0.09	1	0.04		-		0.05	
8	*Sarcocephalus latifolius*	0.048	0.04		-		-		0.04		0.12	3
11	*Hymenocardia acida*	0.044	0.13	3	-		0.04		-		-	
11	*Maytenus senegalensis*	0.044	-		-		0.07		-		0.12	3
14	*Pterocarpus erinaceus*	0.040	0.11	4	0.07	3	-		-		-	
14	*Anogeissus leiocarpus*	0.040	0.07		-		0.11	2	-		-	
16	*Adansonia digitata*	0.035	0.07		0.07	3	0.04		-		-	
16	*Entada africana*	0.035	0.09		-		-		0.09	3	-	
18	*Opilia celtidifolia*	0.031	0.11	4	-		-		-		-	
18	*Vitex simplicifolia*	0.031	-		-		-		-		0.12	3
20	*Bombax costatum*	0.026	-		-		-		0.13	1	-	
20	*Trichilia emetica*	0.026	-		-		-		0.13	1	-	
25	*Cochlospermum planchonii*	0.022	-		-		0.11	2	-		-	
29	*Combretum collinum*	0.018	-		-		-		0.09	3	-	
29	*Flueggea virosa*	0.018	-		-		-		0.09	3	-	
29	*Tamarindus indica*	0.018	-		0.07	3	-		-		-	

B DENTAL CARE (CHEW STICKS) (44 species mentioned in total)

R	**Species /** Species per cat.	UV_{SC}	25	Rank	15	Rank	15	Rank	19	Rank	8	Rank
1	*Prosopis africana*	0.485	0.52	1	0.35	2	0.57	2	0.20	3	0.81	1
2	*Terminalia avicennioides*	0.396	0.50	2	0.09		0.76	1	0.52	1	0.09	
3	*Anogeissus leiocarpus*	0.242	0.35	3	0.43	1	0.09	4	0.15	4	0.19	5
4	*Parinari curatellifolia*	0.141	-		0.09		0.09	4	0.07		0.44	3
5	*Bridelia ferruginea*	0.137	0.11		-		0.07		0.04		0.47	2
6	*Pseudocedrela kotschyii*	0.123	0.09		0.17	4	0.11	3	0.24	2	-	
7	*Pteleopsis suberosa*	0.115	-		0.11		-		0.04		0.42	4
8	*Vitellaria paradoxa*	0.097	0.26	5	0.20	3	-		-		-	
9	*Burkea africana*	0.093	0.30	4	-		0.09	4	-		-	
10	*Tamarindus indica*	0.070	0.04		0.13	5	0.04		0.11		-	
11	*Desmodium velutinum*	0.053	0.26	5	-		-		-		-	
12	*Entada africana*	0.044	0.04		-		-		0.15	4	-	
16	*Crossopterix febrifuga*	0.035	-		-		-		0.15	4	-	
16	*Hannoa undulata*	0.035	-		-		0.09	4	-		-	

4.1.5. Decoration (Colouring matter)

Leaves, bark, timber and roots are used for producing colouring matter to decorate houses (plaster) and terraces, dye clothes and drapery as well as face paints in the course of traditional ceremonies. Moreover, plant dye is a favoured mean to enrich dishes (sauces and soups) in terms of colour. Informants mentioned 14 species used for these applications whereof the by far most frequently cited species was *Lonchocarpus cyanescens* (Table 13) whose fruits provide an indigo blue colour that is used primarily for decoration purposes and dyeing drapery. In particular for the Bariba and the Kabiyé people indigo blue is of high cultural value. Giving a colouring agent for sauces and soups the rootstock of *Cochlospermum planchonii* is used for making a reddish powder preferred by the Fulani, the Ditammarie and the Yom. For colouring lips and teeth the reddish dye of the roots of *Piliostigma thonningii* is used by four of the five ethnic groups (except Kabiyé). In particular valued by the people of the Yom was *Bridelia ferruginea,* whose bark provides a black or purple dye for clothes and pottery. Other important species were those supplying red colouring for decoration purposes: *P. biglobosa* (bark) for the Fulani and the Ditammarie and *P. erinaceus* (timber) for the Bariba and the Kabiyé. *T. avicennioides* is also valued by two ethnic groups as it provides even several colourings: a brown dye extracted from the bark, a yellow dye (roots) and a black dye (leaves) for fabrics.

Table 13 Decoration: list of species covering the five most important tree species harvested for colouring matter (decoration) by ethnic group. Species were ordered according to their importance within the use category (UVSC). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

	COLOURING MATERIAL(14 species mentioned in total)		**Fulani**		**Ditammarie**		**Yom**		**Bariba**		**Kabiyé**	
R	**Species /** Species per cat.	UV_{SC}	4	Rank	7	Rank	4	Rank	4	Rank	2	Rank
1	*Lonchocarpus caynescens*	0.330	0.13	4	-		-		0.78	1	0.77	1
2	*Cochlospermum planchonii*	0.159	0.30	2	0.17	1	0.30	2	-		-	
3	*Piliostigma thonningii*	0.137	0.39	1	0.13	2	0.11	3	0.04	3	-	
4	*Bridelia ferruginea*	0.075	-		-		0.37	1	-		-	
5	*Parkia biglobosa*	0.062	0.17	3	0.11	3	-		-		-	
7	*Pterocarpus erinaceus*	0.031	-		-		-		0.07	2	0.09	2
8	*Terminalia avicennioides*	0.026	-		0.07	5	-		0.04	3	-	
9	*Bridelia scleroneura*	0.022	-		0.11	3	-		-		-	
12	*Ficus spec.*	0.009	-		-		0.04	4	-		-	

Differences between respondents were mostly explained by *C. planchonii* and *P. thonningii* (first axis) and *T. avicennioides* (second axis, Appendix 3). The former showed significant differences for both location and ethnicity.

4.1.6. Commercial use and cash income

Parts of plants being sold by the respondents solely comprise fruits and their components; leaves were merely consumed at home. Table 14 shows the nine most important species (of a totality of 22) with regard to local economic value, i.e. the commercial use of their fruits by rural dwellers. The fruit-tree species reported to generate cash income were preponderant congruent with those used to fulfil home consumption requirements (see Table 11). Top priority across all ethnic groups was given to the fruits of *V. paradoxa* and *P. biglobosa.* Highest mean annual returns from *V. paradoxa* seeds obtained households of the Yom (115 €, Figure 8) equalling 16.7 % of mean income per aeu (Appendix 4) in the year under investigation. The highest relative income from *V. paradoxa*-fruits was obtained by the Bariba who generated 13.3 % of annual mean income per aeu through respective sales which is equivalent to 97 €. Lowest respective income was faced by the Fulani (mean income per aeu: 46 €; share in total income: 6.5 %). The other two ethnic groups lay within this range (see Appendix 4 for further details).

Table 14 Commercial use: list of species covering the five most important tree species harvested for commercial use by ethnic group. Species were ordered according to their importance within the use category (UVSC). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank).

	COMMERCIAL USE (22 species mentioned in total)		**Fulani**		**Ditammarie**		**Yom**		**Bariba**		**Kabiyé**	
R	**Species /** Species per cat.	UV_{SC}	11	R	7	R	9	R	4	R	7	R
1	*Vitellaria paradoxa*	0.811	0.74	1	0.93	1	0.94	1	0.70	1	0.74	1
2	*Parkia biglobosa*	0.718	0.61	2	0.85	2	0.85	2	0.61	2	0.67	2
3	*Adansonia digitata*	0.137	0.15	5	0.15	3	0.28	3	0.07	3	0.07	3
3	*Blighia sapida*	0.137	0.35	3	0.13	4	0.11	4	-		-	
5	*Vitex doniana*	0.048	0.20	4	0.04	5	-		0.07	3	0.05	4
6	*Diospyros mespiliformes*	0.044	0.13		-		-		-		-	
7	*Hyphaene thebaica*	0.026	-		-		0.04		-		-	
7	*Tamarindus indica*	0.026	-		-		0.11	4	-		-	
14	*Ceiba pentandra*	0.009	-		0.04	5	-		-		-	

The second most important cash income was gained by the sale of fruits of *P. biglobosa*: Highest mean returns were obtained by households of the Ditammarie (89 € per aeu, equivalent to 12.84 % of mean income per aeu). Only slightly lower income was gained by the Yom, the Bariba and the Kabiyé (82 €, 73 € and 73 €, respectively). Least returns again were obtained by the Fulani (35 €; 4.9 % of total income).

A. digitata ranked fourth place in terms of cash income. Paramountly engaged in the sale of *A. digitata*-fruits were the members of the people of the Yom (45 € mean income per aeu; 6.6 % of mean income). The other four ethnic groups obtained considerably less mean income from respective sales (Appendix 4). Of further economic importance for at least three of the investigated ethnic groups were the fruits and the calyx of *B. sapida* as well as the fruits of *Vitex doniana* and *Saba senegalensis* (Figure 8). Several species were only marketed by particular ethnic groups: the Fulani sold *D. mespiliformes*, *D. microcarpum*, *S. senegalensis* and *X. americana*, the Ditammarie sold *C. pentandra* and the Yom sold *T. indica*, *P. erinaceus*, *H. thebaica* and *P. curatellifolia* in smaller quantities (Appendix 4).

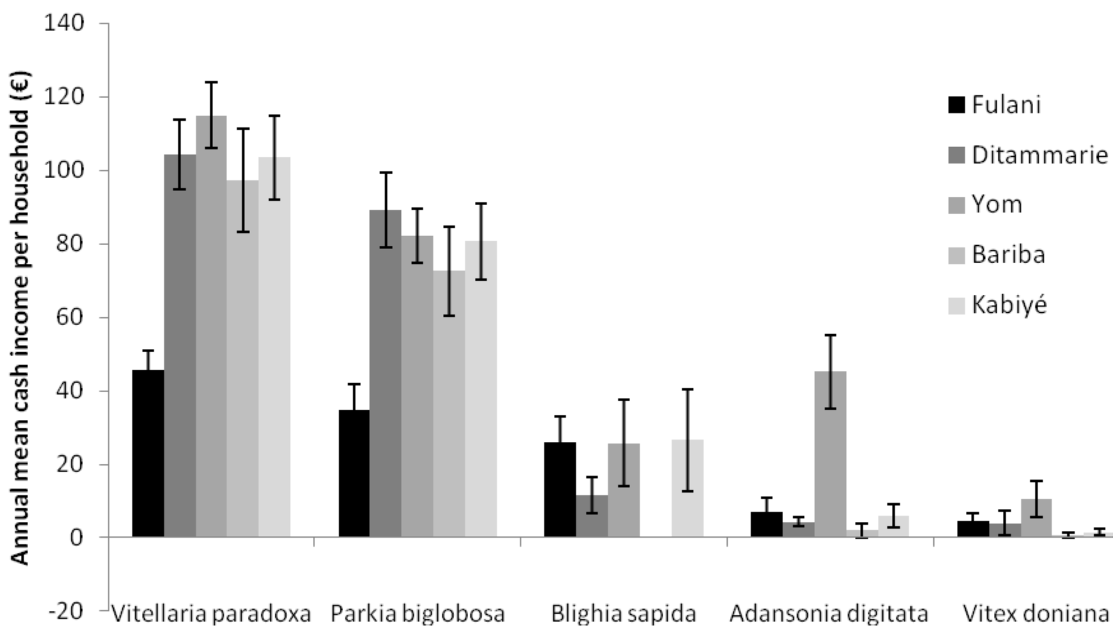


Fig. 8 Comparison of annual mean per household cash income (in Euro) generated by the sale of fruits of the five most important fruit trees by ethnic group.

We found a strong correlation for *V. doniana* and the first axis; informants were significantly separated due to location and ethnicity – this species was predominantly mentioned by Fulani in Papatia (Appendix 3). For the second axis, ethnic affiliation explained most of the observed differences but we found no strong correlations with single species.

4.2. The thirty most important woody species of the sampled population

A total of 90 ligneous species were mentioned by the informants as useful in one or more of the investigated eleven use categories (Appendix 1) whereof 61 % were used for medicinal applications, 49 % for dental care, 41 % as firewood, 39 % for construction purposes and 32 % as tool wood. Furthermore, 32 % of species also contributed to household consumption needs whereof 24 % had commercial use. Out of the 90 species 79 % are multi-purpose useful plants being valued for at least two and up to eight different uses.

According to the overall use-value and autonomous of households' socio-economic characteristics, informants gave two multi-purpose useful species top priority: *Vitellaria paradoxa* and *Parkia biglobosa* were assigned the by far highest overall use-values (Table 15). Out of eleven categories, *V. paradoxa* is four times assigned first place whereas *P. biglobosa* was placed second in three of these categories. *Terminalia avicennioides* was assigned third place and *Adansonia digitata* fourth place. Within the ten most frequently treasured multi-purpose species were furthermore *T. avicennioides, A. digitata, P. thonningii, P. africana, A. leiocarpus, P. erinaceus, R. sudanica* and *P. curatellifolia*. Out of the 21 % of species (N = 19) mentioned in one use category only the three most important ones were *O. abyssinica* (for construction purposes), *L. cyanescens* (for colouring purposes) and *D. cinerea* (for tool wood).

Table 15 The thirty most important woody plant species according to overall use-values (UVS) are shown in Table 15. These thirty species in most cases coevally cover the three most important species per use category. In total, ninety ligneous species were mentioned by the informants (N = 227) as useful for one or more of the investigated use categories (for full list please see Appendix). Colours indicate the three most important species per category (dark orange = 1. rank; middle orange = 2. rank; light orange = 3. rank). R = Rank; CW = construction wood; TW = tool wood; FW = firewood; C = cord; M = mats; EF = edible fruits; EL = Edible leaves; MP = medicinal plants; TT = tooth-twigs; CM = colouring material; CU = commercial use.

		UV_S	UV_{SC}											N cat.
			Wood uses			Constr. material		Wild foods		Health care		Decoration	Comm. use	
		total	CW	TW	FW	C	M	EF	EL	MP	TT	CM	CU	
	Total species per category	90	35	29	37	19	4	29	3	55	44	14	22	
R	Share of total species (%)	100	39	32	41	21	4	32	3	61	49	16	24	
	Species													
1	*Vitellaria paradoxa*	3.084	-	0.374	0.846	-	-	0.877	-	0.066	0.097	0.013	0.811	7
2	*Parkia biglobosa*	2.339	-	0.009	0.599	-	-	0.863	-	0.088	-	0.062	0.718	6
3	*Terminalia avicennioides*	0.956	0.216	0.137	0.101	-	-	-	-	0.079	0.396	0.026	-	6
4	*Adansonia digitata*	0.789	-	-	-	0.119	-	0.273	0.225	0.035	-	-	0.137	5
5	*Piliostigma thonningii*	0.736	-	-	-	0.485	-	-	-	0.088	0.026	0.137	-	4
6	*Prosopis africana*	0.656	0.084	0.044	0.044	-	-	-	-	-	0.485	-	-	4
7	*Anogeissus leiocarpus*	0.626	0.185	0.044	0.106	-	-	-	-	0.040	0.242	0.009	-	6
8	*Pterocarpus erinaceus*	0.621	0.128	0.132	0.260	-	-	0.009	-	0.040	0.013	0.031	0.009	8
9	*Raphia sudanica*	0.515	0.031		0.009	0.225	0.238	-	-	0.013	-	-	-	5
10	*Parinari curatellifolia*	0.511	0.251	0.022	0.070	-	-	0.018	-	-	0.141	-	0.009	6
11	*Diospyros mespiliformes*	0.427	0.119	0.035	0.022	-	-	0.145	-	0.018	0.044	-	0.044	7
12	*Blighia sapida*	0.401	-	-	0.013	-	-	0.216	-	0.026	0.009	-	0.137	5
13	*Pteleopsis suberosa*	0.396	0.026	0.062	0.057	0.066	-	-	-	0.070	0.115	-	-	6
14	*Borassus aethiopum*	0.392	-	-	-	0.013	0.339	0.009	-	-	0.026	-	0.004	5
15	*Isoberlinia doka*	0.383	0.026	-	0.326	-	-	-	-	-	0.031	-	-	3
16	*Isoberlinia tomentosa*	0.379	-	-	0.339	-	-	-	-	0.018	0.022	-	-	3
17	*Hymenocardia acida*	0.370	0.044	0.009	0.273	-	-	-	-	0.044	-	-	-	4
18	*Hyphaene thebaica*	0.361	-	-	-	0.009	0.273	0.040	-	0.013	-	-	0.026	5
19	*Hexalobus monopetalus*	0.357	0.040	-	-	0.278		-	-	0.009	0.018	0.013	-	5
19	*Oxynanthera abyssinica*	0.357	0.357	-	-	-	-	-	-	-	-	-	-	1
21	*Lophira lanceolata*	0.352	0.269	0.018	0.035	-	-	-	-	0.022	0.009	-	-	5
22	*Khaya senegalensis*	0.348	0.097	0.075	0.057	-	-	0.022	-	0.066	0.031	-	-	6
23	*Lonchocarpus cyanescens*	0.330	-	-		-	-	-	-	-	-	0.330	-	1

Table 15 (continued)

		UV$_S$	UV$_{SC}$											N cat.
			Wood uses			Constr. material		Wild foods		Health care		Decoration	Comm. use	
		total	CW	TW	FW	C	M	EF	EL	MP	TT	CM	CU	
	Total species per category	90	35	29	37	19	4	29	3	55	44	14	22	
R	Share of total species (%)	100	39	32	41	21	4	32	3	61	49	16	24	
	Species													
24	*Detarium microcarpum*	0.304	-	-	0.194	0.018	-	0.053	-	0.026	-	-	0.013	5
25	*Daniellia oliveri*	0.286	0.013	-	0.247	-	-	-	-	0.026	-	-	-	3
26	*Cochlospermum planchonii*	0.278	-	-	-	0.093	-	-	-	0.022	-	0.159	0.004	4
27	*Bridelia ferruginea*	0.273	0.013	-	0.035	-	-	-	-	0.013	0.137	0.075	-	5
28	*Hannoa undulata*	0.269	0.150	0.048	0.026	0.009		-	-	-	0.035	-	-	5
29	*Vitex doniana*	0.260	-	0.009	0.009	-	-	0.132	0.053	0.009	-	-	0.048	6
30	*Tamarindus indica*	0.247	0.040	0.013	-	-	-	0.079	-	0.018	0.070	-	0.026	6

5. Discussion

5.1. Preferences for woody species: similarities and differences between ethnic groups

The great number of species mentioned by the respondents (N = 90) displays the high level of local knowledge about and actual use of woody plants corroborating the essential role trees and shrubs play in the maintenance of rural communities living adjacent to savanna woodlands. NTFPs constitute a critical component of the household economy. Whilst there is a certain set of plant species used jointly by all rural dwellers others are exclusively used by particular ethnic groups for specific purposes. Across the full sample *V. paradoxa* is the by far most appreciated species to fulfil several household needs. The reasons for this are manifold: The fruits of *V. paradoxa* (processed as sheabutter) are, firstly, critical to the household's diet because they supply rich fatty acids used for cooking. Boffa (1999) reported the average annual consumption of sheabutter in sub-Saharan countries to be 7.3 up to 10 kg per person. For the same reason, these fruits gain the highest cash. Secondly, *V. paradoxa*-wood is a quickly available primary energy source –easily accessible on farmland – and used for making tools (the soft wood is easy to carve). The second most important common species is *P. biglobosa* whose seeds are also complementing daily consumption needs (processed to the typical and locally high appreciated condiment *moutarde* used in sauces) and are frequently sold on local markets. Its wood is preferably used as firewood, too. In addition, several of its parts are used in traditional medicine. Another mutually highly valued fruit tree species in this regard is *A. digitata* whose vitamin C-rich fruit pulp (Gebauer, El-Siddig et al. 2002) is added to the local drink *l'eau blanche* and the local porridge *bouille*; the roasted seeds are treasured in sauces (Sidibé and Williams 2002). In particular, the leaves of *A. digitata* are an important source of protein and minerals (Yazzie et al., 1994).

V. paradoxa, P. biglobosa and *Adansonia digitata*, accompanied by *B. sapida and V. doniana*, are the economic key species for local dwellers of the parklands of northern Benin. Thus, they obtain high conservation priorities by both the locals and the government: Sparing these trees from chopping, fields and fallows are the most important sources of NTFP extraction containing preponderantly conserved adult trees (Schreckenberg 1999; Schumann et al., 2010). In Burkina Faso, the average yield of *V. paradoxa*-kernels located in agroforestry systems was significantly higher (4 kg per tree) than in the natural formations (1.5 kg per tree; Lamien et al., 2004). In two regions adjacent to our study area (Bassila and Pendjari National Park) *V. paradoxa, P. biglobosa* and *A. digitata* turned out among the three most important NTFP-providing species, too (Vodouhê et al., 2009). However, there are differences between ethnic groups with regard to the cash income generated by the sale of respective fruits: Fulani people considerably earned less than the other groups indicating that the former pastoralists who still own cattle rely stronger on the financial returns of animal husbandry to generate sufficient income, especially through the sale of cow milk (Gaoue and Ticktin 2009), than tiller societies (Heubach et al., 2011).

Another factor separating respondents identified in our study was location. As cited in the introduction other scientific works recorded regional differences between members of the same ethnic group, too (Gouwakinnou et al., 2011; Schumann 2011). In particular, we found that villagers from Chabi-Couma comparatively valued less native species than dwellers from Papatia did. This might be due to the fact that the local market of Chabi-Couma is considerably larger than that of Papatia enabling locals to rather buy NTFPs than extract them themselves, and, replace natural products by modern ones (e.g. wooden kitchen utensils by suitable plastic items). Furthermore, conditional upon the comparatively higher extent of plantations and settlement area people in Chabi-Couma have to face longer walks to extraction areas, i.e. higher opportunity costs for respective activities. This might preclude especially wealthier households from NTFP-harvesting. Our results are accompanied by other studies that explored local use preferences of a wider set of woody species with a view to contextual factors. Among these are the explorations of Lykke et al. (2004) who presented distinctions in local knowledge and actual use of woody species among Fulani from different villages in the Sahelian zone of Burkina Faso resulting from different ecological environments and individual characteristics of informants. Furthermore, Vodouhê (2009) showed gender, ethnicity and species' marketability to influence peoples' valuation priorities for local plant resources in northern Benin whereas Schreckenberg (1999) in central Benin identified, in particular, institutional settings to shape peoples' de facto plant uses. That is, small-scale matters considerably when thinking about which species to prioritize in conservation actions.

5.2. Improving conservation measures for NTFP-providing species

Our study identified the most important species for local dwellers in 11 relevant use categories in general and conditioned by their ethnicity. These results can contribute to design appropriate strategies in terms of conservation priorities.

We conclude, that prioritization should consider, first of all, woody species that fulfil both subsistence needs and coevally have commercial value: Our study listed ten subsistence use categories and found ninety species to meet particular subsistence needs while 22 of these concurrently contributed to the household economy. Thus, plant species with a high economic value should be adequately addressed since they can buffer possible cash shortfalls; this especially holds true for women since they are the main collectors and traders of NTFPs. Subsequently, markets positively affect values assigned to species by beneficiaries (Gustad et al., 2004) resulting in a greater incentive to protect and conserve important native trees while coevally helping to alleviate destructive but economically more relevant forest-based activities like e.g. logging or conservation to farmland (Vadez et al., 2004; Avocèvou-Ayisso, Sinsin et al. 2009; Vodouhê, Coulibaly et al. 2009). This incentive-based 'conservation-through-use' approach is, however, only suitable for tree species characterized by marketability (stable demand and local purchasing power for particular NTFP) and profitability for producers (i.e. adequate financial returns) in connection with land tenure security (Newton 2008). Moreover, they must not compete with agricultural products with regards to cultivation area or labour allocation, i.e. the feasibility for the commercialisation of NTFPs is highest where either arable land or the demand for the same is low (Newton 2008). In our case, species suitable for conservation-through-use are most likely *V. paradoxa*, *P. biglobosa* and *A. digitata*, i.e. abundant economic key species.

Thirdly, in order to design a locally feasible and conducive conservation management, traditional ecological knowledge based on long-term observation should be gathered complementing scientific records (Ford 2001; Donovan and Puri 2004) and guiding the comprehension of the social mechanisms behind traditional use and conservation practices (Berkes et al., 2000). In this regard, it is imperative to give consideration to culturally conditioned differences in use preferences (e.g. with regards to ethnic affiliation) on a small-scale basis as well as conservation measures must be interwoven with the ensuring of local rights on common properties, i.e. securing land tenure and access to extraction sites.

6. Conclusion

The findings of our study provide important information for local policy-makers in order to improve existent conservation measures concerning useful woody species in northern Benin, West Africa. As the main message of this scientific work we can put forward the argument of social differentiation presupposing use-values and, thus, determining the extent of plant diversity to be conserved in order to meet all use preferences. There is no small set of tree species used that would facilitate allocating conservation efforts. Rather, there are both several NTFP-providing tree species jointly appreciated plus a greater assortment of species necessary to obtain ethnically-conditioned household requirements. To gain clarity, broader comprehension of, and knowledge about the issue of contextual factors (institutional and ecological) as well as individual characteristics determining the observed differences in plant use, further small-scale research should be conducted concerning differences between local beneficiaries of NTFPs as well as extraction modes and rates complemented by the analysis of land tenure and market dynamics. Additionally, ecological features of NTFP-providing trees (abundance and population dynamics) as well as information about their de facto abundance (or decline, respectively) gathered both scientifically and through traditional ecological knowledge should attend this data in order to ensure the sustainable use of the culturally and economically most important tree species in the savanna ecosystem.

7. Acknowledgements

The present study was conducted at the Biodiversity and Climate Research Centre (BiK-F), Frankfurt am Main, Germany, and funded by the research funding programme "LOEWE – Landes-Offensive zur Entwicklung Wissenschaftlich-Ökonomischer Exzellenz" of Hesse's Ministry of Higher Education, Research, and the Arts. The authors are grateful to Gnanando Saidou and Laurent Akissatom who assisted in field work and especially all respondents who took part in the survey. Sincere thanks go further to Prof. Brice Sinsin (University of Abomey-Calavi, Benin) for scientific and logistic support. Furthermore, we would like to thank the anonymous reviewers for their constructive comments on this work.

Appendices

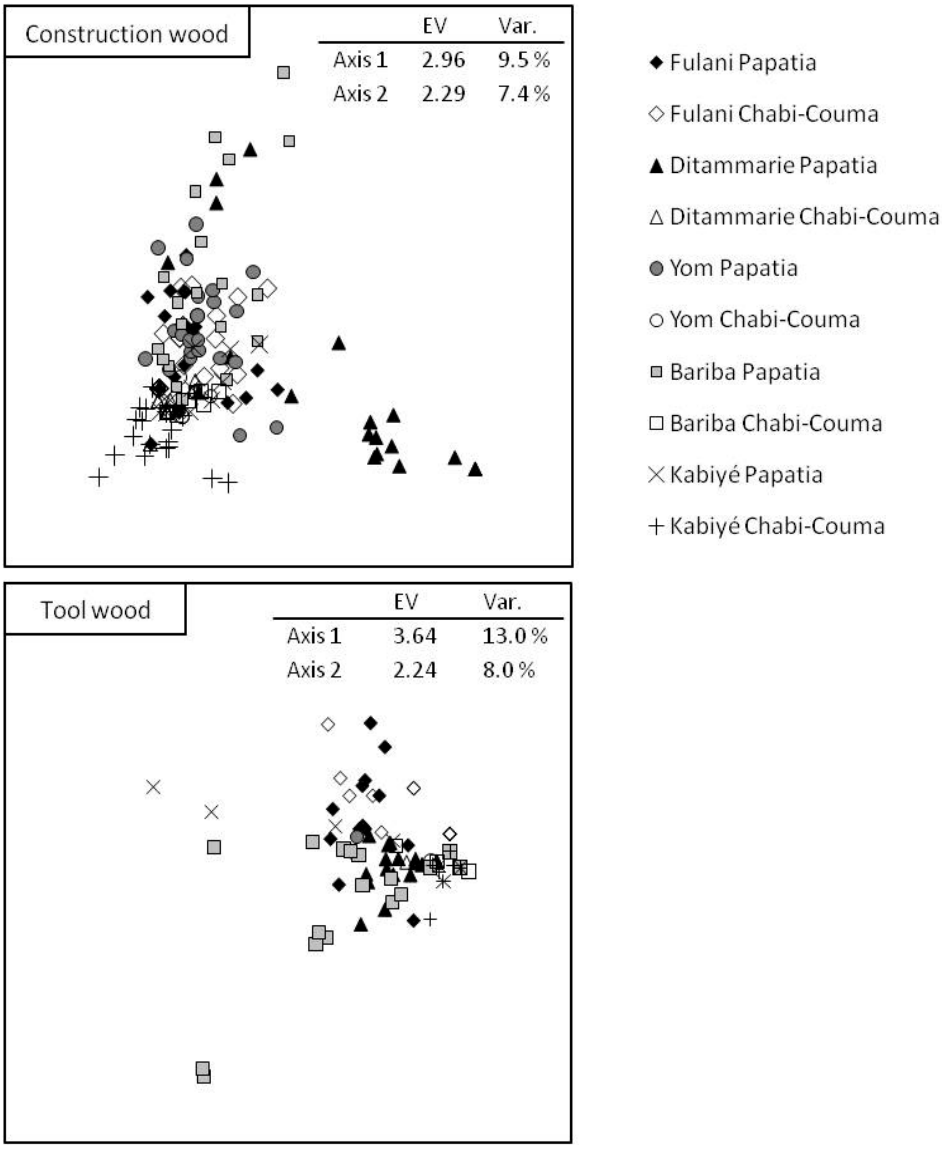
Appendix 1 Full list of plant species mentioned as useful by respondents

		UV_S	UV_{SC}										
			Wood uses			**Constr. material**		**Wild foods**		**Health care**		**Deco.**	**Comm.**
		total	**CW**	**TW**	**FW**	**C**	**M**	**EF**	**EL**	**MP**	**TT**	**CM**	**CU**
	Species / cat.	90	35	29	37	19	4	29	3	55	44	14	22
R	**Species**												
1	*Vitellaria paradoxa*	3.084		0.374	0.846			0.877		0.066	0.097	0.013	0.811
2	*Parkia biglobosa*	2.339		0.009	0.599			0.863		0.088		0.062	0.718
3	*Terminalia avicennioides*	0.956	0.216	0.137	0.101					0.079	0.396	0.026	
4	*Adansonia digitata*	0.789				0.119		0.273	0.225	0.035			0.137
5	*Piliostigma thonningii*	0.736				0.485				0.088	0.026	0.137	
6	*Prosopis africana*	0.656	0.084	0.044	0.044						0.485		
7	*Anogeissus leiocarpus*	0.626	0.185	0.044	0.106					0.040	0.242	0.009	
8	*Pterocarpus erinaceus*	0.621	0.128	0.132	0.260			0.009		0.040	0.013	0.031	0.009
9	*Raphia sudanica*	0.515	0.031		0.009	0.225	0.238			0.013			
10	*Parinari curatellifolia*	0.511	0.251	0.022	0.070			0.018			0.141		0.009
11	*Diospyros mespiliformes*	0.427	0.119	0.035	0.022			0.145		0.018	0.044		0.044
12	*Blighia sapida*	0.401			0.013			0.216		0.026	0.009		0.137
13	*Pteleopsis suberosa*	0.396	0.026	0.062	0.057	0.066				0.070	0.115		
14	*Borassus aethiopum*	0.392				0.013	0.339	0.009			0.026		0.004
15	*Isoberlinia doka*	0.383	0.026		0.326						0.031		
16	*Isoberlinia tomentosa*	0.379			0.339					0.018	0.022		
17	*Hymenocardia acida*	0.370	0.044	0.009	0.273					0.044			
18	*Hyphaene thebaica*	0.361				0.009	0.273	0.040		0.013			0.026
19	*Hexalobus monopetalus*	0.357	0.040			0.278				0.009	0.018	0.013	
19	*Oxynanthera abyssinica*	0.357	0.357										
21	*Lophira lanceolata*	0.352	0.269	0.018	0.035					0.022	0.009		
22	*Khaya senegalensis*	0.348	0.097	0.075	0.057			0.022		0.066	0.031		
23	*Lonchocarpus cyanescens*	0.330										0.330	
24	*Detarium microcarpum*	0.304			0.194	0.018		0.053		0.026			0.013
25	*Daniellia oliveri*	0.286	0.013		0.247					0.026			
26	*Cochlospermum planchonii*	0.278				0.093				0.022		0.159	0.004
27	*Bridelia ferruginea*	0.273	0.013		0.035					0.013	0.137	0.075	
28	*Hannoa undulata*	0.269	0.150	0.048	0.026	0.009					0.035		
29	*Vitex doniana*	0.260		0.009	0.009			0.132	0.053	0.009			0.048
30	*Tamarindus indica*	0.247	0.040	0.013				0.079		0.018	0.070		0.026
30	*Burkea africana*	0.247	0.079	0.031	0.044						0.093		
32	*Monotes kerstingii*	0.238	0.145	0.018				0.013		0.053	0.009		
33	*Swartzia madagascariensis*	0.207	0.093	0.088							0.026		
34	*Afzelia africana*	0.190	0.066	0.048	0.066					0.009			
35	*Pericopsis laxiflora*	0.154	0.057	0.044	0.044						0.009		
35	*Erythrophleum africanum*	0.154	0.022	0.057	0.053						0.022		
37	*Pseudocedrela kotschyi*	0.150			0.009	0.009				0.009	0.123		
38	*Uapaca togoensis*	0.145	0.044		0.101								
39	*Crossopterix febrifuga*	0.110			0.062					0.013	0.035		

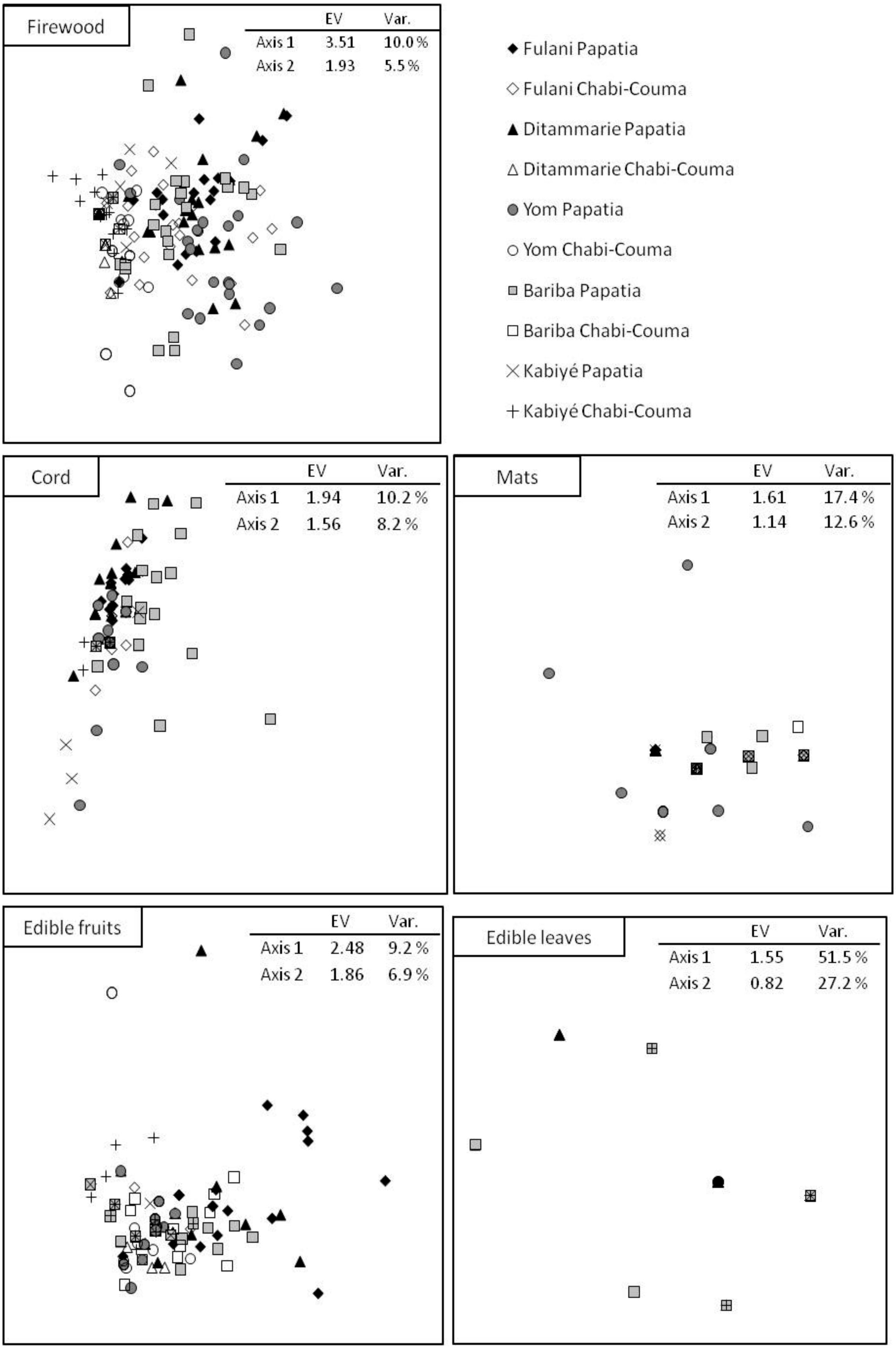
Appendix 1 (continued)

		UV_S						UV_{SC}					
			Wood uses			**Constr. material**		**Wild foods**		**Health care**		**Deco.**	**Comm.**
		total	**CW**	**TW**	**FW**	**C**	**M**	**EF**	**EL**	**MP**	**TT**	**CM**	**CU**
	Species / cat.	90	35	29	37	19	4	29	3	55	44	14	22
R	**Species**												
39	*Bombax costatum*	0.110		0.066						0.026			0.009
41	*Dichrostachys cinerea*	0.106		0.106									
42	*Ceiba pentandra*	0.101	0.009					0.044	0.040				0.009
43	*Annona senegalensis*	0.097						0.040		0.022	0.018		0.018
44	*Sarcocephalus latifolius*	0.093			0.009			0.018		0.048	0.018		
44	*Entada africana*	0.093				0.013				0.035	0.044		
46	*Ficus spec.*	0.088			0.009	0.013		0.013		0.044		0.009	
46	*Manilkara multinervis*	0.088	0.009	0.066	0.013								
48	*Lannea acida*	0.084						0.018				0.062	0.004
48	*Combretum spec.*	0.084			0.053					0.013	0.018		
48	*Elaeis guineensis*	0.084				0.018		0.040					0.026
51	*Acacia spec.*	0.075		0.009	0.009					0.018	0.040		
52	*Saba senegalensis*	0.070						0.044					0.026
53	*Bridelia microcantha*	0.066	0.013		0.053								
54	*Syzigium guineense*	0.062	0.009							0.009	0.044		
55	*Saba comorensis*	0.057				0.031		0.018		0.009			
55	*Gmelinia arborea*	0.057		0.009						0.048			
57	*Trichilia emetica*	0.053	0.009							0.026	0.018		
57	*Securidaca longepedunculata*	0.053	0.031							0.009	0.013		
57	*Desmodium velutinum*	0.053									0.053		
60	*Vitex simplicifolia*	0.048						0.018		0.031			
60	*Bridelia scleroneura*	0.048									0.026	0.022	
60	*Pavetta crassipes*	0.048								0.048			
63	*Maytenus senegalensis*	0.044								0.044			
64	*Lannea microcarpa*	0.040				0.031						0.009	
64	*Combretum molle*	0.040	0.013		0.013					0.013			
64	*Ximenia americana*	0.040						0.026					0.013
64	*Securinega virosa*	0.040								0.022	0.018		
68	*Haematostaphis barteri*	0.035	0.026								0.009		
69	*Combretum collinum*	0.031		0.013						0.018			
69	*Cussonia barteri*	0.031			0.031								
71	*Opilia celtidifolia*	0.031								0.031			
72	*Gardenia erubescens*	0.026						0.018					0.009
72	*Gardenia ternifolia*	0.026						0.018					0.009
72	*Erythrina senegalensis*	0.026								0.018	0.009		
72	*Stereospermum kunthianum*	0.026	0.013	0.013									
76	*Vernonia colorata*	0.022								0.013	0.009		
77	*Stercularia setigera*	0.018	0.009			0.009							
77	*Flueggea virosa*	0.018								0.018			
77	*Jatropha curcas*	0.018								0.000	0.018		
77	*Vernonia amygdalina*	0.018								0.018			
81	*Lannea barteri*	0.013				0.013							
81	*Lannea velutina*	0.013				0.013							
81	*Cassia sieberiana*	0.013								0.013			
81	*Paulinia pinnata*	0.013			0.013								
85	*Spondias monbin*	0.009						0.009					
85	*Calotropis procera*	0.009			0.009								
85	*Senna siamea*	0.009								0.009			
85	*Combretum microcanthum*	0.009								0.009			
85	*Heeria insignis*	0.009								0.009			
85	*Ochna schweinfurthiana*	0.009								0.009			

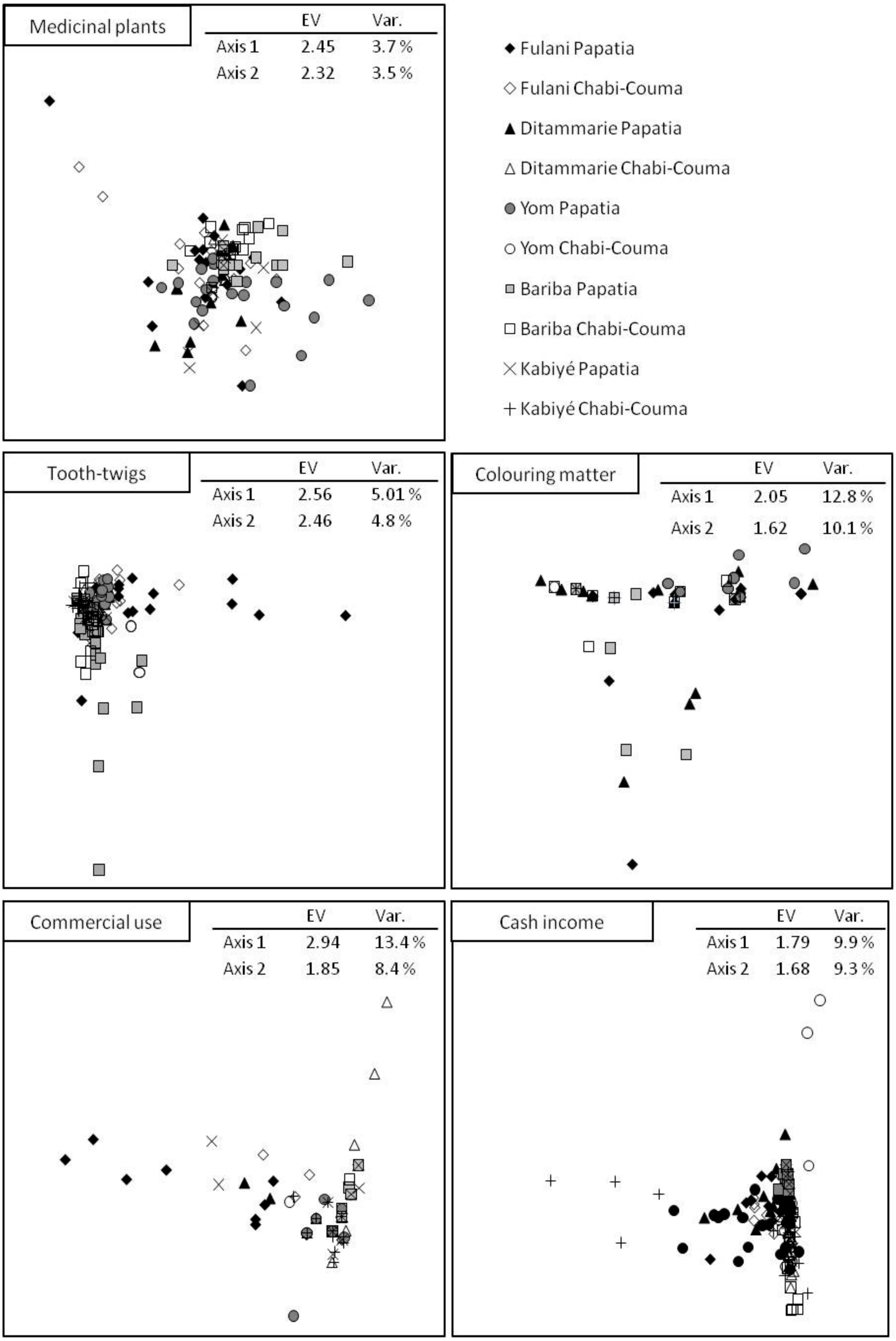
Appendix 2 Ordination plots for each of the eleven use categories. Shown are Eigenvalues and variance of the axes.



Appendix 2 (continued)



Appendix 2 (continued)



Appendix 3 Results of regressions, testing whether residence (village) and ethnic affiliation are affecting informants' choices for plant species used in the eleven investigated use categories. (***p < 0.001; **p < 0.01; *p < 0.05; SE = Standard error)

CONSTRUCTION WOOD								
	1. Axis (*Afzelia africana, Swartzia madagascariensis, Prosopis africana, Tamarindus indica*)				**2. Axis** (*Pericopsis laxiflora*)			
Term	Coefficient	SE	Beta	*t*-value	Coefficient	SE	Beta	*t*-value
(Intercept)	(3.024)	(0.400)		(7.552***)	(2.503)	(0.357)		(7.013***)
Village	-1.439	0.208	-0.418	-6.935***	-1.270	0.185	-0.419	-6.865***
Ethnicity	-0.277	0.074	-0.224	-3.716***	-0.189	0.066	-0.174	-2.849**

First axis: N = 215; R^2 = 0.226; R²adj = 0.218; F = 31.031; Eigenvalue: 2.96; Explained variance: 9.5 %; Correlation with species: *A. africana*: r = 0.751**, *S. madagascariensis*: r = 0.698**, *P. africana*: r = 0.686**, *T. indica*: r = 0.665**; Second axis: N = 215; R^2 = 0.206; R²adj = 0.199; F = 27.684; Eigenvalue: 2.29; Explained variance: 7.4 %; Correlation with species: *P. laxiflora*: r = 0.607**

FIREWOOD								
	1. Axis (*Hymenocardia acida, Isoberlinia doka, I. tomentosa*)				**2. Axis** (*Vitellaria paradoxa)*			
Term	Coefficient	SE	Beta	*t*-value	Coefficient	SE	Beta	*t*-value
(Intercept)	(4.912)	(0.358)		(13.727***)	(0.410)	(0.367)		(1.118)
Village	-2.197	0.184	-0.586	-11.930***	-0.370	0.189	-0.133	-1.961
Ethnicity	-0.518	0.066	-0.384	-7.819***	-0.051	0.068	-0.051	-0.751

First axis: N = 215; R^2 = 0.487; R²adj = 0.482; F = 101.061; Eigenvalue: 3.51; Explained variance: 10.0 %; Correlation with species: *H. acida*: r = 0.604**, *I. doka*: r = 0.737**, *I. tomentosa*: r = 0.800**; Second axis: N = 215; R^2 = 0.020; R²adj = 0.011; F = 2.216; Eigenvalue: 1.93; Explained variance: 5.5 %; Correlation with species: *V. paradoxa*: r = 0.661**.

CORD				
	1. Axis (*Entada africana*)			
Term	Coefficient	SE	Beta	*t*-value
(Intercept)	(1.755)	(0.346)		(5.074***)
Village	-0.896	0.179	-0.322	-5.006***
Ethnicity	-0.130	0.064	-0.130	-2.020*

First axis: N = 216; R^2 = 0.120; R²adj = 0.112; F = 14.568; Eigenvalue: 1.94; Explained variance: 10.2 %; Correlation with species: *E. africana*: r = 0.606**;Second axis: N = 216; R^2 = 0.147; R²adj = 0.143; F = 36.842; Eigenvalue: 1.56; Explained variance: 8.2 %.

Appendix 3 (continued)

MATS				
	1. Axis (*Borassus aethiopum, Hyphaene thebaica*)			
Term	Coefficient	SE	Beta	*t*-value
(Intercept)	(1.583)	(0.296)		(5.343***)
Village	-0.952	0.157	-0.376	-6.078***
Ethnicity	-0.050	0.056	-0.056	-0.899

First axis: N = 227; R^2 = 0.142; R²adj = 0.138; F = 37.200; Eigenvalue: 1.61; Explained variance: 17.8 %; Correlation with species: *B. aethiopum*: r = 0.768*, *H. thebaica*: r = 0.777*. Second axis: N = 227; R^2 = 0.015; R²adj = 0.006; F = 1.723; Eigenvalue: 1.14; Explained variance: 12.6 %

EDIBLE FRUITS								
	1. Axis (*Diospyros mespiliformes, Vitex doniana*)				**2. Axis** (*Saba comorensis*)			
Term	Coefficient	SE	Beta	*t*-value	Coefficient	SE	Beta	*t*-value
(Intercept)	(2.085)	(0.377)		(5.533***)	(0.324)	(0.351)		(0.924)
Village	-0.335	0.070	-0.298	-4.774***	-0.129	0.183	-0.047	-0.705
Ethnicity	-0.714	0.197	-0.227	-0.3634***	-0.043	0.065	-0.044	-0.658

First axis: N = 224; R^2 = 0.140; R²adj = 0.133; F = 18.056; Eigenvalue: 2.48; Explained variance: 9.2 %; Correlation with species: *D. mespiliformes*: r = 0.651**, *V. doniana*: r = 0.679**; Second axis: N = 224; R^2 = 0.004; R²adj = -0.005; F = 0.467; Eigenvalue: 1.86; Explained variance: 6.9 %; Correlation with species: *Saba comorensis*: r = 0.750**; Correlation with species: *S. comorensis*: r = 0.750**.

EDIBLE LEAVES								
	1. Axis (*Adansonia digitata, Ceiba pentandra, Vitex doniana*)				**2. Axis** (*Vitex doniana*)			
Term	Coefficient	SE	Beta	*t*-value	Coefficient	SE	Beta	*t*-value
(Intercept)	(-2.971)	(0.282)		(-6.982***)	(-0.356)	(0.227)		(-1.570)
Village	0.982	0.149	0.395	6.581***	0.224	0.120	0.124	1.868
Ethnicity	0.165	0.053	0.187	3.112**	0.006	0.043	0.010	0.148

First axis: N = 227; R^2 = 0.194; R²adj = 0.186; F = 26.900; Eigenvalue: 1.55; Explained variance: 51.5 %; Correlation with species: *A. digitata*: r = -0.734**, *C. pentandra*: r = -0.657**, *V. doniana*: r = -0.605**; Second axis: N = 7R^2 = 0.015; R²adj = 0.007; F = 1.761; Eigenvalue: 0.82; Explained variance: 27.2 %. Correlation with species: *V. doniana*: r = -0.611**.

DENTAL CARE (CHEW STICKS)								
	1. Axis (*Acacia spec., Securinega virosa, Vernonia colorata)*				**2. Axis** (*Erythrina senegalensis, Swartzia madagascariensis)*			
Term	Coefficient	SE	Beta	*t*-value	Coefficient	SE	Beta	*t*-value
(Intercept)	(2.037)	(0.368)		(5.530***)	(0.230)	(0.394)		(0.584)
Village	-0.503	0.195	-0.157	-2.583**	0.083	0.208	0.026	0.399
Ethnicity	-0.430	0.069	-0.378	-6.208***	-0.119	0.074	-0.107	-1.611

First axis: N = 227; R^2 = 0.170; R²adj = 0.162; F = 22.917; Eigenvalue: 2.56; Explained variance: 5.0 %; Correlation with species: *A. spec.*: r = 0.663**, *S. virosa*: r = 0.657, *V. colorata*: r = 0.652**; Second axis: N = 219; R^2 = 0.012; R²adj = 0.003; F = 1.366; Eigenvalue: 2.46; Explained variance: 4.8 %; Correlation with species: *E. senegalensis*: r = -0.625**, *S. madagascariensis*: r = -0.687**.

Appendix 3 (continued)

COLOURING MATTER								
	1. Axis (*Cochlospermum planchonii, Piliostigma thonningii*)				**2. Axis** (*Terminalia avicennioides*)			
Term	Coefficient	SE	Beta	*t*-value	Coefficient	SE	Beta	*t*-value
(Intercept)	(2.488)	(0.321)		(7.752***)	(-0.512)	(0.324)		(-1.583)
Village	-0.366	0.060	-0.358	-6.094***	0.159	0.170	0.062	0.935
Ethnicity	-0.923	0.169	-0.322	-5.478***	0.091	0.060	0.101	1.507

First axis: N = 224; R^2 = 0.235; R^2adj = 0.228; F = 34.017; Eigenvalue: 2.05; Explained variance: 12.8 %; Correlation with species: *C. planchonii*: r = 0.780**, *P. thonningii*: r = 0.666**; Second axis: N = 219; R^2 = 0.014; R^2adj = 0.005; F = 1.591; Eigenvalue: 1.62; Explained variance: 10.1 %; *T. avicennioides*: r = -0.866**.

COMMERCIAL USE				
	1. Axis (*Vitex doniana*)			
Term	Coefficient	SE	Beta	*t*-value
(Intercept)	(-1.388)	(0.426)		(-3.258***)
Village	0.606	0.224	0.177	2.703**
Ethnicity	0.159	0.080	0.130	1.908*

First axis: N = 226; R^2 = 0.049; R^2adj = 0.040; F = 5.704; Eigenvalue: 2.94; Explained variance: 13.4 %; Correlation with species: *V. doniana*: r = -0.676*; Second axis: N = 226; R^2 = 0.085; R^2adj = 0.080; F = 20.687; Eigenvalue: 1.85; Explained variance: 8.4 %.

Appendix 4 Cash income: list of species covering the five most important tree species generating cash income by ethnic group. Shown are the absolute and mean (in parentheses) annual incomes by ethnic group and species as well as their respective share in total household income. Species were ordered according to their importance within the use category. Colours indicate the three most important species per category (dark grey = 1. rank; middle grey = 2. rank; light grey = 3. rank). Share = share in total income per aeu.

	Fulani (Species = 10)		**Ditammarie** (Species = 6)		**Yom** (Species = 9)		**Bariba** (Species = 4)		**Kabiyé** (Species = 4)	
Species	Mean income per aeu	Share (%)	Mean income per aeu	Share (%)	Mean income per aeu	Share (%)	Mean income per aeu	Share (%)	Mean income per aeu	Share (%)
V. paradoxa	45.5	6.5	104.2	15.0	114.9	16.7	97.2	13.3	97.2	15.1
P. biglobosa	34.9	4.9	89.1	12.8	82.0	11.9	72.6	9.9	72.6	11.3
B. sapida	26.1	3.7	11.6	1.7	25.7	3.7	-		-	
A. digitata	6.9	1.0	4.4	0.6	45.2	6.6	2.0	0.3	2.0	0.3
V. doniana	4.6	0.7	4.0	0.6	-		0.7	0.1	0.7	0.1
T. indica	-		-		6.1	0.9	-		-	
P. erinaceus	-		-		2.7	0.4	-		-	
D. mespiliformes	2.4	0.3	-		-		-		-	
A. senegalensis	0.3	0.04	-		2.1	0.3	-		-	
H. thebaica	-		-		1.6	0.2	-		-	
P. curatellifolia	-		-		1.8	0.3	-		-	
D. microcarpum	0.2	0.03	-		-		-		-	
S. senegalensis	0.2	0.03	-		-		-		-	
C. pentandra	-		0.6	0.1	-		-		-	
X. americana	0.1	0.01	-		-		-		-	

Chapter 4

Impact of future climate and land use change on Non-Timber Forest Product provision in Benin, West Africa: Linking niche-based modelling with ecosystem service values

with Jonathan Heubes, Marco Schmidt, Rüdiger Wittig, Georg Zizka, Ernst-August Nuppenau and Karen Hahn
submitted to *Ecological Economics*.

Abstract

Non-timber forest products (NTFPs) make a major contribution to the livelihoods of the West African population. However, these ecosystem services are threatened by climate and land use change. Our study aims at developing a novel approach to assess the impacts of climate and land use change on the economic benefits derived from NTFPs. We performed 60 household interviews in Northern Benin to gather data on annual quantities and revenues of collected NTFPs from the three most important savanna tree species: *Adansonia digitata*, *Parkia biglobosa* and *Vitellaria paradoxa*. We assessed the species' current and future (2050) occurrence probabilities by calibrating niche-based models with climate and land use data at a 0.1° resolution. To assess future economic gains and losses, respectively, we linked modelled species' occurrence probabilities with the spatially assigned monetary values. Highest current benefits are obtained by locals from *V. paradoxa* (54,111±28,126 US$/yr/grid cell), followed by *P. biglobosa* (32,246±16,526 US$/yr/grid cell) and *A. digitata* (9,514±6,243 US$/yr/grid cell). However, in the prediction large areas are projected to lose up to 50% of their current economic value by 2050. Our findings provide a first benchmark for local policy-makers to economically compare different land use options and adjust existing management strategies.

1. Introduction

For millennia, the livelihoods of rural West African communities have been based on goods and services provided by plants and animals of surrounding ecosystems. In particular, products of native plant species (e.g. fruits, leaves, bulbs) have played a central role in satisfying household subsistence needs including nutrition needs, medical treatment, energy supply, as well as construction material and firewood. Furthermore, non-timber forest products (NTFPs) contribute to the household economy by generating cash income helping to diversify livelihood strategies, and coevally they hold an important insurance function in times of financial crisis (Angelsen and Wunder, 2003; Cavendish, 2002). The extraction of NTFPs particularly attracts the African rural poor because no professional skills or equipment are required (low-threshold activity), extraction sites are characterized by open or semi-open access, and labor markets are generally thin, i.e. income alternatives are scarce (Angelsen and Wunder, 2003; Shackleton and Shackleton, 2004; Shackleton et al., 2007).

The economic relevance of NTFPs for rural livelihoods in Africa, both in terms of subsistence and cash income, has been increasingly reported. Their contribution to the annual total household income was found to range from 15% in Malawi (Kamanga et al., 2009) to roughly 40% in Mali (Faye et al., 2010). In Northern Benin, NTFPs make up 39% of the yearly income (Heubach et al., 2011); major contributors to this NTFP income are three native woody species: *Vitellaria paradoxa* (subspecies *paradoxa*, Shea Tree or karité), *Parkia biglobosa* (African Locust Bean Tree or néré) and *Adansonia digitata* (African Baobab) (Heubach et al., unpublished data; Vodouhê et al., 2009). All three species occur throughout the Sudanian zone from Senegal to Sudan within the isohyets of 600 and 1400 mm; the baobab tree also occurs throughout the savanna regions of eastern and southern Africa (Arbonnier, 2004). NTFPs of these three species traditionally serve as a dietary supplement. In particular, two products are increasingly demanded and traded on international markets: shea butter due to its qualities as surrogate for cocoa butter (INSAE, 2008) and baobab fruit powder because of its health benefits (Besco et al., 2007).

However, Africa is expected to face severe changes in climatic conditions and land use this century (IPCC, 2007; Sala et al., 2000). How will these environmental changes affect ecosystem functions and, therewith, the provision of ecosystem services such as

NTFPs (MA, 2005)? Given that rural communities often heavily depend on a constant provision of NTFPs (Heubach et al., 2011) and, thus, can be considered as highly vulnerable to the expected changes, what are the immediate consequences for their well-being and livelihoods? Additionally, there might be low adaptive capacity in this regard due to a comparatively weak ability of the regional government to regulate environmental impacts (UNECA, 2005).

Subsequently, it is crucial to map the economic value of ecosystem services such as NTFPs reflecting their current use, and simulate future monetary benefits, in order to potentially adapt management practices in view of environmental changes (Chen et al., 2009; Costanza et al., 1997). In the past years, a remarkable number of methods, at different scale, have been developed to evaluate ecosystem services (Eade and Moran, 1996; Egoh et al., 2008; Hein et al., 2006; Troy and Wilson, 2007). However, little attention has been given to their spatial visualization and regional mapping of direct use monetary values of ecosystem services (Chen et al., 2009). Large scale mapping of ecosystem services often only represents crude estimates (cf. Naidoo et al., 2008), due to the lack of primary data (Eigenbrod et al., 2010). Moreover, projections of ecosystem services, contingent on scenarios, are scare and mostly limited to aspects of the carbon and water cycles (e.g. Schröter et al., 2005). There is a strong need for more detailed on-site knowledge as derived from local field data. However, relating primary data (e.g., on household economics) to specific areas and give spatially explicit answers is challenging.

As NTFPs are derived from plants, the NTFP supply is related to the species' occurrence probabilities. To calculate changes in these occurrence probabilities and therewith NTFP availability, niche-based models (NBMs) can be used. NBMs, also known as 'bioclimatic envelope models', rely on the niche concept (Guisan and Zimmermann, 2000). These models fit a relationship between the presence/absence of species and the environmental conditions (e.g., climate and land use). Linking the monetary values of NTFPs with the occurrence probabilities of the NTFP-providing species represents a promising new approach to assess the impact of climate and land use change on provisioning ecosystem services. To our knowledge, this novel approach has not been applied so far.

With regard to both the local importance and the growing international relevance of several NTFPs, the objective of the study is to increase the understanding of current and future benefits derived from savanna species, in order to help local policy-makers to design adaptive management strategies.

The article is organized as follows: Section 2 describes the socio-economic environment of the study area, the investigated savanna species, the data collection, the monetary mapping and the niche-based modeling approach. In section 3 we present and discuss our results and the approach. Section 4 closes with some concluding remarks and sheds light on possible implications for future management of the investigated NTFP-providing species.

2. Methods

2.1. Biophysical and socio-economic environment of the study area

The research was conducted in the surroundings of three villages in Northern Benin, West Africa. The villages were selected to cover the different phytogeographical districts (Adomou, 2005) of Northern Benin (Figure 9): These phytogeographical districts are characterized by their species composition (major plant formations and exclusive species). From north to south the study villages are: Sampéto (district 'Mékrou-Pendjari': tree and shrub savannas, dry and riparian forest on ferruginous soils; precipitation: 950–1000 mm/yr), Niangou (district 'Chaîne de l'Atacora': riparian and dry forest, woodland on poorly evolved soils and mineral soils; precipitation: 1000–1200 mm/yr) and Papatia (district 'Borgou-Nord': dry forest, woodland, and riparian forest on ferruginous soils on crystalline rocks; precipitation: 1000–1200 mm/yr). All three study areas are characterized by one rainy season.

Rural livelihoods in the studied villages are preponderantly based on rain-fed crop production in traditional shifting cultivation systems. After few years of tillage the cleared fields lie fallow between 6 and 15 years which, by reason of habitual small-scale land use, leads to a typical mosaic pattern of cultivated area and fallow. Crops grown for the local diet encompass sorghum, millet, maize, legumes, yams and manioc, amongst others.

While clearing an area for cultivation, particular socio-economically important trees are spared from felling (Boffa, 1999). This type of agroforestry system, also known as parkland, includes cultivation and conserving of NTFP-providing tree species, thereby forming an inherent aspect of the savanna landscape. Animal husbandry is only a minor income activity.

2.2. NTFP providing tree species

We investigated the three socio-economically most important NTFP-providing woody species in Northern Benin: *V. paradoxa*, *P. biglobosa*, and *A. digitata*. The finding is based on previous research in this region (Heubach et al., unpublished data), which included household surveys and participatory field work with rural dwellers and traditional healers. The shea tree is the multi-purpose useful tree species most commonly conserved in the agroforestry parklands of West Africa (Breman and Kessler, 1995; FAO, 1999b). Typically, 25–60 *V. paradoxa* trees are found per hectare (Schreckenberg, 1996). The shea seeds contain 20–50 % fatty acids (Teklehaimanot, 2004) contributing to the local diet as principal cooking oil (beurre de karité, shea butter), whereas the fruit pulp is an excellent source of protein, calcium and sugar (Maranz et al., 2004). The average annual consumption of shea butter in Sub-Saharan countries is estimated with 7–10 kg per person (Boffa, 1999; Dah-Dovonon and Gnangle, 2006). The international market demands for shea butter as a surrogate for coconut oil and cocoa butter in the chocolate industry as well as excipient of cosmetic and pharmaceutical products (INSAE, 2000).

P. biglobosa often accompanies the shea tree in parklands due to similar habitat requirements (FAO, 1999c), but is far less abundant: In central Benin, its density is 2–5 trees per hectare (Agbahungba and Depommier, 1989; Schreckenberg, 1996). One of the major uses of néré is as ‘moutarde’, a local protein-rich condiment of its fermented seeds which is used to supplement sauces. In contrast to the shea tree, *P. biglobosa* has no relevance for the international market.

The fruits of *A. digitata* offer a vitamin C-rich fruit pulp (Gebauer et al., 2002) which is added to the local drink ‘l’eau blanche’ and the local porridge ‘bouille’; the roasted seeds are greatly appreciated in sauces (Sidibé and Williams, 2002). The leaves of *A. digitata* are an important source of protein, minerals and vitamins, prepared as sauce gluante de la brousse (Yazzie et al., 1994). Beyond, the baobab is a key species in the indigenous spirituality and belief systems being tightly connected to healing procedures. While *A. digitata* is hardly found on fields and fallows, its density within the settlement area is given with 1–14 trees per hectare (Heubach et al., unpublished data; Schumann et al., 2010). Recently, the international market has become interested in baobab products – notably, since a recently published study noted that the baobab fruit pulp reveals a four time higher antioxidant activity compared to kiwi and apple pulps (Besco et al., 2007). Furthermore, the European Union decided to allow dried fruit pulp for trade in Europe under the Novel Food Regulation in 2008 (Vassiliou, 2008).

2.3. NTFP data collection and monetary mapping

Traditional collectors of NTFPs are women. Consequently, firstly, we randomly selected 20 women from individual households in each of the three studied villages to gather data on extracted annual quantities of the harvested products from *V. paradoxa*, *A. digitata* and *P. biglobosa*. Secondly, the individually harvested trees were recorded by a GPS (Garmin 60CSx). The quantities were reported in locally used measuring units (e.g., bassine, sac de 100 kilograms). Thirdly, we observed current market prices of the respective products' quantities on each village's local market. Thus, we could calculate the annual monetary benefits that are derived from NTFPs for each woman. Current market prices were reported in CFA-Franc and converted to US Dollar (exchange rate August 2011). The structured interviews as well as the market surveys took place in June 2009 (Papatia), September 2010 (Sampéto) and February 2011 (Niangou), in collaboration with local assistants. Since opportunity costs of NTFP extraction are low (no labor alternatives, no high-capital equipment required), labor was not deducted from gross benefits. That is, net income (per woman) from these products equals their gross benefits. Prices are not inflation-adjusted since prices for locally sold NTFPs occur to be very conservative.

We chose a 0.1° resolution for mapping the economic values, in accordance with the resolution of the spatial probability projections from the NBMs. To describe the direct use values (Torras, 2000) of the grid cells that cover the surroundings of the studied villages, we calculated mean monetary values (n=20) over the respective women. The averaging over 20 women is a conservative estimate, as women with no income in the questioned year (due to pregnancy or diseases) were included, following the random sampling design. These values were then assigned to all grid cells sharing the same phytogeographic districts (benefit transfer) using ArcGIS 10 (http://www.esri-germany.de/). Used phytogeographic districts (i.e., plant species composition) represent an optimal generalization basis, because many interacting factors such as climate, geology, type of soil, land form and historical factors are included (Adomou, 2005). Finally, this average monetary estimate was multiplied with the number of women that live within a grid cell. Detailed data on population density (gender aspect, different age classes) were derived from the INSAE (2008). As the human population data were based on commune-level, they were transferred to a grid at our target resolution of 0.1°. Unmarried and old women do not actively collect NTFPs (Heubach et al., unpublished data). Therefore, we considered only women aged between 15 and 79 years in our analysis. Furthermore, we excluded four grid cells from the analysis which contained the biggest cities in Northern Benin, to avoid unrealistic high economic values from NTFPs in urbanized areas.

Additionally we calculated economic values on a per-hectare basis as extrapolation, which were derived per woman and tree species to better contextualize our results. Therefore, we related the reported monetary values from each woman to the respective areas where the women actively collected NTFPs. The areas were derived by calculating convex hulls (de Berg et al., 2008) from the coordinates of the harvested trees. The analysis was performed using the R-package ‘spatstat’ (Baddeley and Turner, 2005).

2.4. Niche-based modelling

2.4.1. Species records

Species occurrence points of *A. digitata*, *P. biglobosa* and *V. paradoxa* were taken from various databases that cover Benin, Burkina Faso and Côte d’Ivoire. It is also important to consider species occurrence points outside of the study area, where the environmental conditions differ, to fully capture the environmental niche of the species. We used data from the West African Vegetation database (Janßen et al., 2011), the SIG-IVOIRE database (Chatelain et al., 2011), herbarium records from the Herbarium Senckenbergianum (FR; http://sesam.senckenberg.de/), the Ouagadougou University Herbarium (OUA) and personal field surveys conducted in Benin and Burkina Faso (2009). The species occurrence points were aggregated within grid cells of a 0.1° resolution, resulting in 122 (*A. digitata*), 127 (*P. biglobosa*) and 192 (*V. paradoxa*) grid cells with species presences.

2.4.2. Environmental coverages

We focused on two climatic parameters and one land use predictor. The drought index (DI) is a proxy for the water availability, which is the most important climatic factor in this region (Scholes, 1997) and largely explains the spatial distribution patterns of the studied species. The DI is defined as the ratio of annual mean precipitation to potential evapotranspiration (PET). While the first parameter was taken from the WorldClim database (Hijmans et al., 2005; http://www.wordclim.org), the latter one was calculated following Thornthwaite (1948). The minimum temperature of the coldest month (Tmin) was included as 15.5° C (Tmin) is an important lower threshold for the survival of tropical trees (Sitch et al., 2003).

Extremely high variability is given for future precipitation projections based on different GCMs, causing a remarkable uncertainty (Heubes et al., 2011; Scheiter and Higgins, 2009). Extracting the information that describes a central tendency of different simulations provides an alternative to deal with this kind of variability (Araújo and New, 2007; Araújo et al., 2005; Thuiller, 2004). Therefore, we ran a 'principal component analysis' (PCA) on the future (2050, SRES A2 scenario) annual mean precipitation projections, which is used as part of DI, from 17 different GCMs (cf. Heubes et al., 2011). The precipitation projections from Miroc3.2medres (Center for Climate System Research, Japan) were most strongly correlated with the first PCA axis and can, thus, be considered as a consensus projection (Araújo et al., 2005; Thuiller, 2004). Consequently, we used the future climate projections (2050) from Miroc3.2medres (Ramirez and Jarvis, 2008) for further analysis at our target resolution of 0.1°. We chose the IPCC SRES A2 scenario, which assumes intermediate levels of CO2 emissions and an intermediate increase in temperature. We recognize that other climate models and storylines yield predictions that differ in their specifics in view of climate change, however, it is beyond the scope of the study to consider multiple scenarios of future climate.

The land use simulations were generated by LandSHIFT (Schaldach et al., 2011), a dynamic and spatially explicit land use and land cover model. LandSHIFT was specifically adopted for West Africa and runs with a spatial resolution of ~0.01°. The study area is primarily covered by the land use categories 'cropland (> 50% cover)' and 'deciduous woodland'. In this study, 'cropland (> 50% cover)' was renamed as 'parkland' to better describe the agricultural system, which is characterized by the deliberate retention of trees on fields. The climate data to generate the land use simulations were taken from Miroc3.2medres in accordance with the climate data used for the NBMs. LandSHIFT was run with the 'market first' scenario from the UNEP Global Environmental Outlook-4 (Rothman et al., 2007), which roughly corresponds to the IPCC A2 storyline. We assumed no technological change, as crop yields have been stagnant during the past few decades (Norris et al. 2010). The spatial projections of parkland were aggregated to the target resolution ('nearest neighbor') and used as a predictor in the NBMs, as the three key species are tightly linked to this land use unit.

2.4.3. Algorithm

Three familiar modeling techniques from regression methods, machine learning methods and classification methods, which are implemented in the BIOMOD package (Thuiller et al., 2009), were used to model species distributions: (1) generalized additive models (GAM) with cubic-smooth splines (polynomial of degree 3), (2) generalized boosting models (GBMs) with a maximum of 3000 trees fitted, and (3) flexible discriminant analysis (FDA). Pseudo-absences were randomly selected (n=1000) in Côte d'Ivoire, Burkina Faso and Benin. To evaluate the model performances, the data were split into training (30%) and testing data (70%). Models were calibrated on the training data, while threshold independent area under the receiver operating characteristic curve (AUC) values (Fielding and Bell, 1997) were calculated on the test data. We applied a 3-fold cross-validation to increase the robustness. Final accuracy of the consensus projections were assessed using receiver operating characteristic (ROC) curves (e.g. Thuiller et al., 2009). To maintain a maximum of information, we considered the probability values of the models rather than transforming these into presence and absence information. The average probabilities across the three model simulations were used for subsequent analysis. All statistical analysis and modeling was carried out using the free software environment R, v. 2.13.1 (R Development Core Team, 2011).

2.5. Calculating future monetary gain and loss

To calculate future monetary values per grid cell, we linked the monetary values derived from current NFTP collection with the current standardised occurrence probabilities of the three target species (Figure 9). The latter were generated by the NBMs. We then used this relation, together with the future NBM generated occurrence probabilities of the plant species, to derive the future monetary values (Figure 9). Thus, we assume that higher occurrence probabilities would result in higher NTFP quantities, and therewith in higher monetary values (and vice versa). The change in monetary value due to predicted climate and land use change then equals the change in marginal value.

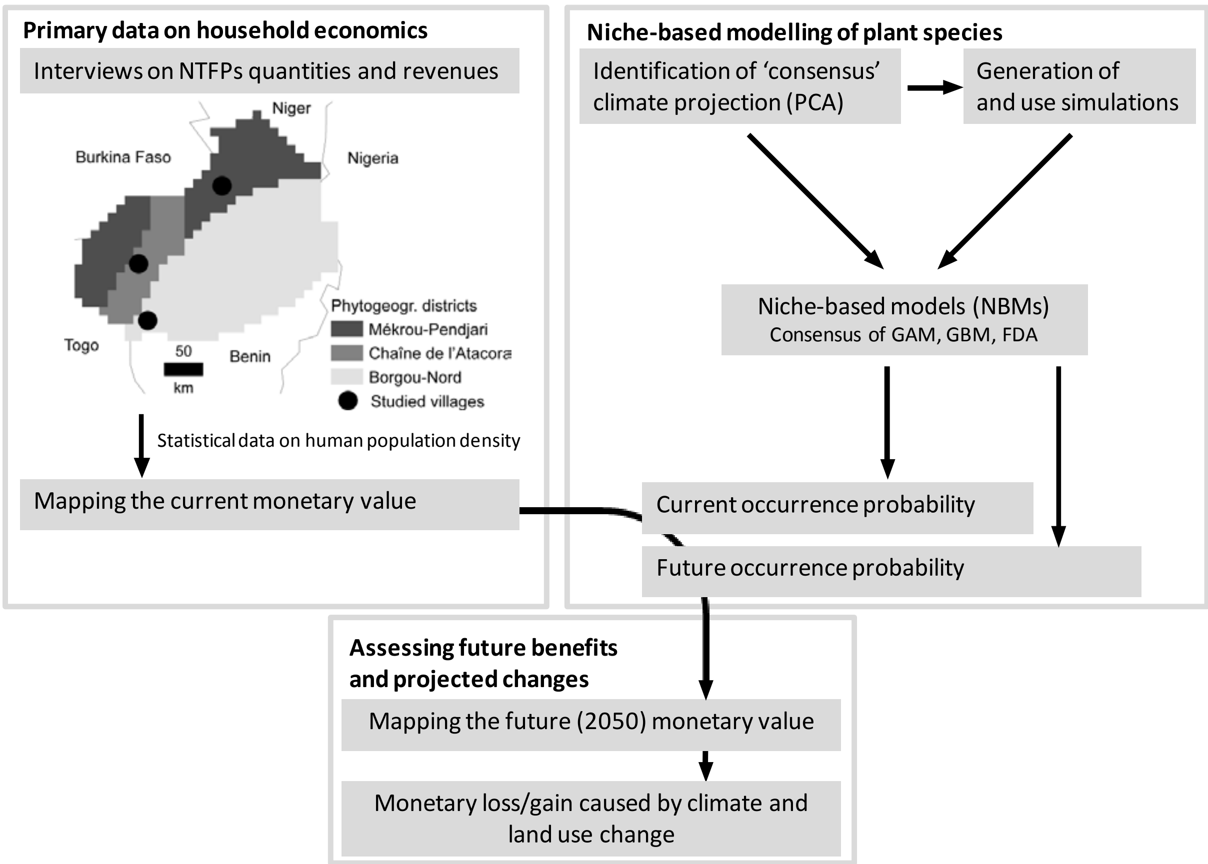


Fig. 9 Schematic of generating monetary ecosystem service values from NTFPs (left), the niche-based modeling procedure (right) and the linkage of both parts, in order to generate future (2050) monetary gain/loss (bottom).

3. Results and Discussion

3.1. The current economic relevance of the three species

The majority of interviewed women collected fruits of *V. paradoxa* and *P. biglobosa* as well as leaves of *A. digitata*. Only few respondents in Papatia stated to gather baobab fruits. Our results show that the monetary value flows differ between the three savanna species (Figure 10). Monetary benefits increased from *A. digitata* (9,514±6,243 US$/grid cell) over *P. biglobosa* (32,246±16,526 US$/grid cell) to *V. paradoxa* (54,111±28,126 US$/grid cell; Figure 10). The differences correspond to the per-hectare values, extracted per woman: *A. digitata* is the least important species with 0.3 US$/ha/yr. Higher annual benefits are obtained from *P. biglobosa* (~2 US$/ha/yr), while the highest value is found for *V. paradoxa* (6 US$/ha/yr). We report median values, as there was considerable variability among the women. Note that the per-grid values include all collecting women, while the per-hectare values refer to a single woman (median); the latter values were not derived by down-scaling the grid values. Our findings can be also compared to the relative economic contributions of the three species to the total annual income of a rural household in Northern Benin as identified by Heubach et al. (unpublished data): In Papatia, the average income share of *A. digitata* is 2%, while *P. biglobosa* contributes with 10% and *V. paradoxa* even with 13% to the total income. The total NTFP-income accounted for 39% of the annual household income, which represented the second largest income share next to crop production (Heubach et al., 2011). It was also found, that the majority of collected NTFPs is sold on local markets: On average, 89% of collected shea nuts, 88% of néré seeds and 73% of baobab fruit powder are sold to other rural dwellers or middlemen on local markets (Heubach et al., unpublished data).

Summed up for all three species, the per-hectare values (ca. US$ 8/ha) range at the bottom level compared with studies from Central and Latin America. Here, actual per-hectare returns from extracted forest / woodland products ranged between US$ 9–17 (Gram, 2001), US$ 18–24 (Godoy et al., 2000) and US$ 7–35 (Shone and Caviglia-Harris, 2006), respectively. However, our figures only comprise three selected NTFP-providing species. Yet, as adequate studies for African tree species are largely missing, our data fill an important knowledge gap concerning NTFP-benefits.

As stated in the introduction, the seeds of *V. paradoxa* are not only exceedingly important at the local level, but are of constantly rising international interest. In 2006, the shea nut (botanically a berry) was the third most important export product of Benin after cotton and cashew nuts (Dah-Dovonon and Gnangle, 2006). Importing nations are predominantly European states (INSAE, 2000; Teklehaimanot, 2004). In Benin, export peaks were reached in the years 1993-1994 (15,000 tons), 2003-2004 (34,000 tons) and again in 2008-2009 (35,000 tons) (Dah-Dovonon and Gnangle, 2006; ProCGRN, 2011). In 2010, a ton of shea seeds was sold at US$ 300 (Business Times, 2010). Interestingly, we found similar prices at the investigated local markets. A ton of collected shea seeds was sold at 343 US$ on average. However, there are strong regional differences: In Sampéto a ton shea seeds was 160 US$/ton, in Niangou 395 US$/ton and 474 US$/ton in Papatia, which might be explained by the seasonal availability of the NTFPs as well as international and local market dynamics.

Comparing our results with the international market prices it becomes evident that these savanna products are not only important for the rural poor as major income source, but represent high value export goods.

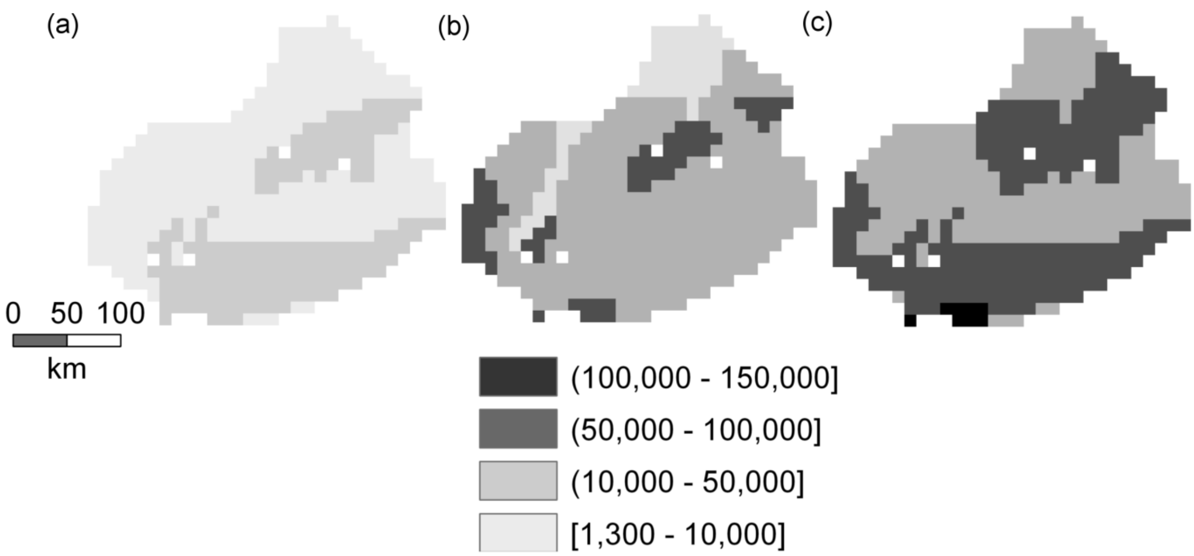


Fig. 10 Economic value map (US$/yr) of three savanna species in Northern Benin at a 0.1° resolution (~10×10 km): (a) *Adansonia digitata*, (b) *Parkia biglobosa*, (c) *Vitellaria paradoxa.*

Besides species-specific differences there is variation in the spatial distribution of monetary flows for each species (Figure 10 a-c). While the patterns in Figure 10 a, c are largely explained by the number of NTFP-collecting women they also rise by the abiotic environment (Figure 10b). The vertical structured area with low economic values (1,300–10,000 US$/yr/grid cell; Figure 10b), represents the 'Chaîne de l'Atacora'. This mountain range exhibits poorly evolved soils, which resulted in low provision of NTFP quantities and respective monetary benefits. Regional differences become more evident, considering the average benefits per woman from the different studied sites: The lowest revenues are derived at the 'Chaîne de l'Atacora' from *P. biglobosa* and *V. paradoxa* (36 US$/yr and 54 US$/yr). Highest average benefits for all species are found in the 'Mékrou-Pendjari' district with 26 US$/yr (A. digitata), 70 US$/yr (P. biglobosa) and 121 US$/yr (*V. paradoxa*).

3.2. Predicted future changes

The model performances of the three species were good (cf. Swets, 1988) with AUC values of 0.88 (*A. digitata*), 0.84 (*P. biglobosa*) and 0.86 (*V. paradoxa*) for the consensus projections. Projected climate and land use change (2050) have primarily negative effects on the value flows (Figure 11). Our models project losses of 1–50% (Figure 11 a-c), however, the three species are affected differently. The highest loss is projected for *V. paradoxa* and this should particularly be cause for concern, because it is also the economically most important species (Figure 11 c). However, models projected spatially varying impacts with also positive effects (monetary gain) in the south-eastern parts for all species, and in the western regions for *A. digitata*. While the tree species, predominantly *A. digitata*, profit from decreasing moisture (reduced drought index), there is negative interference with the increasing temperature. The highest monetary gain is projected for *A. digitata* (1–20% monetary gain), whereas gains are less pronounced for *P. biglobosa* and *V. paradoxa*. The expected absolute values of changes range between -3,302–2,635 US$/grid cell (*A. digitata*), -28,530–9,727 US$/grid cell (*P. biglobosa*) and -52,980–19,320 US$/grid cell (*V. paradoxa*) per grid cell. However, the projected absolute values of change for 2050 should be considered with caution and rather be seen as a tendency, as we assumed constant human population development for this prediction. We refrained from calculating these changes on the basis of future

(2050) population density as the knowledge of the tipping points after depletion and overexploitation of these agroforestry systems is very limited. Furthermore, the benefits from NTFPs can also decrease, as traditional crops are increasingly replaced by cash crops, such as cotton. Note that cotton cultivation requires a complete clearance of the parklands (Schreckenberg, 2004) and recently has been progressively promoted by the government. Even if farmers are encouraged to replant the studied species along the field boundaries, they would likely refuse to do so since exotic species like mango or cashew trees are economically more rewarding. This intensification of land management is not reflected in our approach, as NBMs can only use the information on the spatial extent of different land use types.

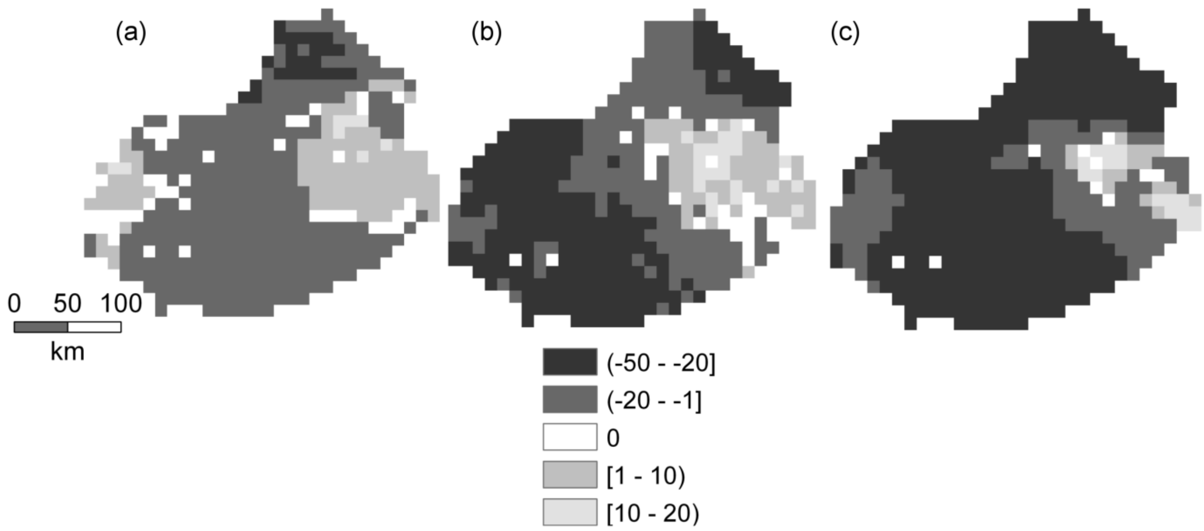


Fig. 11 Projected future monetary gain and loss (%) for 2050 in Northern Benin, considering three savanna species: (a) *Adansonia digitata*, (b) *Parkia biglobosa*, and (c) *Vitellaria paradoxa*. Calculations are based on consensus projections of three different niche-based models (GAM, GBM, FDM). The projections include climate and land use change scenarios (2050), whereby the latter assumes technological stagnation.

Yet, as the predicted monetary changes (in percentage) correspond to the altered occurrence probabilities of the species, severe negative impacts on the livelihoods of the studied local poor being dependent on NTFPs are expected by 2050. The projected income loss from the NTFP-providing species will likely increase the pressure on remaining income opportunities, for instance, it could foster non-sustainable cotton production or reduce expenditures on household needs; the latter would inevitably reduce human well-being.

3.3. Local elasticity for NTFP-providing species

Since income alternatives, in particular for women, are practically absent in the study region, investigated communities face only little economic elasticity concerning the provision of NTFPs. Asked for possibilities to substitute currently as dietary supplement used NTFPs, women from Papatia (n = 200, Heubach, unpublished data) reported, that shea butter could be replaced by palm oil which is derived from the native palm tree *Elaeis guineensis*. However, women noted that palm oil is far too expensive to be used on a daily basis, *E. guineensis* is less abundant than *V. paradoxa* and, in addition, is exclusively managed by men, i.e. women have to pay men for seed extraction. A second surrogate for shea butter could be peanut oil, that seems to be a slightly better alternative, especially because peanuts can be independently cultivated by women and oil processing is less labor and time intensive. Beyond that, peanuts are highly marketable. The seeds of *P. biglobosa* could be replaced by 12 other products as ingredient in sauces whereof the five most important surrogates were fish, Maggie (a manufactured condiment) or the field crops peanut, chilies, and onion. But all products are more expensive. Favored to replace 'moutarde' are also the seeds of Ceiba pentandra. In case of baobab fruits (7 substitutes), major surrogates are sesame and peanut, but also the seeds of the local species *Blighia sapida* were highly treasured. The baobab leaves (6 substitutes) are mainly replaced by lady's fingers or sesame, but also by the leaves of the native woody species *Vitex doniana*. However, before promoting these substitute-providing species, further research is needed to investigate their future performance in view of climate and land use change and in terms of sustainability.

3.4. Methodological limitations and uncertainty

Even though gathering primary data by interviews for the monetary mapping, we could not fully avoid 'benefit transfer' as our approach assumes equal value flows of the grid cells within a particular phytogeographic district. Thus, our approach might include a generalization error due to extrapolation (Costanza et al., 2006; Plummer, 2009) leading to some areas being overestimated and others being understated. However, we used plant species composition (phytogeographic districts) for a generalization basis which includes many interacting factors such as climate, geology, type of soil, land form and historical factors (Adomou, 2005).

The pros and cons of niche-based modeling methods are not discussed here, as several papers have already highlighted their limitations and methodological uncertainties (e.g. Dormann, 2007; Guisan and Thuiller, 2005; Heikkinen et al., 2006). We rather focus on specific aspects that are related to this study. Our approach assumes that an increased species occurrence probability would result in higher monetary value flows (and vice versa). The assumption follows a rational logic: Higher habitat suitability (which is in fact modeled) increases the performance and vitality of species (e.g., germination and photosynthesis) and, consequently, increases the fruit production (e.g., Glèlè Kakaï et al., 2011) and benefits. However, the latter also depends on future market dynamics (see discussion below). Furthermore, our results are based on climate projections from the GCM Miroc3.2medres. Although the common view from the climate modeling community is that no single climate model is superior, we used this GCM following the rational of consensus projections (Araújo and New, 2007; Araújo et al., 2005; Thuiller, 2004). We think that this approach is better than arbitrarily selecting GCMs, however, the climate uncertainty remains a major source of uncertainty in predictive modeling for this region (Heubes et al., 2011).

There are also ecological and economical limitations inherent to our approach. That is, the fruit productivity of trees might differ inside the same district due to small-scale varying environmental conditions and, additionally, may alter between years (Gram, 2001). Moreover, the NTFP-providing trees may be inhomogeneously distributed within the parklands and abiotic factors such as lateritic soils may locally prevent the species to grow.

Even though the reported per-hectare yields are a result of a conservative calculation, including women who did not collect at all, there might be an overestimation of value flows, as we assume all women aged between 15–79 years to equally take part in NTFP extraction activities. Considering the economical factors we cannot fully exclude a recall bias (i.e. the respondents having problems to precisely remember the collected amounts of NTFPs), as annual per-hectare values are calculated on the basis of respondents' self-reported quantities. However, given the demonstrated socio-economic importance of NTFPs in rural household economics, we assume the data to be reliable.

More generally, we would like to address several issues of marginal values and discounting. That is, the change in monetary value due to predicted climate and land use change should equal the change in marginal value. In economic analysis marginal values are in general associated with unit changes of assets. The precondition is that each unit is homogenous and yields the same return which, in fact, does not hold true for our resources in question: as mentioned above, NTFP-providing trees are not equally distributed over the studied area and might not show the same productivity. Thus, the per-hectare values calculated in our study do not strictly reflect the range of real marginal values of each single hectare but an average value across all units (Costanza et al., 2006). One possible attempt to elaborate on this issue is to gain more species-specific ecological data (abundance, productivity).

Whether to discount or not to discount long-term monetary values derived from ecosystem services is a matter of ongoing scientific and political debate and has not yet been concludingly answered yet (Costanza et al., 2006; Dasgupta, 2008; Goklany, 2009; Newell and Pizer, 2003; TEEB, 2008). Assuming that future generations are better off than the present one, i.e. in a world of unbowed economic growth, discounting aims at determining the current value of a future cash flow from a particular commodity or asset or ecosystem service. Coherently, standard economic discounting hypothesizes that present gains are more valuable than those obtained in the future, if the net present value is equal or higher than the future value under the chosen discount rate. However, in terms of ecosystem service flows this assumption may be biased since the ongoing depletion of non-substitutable natural resources (i.e. natural capital) and biophysical infrastructure (i.e. ecosystem functions) is likely to increase ecosystem services' scarcity and, accordingly, their economic value. Furthermore, applying a positive discount rate might fortify decision-making that disproportionally prefers short-term benefits from ecosystem services while coevally postponing involved costs (e.g. restoration costs for damaged ecosystems. i.e. externalities) into the future. Certainly, in view of intergenerational equity this should be out of the question. Thus, the consideration to apply even a negative discount rate on ecosystem service flows has emerged in the debate recently (Stern, 2006). With regard to this controversial discussion, we decided to apply a zero discount rate in this study.

4. Conclusions

In this study we present a novel approach of assessing the impact of climate and land use change on provisioning ecosystem services. Therefore, we related primary data on household economics with niche-based models. We demonstrated the transfer of the economic data to specific areas, to map the monetary value flows of three woody species in Northern Benin. Thus, we shed light on their remarkable socio-economic importance for the local poor. Based on current monetary maps of these NTFP-providing species we calculated future flows of ecosystem service values in order to estimate possible economic gains and losses, respectively.

We showed that the projected changes will preponderantly negatively impact the economic returns of the three socio-economically important woody species in Northern Benin, *V. paradoxa*, *P. biglobosa*, and *A. digitata* by 2050. Our results further indicate that in particular the benefits obtained from *V. paradoxa* are threatened and should raise major concern with respect to current management policies. Possible pathways to cope with the reduced species occurrence probabilities are, on the one hand, to foster plantations of shea tree, néré and baobab in appropriate regions (e.g. in the eastern part of the 'Borgou-Nord' district) in order to safe-guard local livelihoods and maintain export activities. On the other hand, substitute-providing species could be promoted after proper previous analysis of their performances under projected climate and land use change as well as the consideration of sustainability criteria. Finally, more effort is needed to create alternative income opportunities, particularly for women.

To further increase our understanding of this complex socio-ecological system, higher sample sizes of interviewed women together with long-term observation of monetary values are needed as well as gathering data on the ecological performance of the investigated species (productivity, abundance). On the other hand there is a strong need to improve and harmonize climate models to reduce the inter-model variability.

In this study, we present a valuable first benchmark for local decision-makers to economically compare different land-use options today and adjust existing management strategies.

5. Acknowledgements

The present study was conducted at the Biodiversity and Climate Research Centre (BiK-F), Frankfurt am Main, Germany, and funded by the research funding program "LOEWE – Landes-Offensive zur Entwicklung Wissenschaftlich-Ökonomischer Exzellenz" of Hesse's Ministry of Higher Education, Research, and the Arts. The authors are grateful to Gnanando Saidou, Laurent Akissatom and Etienne Dossou who assisted in field work and especially all respondents who took part in the surveys. We thank Marion Mehring for valuable comments on the manuscript. Sincere thanks go further to Prof. Brice Sinsin (University of Abomey-Calavi, Benin) for scientific and logistic support in Benin. Furthermore, we would like to thank two anonymous reviewers for their constructive comments on this work.

Chapter 5

Synthesis

Climate and land use change have major impacts on the provision of ecosystem services essential to sustain rural livelihoods in West Africa. In particular, they severely affect the availability of wild products extracted from the surrounding ecosystems (e.g. fruits, leaves, barks, wooden sticks, bulbs, and bark) in order to meet daily diet and energy needs, to build houses, to feed animals, and to treat illnesses, amongst others. These non-timber forest products (NTFPs) have been forming an inherent part of peoples' daily viability for millennia: They satisfy both subsistence and cash needs, and serve as a safety-net in times of famine and financial shortfalls, i.e. they make a considerable contribution to the household economy. Since the extraction of NTFPs does require neither technical equipment nor professional skills and local labour markets are generally thin, this income opportunity particularly attracts the rural poor. Consequently, the decline of these resources notably makes an impact on the poorest parts of the African society.

In addition, present land-use management in Africa has to cope with serious trade-offs between satisfying the ever-expanding need for subsistence crops due to continuous population growth, and the concurrently rising international demand for cash crops. Within this decision-making, NTFPs have been constantly understated in terms of their economic contribution to rural livelihoods due to a lack of appropriate economic data to use within common cost-benefit analysis. As a result, the economic benefits people obtain from NTFPs have not yet been reflected in land-use policies and, thus, have been frequently outcompeted by seemingly more profitable land-use options. Therefore, it is crucial to provide appropriate economic data for NTFPs in order to create positive incentives for both decision-makers to acknowledge forest conservation as a profitable land-use option with regard to the ecosystem service flows obtained by locals, and these NTFP beneficiaries to sustainably harvest respective NTFP-providing species, i.e. to achieve 'conservation for development'.

The major objective of this thesis was to analyse the economic importance of NTFPs in rural household economy in the Sudanian zone of West African savannas, aiming at understanding the current role of these ecosystem services within livelihood strategies of different socio-economic groups and assess their future availability with regard to severe environmental changes.

The key finding of the comprehensive household survey with 230 rural households is that income from NTFPs accounts for 39 % on average of an annual total household income (chapter 2). That is, NTFP income equals the second largest income share next to crop income, and thus, undoubtedly, makes a significant contribution to rural household economies. However, the economic relevance of NTFPs differs subject to the overall income of households: While poorer ones are relatively more dependent on NTFPs in terms of income share, wealthier households extract more in quantitative terms which is due to a greater access to 'private' trees on cultivated fields (i.e. land holding). Accordingly, the latter yield comparatively higher returns from the sale of NTFPs than poorer households. Taken as a whole, NTFP income considerably reduces observed inequality between households.

The second major outcome of this thesis is that socio-economic characteristics of NTFP users tremendously shape their preferences for woody species (chapter 3). Particularly ethnicity has a major impact on the species used and the economic return obtained by them, reflecting a culturally conditioned appreciation for native plants. In general, the Fulani, a pastoralist society, show the highest income from NTFPs – roughly one and a half times higher than the investigated four tiller societies – of which fodder constitutes one third, reflecting their traditional source of livelihood, i.e. animal husbandry (chapter 2). In contrast, all ethnic groups harvest alike quantities of e.g. wild foods and firewood, mirroring the ubiquitary need to satisfy basic needs.

On the level of species, both ethnic affiliation and residence have significant effects on use-values (chapter 3): Out of 90 species in total, particular trees are used by all dwellers equally which is, for instance, the case with those providing wild foods (*V. paradoxa, P. biglobosa, A. digitata, Blighia sapida, Diospyros mespiliformes and Vitex doniana)*, firewood (*V. paradoxa, P. biglobosa, Hymenocardia acida, Pterocarpus erinaceus, Daniellia oliveri and Detarium microcarpum)*, and construction material (*Borassus aethiopium*, *Hyphaene thebaica*, *Raphia sudanica*) – once again, reflecting NTFP uses meeting basic needs. In contrast, other woody species are exclusively mentioned by particular ethnic groups, like is especially the case for medicinal plants: While the Fulani solely highly appreciate *Opilia celtidifolia*, the Ditammarie exclusively use *Tamarindus indica*, the Yom *Cochlospermum planchonii*, the Bariba *Bombax costatum*, and the Kabiyé *Vitex simplicifolia* for a special medicinal purpose. In general, the greatest diversity and the majority of tree species were mentioned to be used within traditional medicine.

In contrast, with regard to the economic relevance of tree species all respondents, independently of their ethnic affiliation, stated the same three species as the most important ones: *Vitellaria paradoxa* (shea tree or karité), *Parkia biglobosa* (African locust tree or néré), and *Adansonia digitata* (baobab) which are traditionally used in food preparation and are frequently sold on the local markets. Interestingly, the awareness for these economic key species has recently exceeded the investigated countries' frontiers: Especially baobab fruit powder and shea nuts, respectively, have increasingly gained attention by the international market.

Taking this up, the above-mentioned three socio-economically important tree species were considered in a niche-based modeling approach (chapter 4) that aimed at assessing the impact of climate and land use change on the species' future ecological performances (occurrence probabilities) and, subsequently, economic performances (monetary flows). Linked to current monetary maps, the objective of the study was to generate a map displaying the future occurrence of these species, and, thus, the likelihood to obtain income from respective NTFPs. An improved understanding of current and future NTFP benefits is crucial for decision-makers in order to design appropriate management strategies securing welfare. The results show that the expected environmental changes will have primarily negative effects on the economic returns from all the three species. This especially holds true for the economically most important of the investigated woody species, *V. paradoxa*, for which the highest loss is anticipated. In general for all three species, large areas are projected to lose up to 50 % of their current economic value by 2050. Bearing in mind the above-elaborated dependence of rural dwellers on NTFPs in an economic inelastic setting, the predicted future availability of these ecosystem services indicates an increase in vulnerability of rural communities in this regard.

Conflating these lessons learned, the major conclusion to be drawn from the research at hand is that rural communities living in savanna ecosystems of Northern Benin are economically heavily dependent on NTFPs, both in terms of subsistence and cash income, while the level of this dependency is determined by certain socio-economic factors like overall income, land holding, access to NTFPs, and alternative income opportunities as well as ethnicity and residence. Taken as a whole, this thesis contributes to improving the basis of decision-making with reference to local land-use policies by providing key figures on the current and future economic benefits from NTFPs allowing for comparison of different land-use options via cost-benefit analysis while concurrently considering the most valued tree species for different ethnic groups.

Accordingly, NTFP-management strategies that appropriately strive after achieving 'conservation for development' take the cognition as a basis that strict conservation measures (protected areas, target-based conservation) and development activities complement rather than exclude each other. While protected areas and other enclosures are crucial to preserve biodiversity and maintain life-supporting ecosystem services, development measures have to concurrently safeguard rural livelihoods via ensuring income opportunities.

Thought from the 'NTFP-dependent perspective', a feasible way could be the active planting of socio-economic important NTFP-providing species, firstly, according to locals' use preferences, and, secondly, only were effectively applicable with regard to projected impacts of climate and land use change on these species – on the basis of adequate data as given by, for instance, the studies at hand carried out for Northern Benin. Since our research focussed on the demand side of NTFPs, our knowledge would very much profit from the long-term evaluation of the ecological performances of the species in question (population dynamics, abundance, productivity etc.), i.e. the supply side, since species' performances are subject to shifts due to biotic and abiotic factors, and, subsequently, NTFP availability might change, too. For this, both scientific and traditional ecological knowledge should be the foundation of research.

Approximating from a 'NTFP-independent perspective', possible pathways could be, firstly, creating income opportunities alternative to NTFPs, particularly in view of the ongoing population growth in the region with the simultaneous limitedness of resources that challenge the conciliation of the trade-off between essential crop yields and NTFP needs, and, secondly, improving the efficiency of existing crop systems. Measures for the latter could comprise of the diversification of crops in terms of healthier ones that are rich in nutrients, vitamins, and minerals in order to achieve a calorie-sufficient and well-balanced diet as well as to serve as possible substitutes for important NTFPs. Again, the respective species' future performances under prospected environmental changes are to be tested thoroughly beforehand.

In summary, if 'NTFP-dependent' and 'NTFP-independent' measures are implemented as complementary, there is a viable chance to successfully sustain the well-being of rural livelihoods in Northern Benin while simultaneously contribute to conserve biodiversity.

Summary

For millennia, rural West African communities living in or adjacent of savanna ecosystems have been collecting components of local plant species (e.g. fruits, leaves, barks, wooden sticks, bulbs, and bark) in order to fulfil essential household subsistence needs in terms of alimentation, medical care, energy demand, and construction purposes, amongst others, to generate cash income and to overcome times of (financial) crisis due to, for instance, crop failure (safety-net function). That is, these non-timber forest products (NTFPs) make a considerable contribution to the well-being of local households. World-wide, the number of forest-dependent people is estimated at some 1.6 billion people.

However, climate and land use change severely impact West African savanna ecosystems, soaringly jeopardizing the availability of NTFPs, and consequently, the safe-guarding of dependent rural livelihoods. The conversion of savanna area into cultivated land for subsistence farming owing to the ongoing population growth, as well as the progressive promotion of cash crops (e.g. cotton, cashew nuts) is ever-increasing, resulting in massive land reclamation. As a consequence, present land-use management in West Africa has to cope with a serious trade-off between satisfying the ever-expanding subsistence needs and the concurrent international demand for cash crops. Within this decision-making, ecosystem services such as NTFPs have been constantly understated in terms of their economic contribution to rural livelihoods due to a lack of appropriate economic figures to use within common cost-benefit analysis in this regard. As a result, the economic benefits people obtain from NTFPs have not yet been reflected in land-use policies and, thus, have been frequently outcompeted by seemingly more profitable land-use options. Since the extraction of NTFPs does require neither technical equipment nor professional skills and local labour markets are generally thin, this income opportunity particularly attracts the rural poor who face low income elasticity. Consequently, the decline of these resources notably makes an impact on the poorest parts of the West African society.

Therefore, it is crucial to provide appropriate economic data for NTFPs in order to create positive incentives for both decision-makers to acknowledge nature conservation as a profitable land-use option with regard to the ecosystem service flows obtained by locals, and these NTFP beneficiaries to sustainably harvest respective NTFP-providing species, i.e. to achieve ‘conservation for development’.

The major objective of this thesis was to analyse the economic importance of NTFPs in rural household economy in the Sudanian zone of West African savannas, aiming at understanding the current role of these ecosystem services within livelihood strategies of different socio-economic groups and assess their future availability with regard to severe environmental changes.

Such an improved knowledge base is key to design appropriate management strategies for safe-guarding the future provision of NTFP-providing species for the local communities. The studies took place in two districts of Northern Benin, where to date no such data exists. Local rural livelihoods preponderantly base on rain-fed crop production in traditional shifting cultivation systems with selective retention of important NTFP-providing species (parklands); animal husbandry is only a minor income activity. The analysis compares current NTFP income and use preferences for woody species between the five major ethnic groups in the study area (Fulani, Ditammarie, Yom, Bariba and Kabiyé) and assesses the impact of climate and land use change on the future provision of and, thus, economic benefit obtained from NTFPs.

The thesis consists of three major parts: The first study addresses the economic contribution of NTFPs to a local household’s livelihood (chapter 2). Based on a household survey comprising of 230 rural households I gathered information about collected quantities of and revenues gained from extracted NTFPs. Comparing them to income generated by other livelihood activities (e.g. crop cultivation, animal husbandry, off-farm income) enabled me to determine the economic relevance of NTFP in the investigated households, i.e. in view of total household income. Furthermore, I investigated differences between the above-mentioned five ethnic groups as well as three different income groups in order to assess whether patterns of NTFP dependency exist.

The key finding of this analysis is that income from NTFPs accounts for 39 % on average of an annual total household income, representing the second largest income share next to crop income. However, the economic relevance of NTFPs differs subject to the overall income of households: While poorer ones are relatively more dependent on NTFPs in terms of income share, wealthier households extract more in quantitative terms, which is due to a greater access to ‘private’ trees on cultivated fields (i.e. land holding).

Accordingly, the latter yield comparatively higher returns from the sale of NTFPs than poorer households. Moreover, NTFP income considerably reduces observed inequality between households. When compared across ethnic groups, in general, the pastoralist society, the Fulani, show the highest income from NTFPs – roughly one and a half times higher than the investigated four tiller societies – of which fodder constitutes one third, reflecting their traditional source of livelihood, i.e. animal husbandry. In contrast, all ethnic groups harvest alike quantities of e.g. wild foods and firewood, mirroring the ubiquitary need to satisfy basic needs. The major conclusion to be drawn from this analysis is that rural communities living in savanna ecosystems of Northern Benin are economically heavily dependent on NTFPs, both in terms of subsistence and cash income, while the level of this dependency is determined by certain socio-economic factors like overall income, land holding, access to NTFPs, and alternative income opportunities as well as ethnicity.

The second study investigates the impact of social differentiation (ethnicity, residence) on the valuation of local species (chapter 3). I studied differences in use preferences for native woody species between the five major ethnic groups in two villages (230 households), examining eleven NTFP use categories (e.g. nutrition, health care, energy supply, construction purposes). Specifically, I sought to identify which tree species are the economically most important for rural households and if their economic relevance change due to their ethnic affiliation.

As the major outcome of this investigation I can put forward the argumentation that socio-economic characteristics of NTFP users tremendously shape their preferences for woody species. Particularly ethnicity has a major impact on the species used and the economic return obtained by them, reflecting a culturally conditioned appreciation for native plants. Out of 90 species in total, particular trees are used by all dwellers equally which is, for instance, the case with those providing wild foods, firewood, and construction material – once again, reflecting NTFP uses meeting basic needs. In contrast, other woody species are exclusively mentioned by particular ethnic groups, like is especially the case for medicinal plants. The economically most important NTFP-providing species are *Vitellaria paradoxa* (shea tree), *Parkia biglobosa* (African locust tree), and *Adansonia digitata* (African baobab). Our findings provide valuable information for local policy-makers aiming at adjusting existing conservation measures to peoples' real needs.

The third study was conducted in collaboration with my colleague Jonathan Heubes. We aimed at developing a novel approach to assess the impacts of climate and land use change on the economic benefits derived from the three economically most important NTFP-providing tree species in the region as identified in my second study: *V. paradoxa*, *P. biglobosa*, and *A. digitata*. The objective of the study was to generate a map displaying the future occurrence of these species and, thus, the likelihood to obtain income from respective NTFPs. In particular, with regard to both the local importance and the growing international relevance of these NTFPs – recently, especially for shea nuts and baobab fruit powder there is a growing international recognition and an increasing market demand – an improved understanding of current and future NTFP availability and, thus, benefits is crucial for decision-makers in order to design appropriate management strategies. The species' current and future (2050) occurrence probabilities were appraised by calibrating niche-based models with climate and land use data at a 0.1° resolution. To assess future economic gains and losses, respectively, we linked the modelled species occurrence probabilities with the spatial monetary values we had gained from a household survey. The results show that the expected environmental changes will have primarily negative effects on the economic returns from all the three species. This especially holds true for the economically most important of investigated woody species, *V. paradoxa*, for which the highest loss is anticipated. In general, for all three species, large areas are projected to lose up to 50 % of their current economic value by 2050. Bearing in mind the above-stated dependence of rural dwellers on NTFPs in an economic inelastic setting, the predicted future availability of these ecosystem services indicate an increase in vulnerability of rural communities in this regard. With our findings, we provide a first benchmark for local policy-makers to economically compare different land-use options and adjust existing management strategies for the three species.

Overall, the findings of my studies underpin the economic relevance of NTFPs for rural communities in West African savannas and, consequently, the necessity to appropriately sustain them in order to safe-guard local livelihoods. Providing key figures on the current and future economic benefits obtained from NTFPs that can be integrated into common cost-benefit analysis, and delivering detailed information about peoples' use preferences for woody species, this thesis clearly contributes to improve the basis of decision-making with reference to local land-use policies.

ZUSAMMENFASSUNG

Die Bewohner der westafrikanischen Savanne leben seit Jahrtausenden von der Vielfalt der lokalen Wildpflanzen, deren Blätter, Früchte, Wurzeln, verholzte Teile, Nektare usw. essentielle Grundbedürfnisse befriedigen: Nicht nur leisten sie einen wichtigen Beitrag für die tägliche Ernährung – Früchte und Blätter enthalten zahlreiche Vitamine, Mineralstoffe und wichtige sekundäre Pflanzenstoffe – sie bilden auch die medizinische Grundversorgung einer Bevölkerung, die zumeist nur geringen Zugang zu schulmedizinischen Arzneien und Verfahren hat, liefern Feuerholz und solches für bauliche Zwecke. Diese Wildpflanzenprodukte oder auch ‚Nicht-Schnittholz-Waldprodukte' (non-timber forest products, im Folgenden als NTFPs abgekürzt und synonym zu Wildpflanzenprodukten und Savannenprodukten verwendet) spielen darüber hinaus eine bedeutende Rolle für die Schaffung von Einkommen und dienen in Krisenzeiten, z.B. in durch Ernteausfällen ausgelösten Hungerszeiten, als maßgebliche (finanzielle) Rücklage. In ihrer funktionellen Gesamtheit leisten die NTFPs also einen essentiellen Beitrag für die Wohlfahrt der Savannenbewohner – sowohl im Hinblick auf Subsistenzbedürfnisse als auch finanzielle Ressourcen. Weltweit wird die Anzahl der Menschen, die direkt oder indirekt von frei zugänglichen Wildpflanzenprodukten abhängig sind, auf 1,6 Milliarden geschätzt.

Allerdings sind diese Ressourcen zunehmend massiv durch die Auswirkungen des globalen Klimawandels einerseits (z.B. Sahelisierung, verkürzte Regenzeiten, höheres Erosionsrisiko) sowie tiefgreifende Veränderungen in der lokalen Landnutzung in Westafrika andererseits bedroht. Letzteres äußerst sich insbesondere in der fortschreitenden Umwandlung von Savannenfläche in Agrarfläche, um zum einen die durch das anhaltende Bevölkerungswachstum zunehmenden Subsistenzbedürfnisse nach Nahrungspflanzen zu befriedigen, und zum anderen die steigende internationale Nachfrage nach Devisen bringenden *cash crops*, insbesondere Baumwolle, zu decken. Es besteht also ein massiver Nutzungskonflikt über bestehende ländliche Ressourcen, die zu verkürzten Brachezeiten, deutlichen Eingriffen in die traditionellen Feldbaumethoden (Einsatz von maschineller Technik, Düngemitteln sowie Pestiziden, Einführung exotischer Nutzpflanzen) und in Folge zum Verlust solcher einheimischer Savannenarten sowie deren Habitate führen, die die oben beschriebenen, für die ländliche Bevölkerung lebensnotwendigen NTFPs liefern.

Ungeachtet der allgemeinen Kenntnis dieser funktionellen Wechselbeziehungen spielen Wildpflanzen im Rahmen der lokalen Landnutzungsentscheidungen keine Rolle. Grund hierfür ist insbesondere der Mangel an ökonomischen Grunddaten, die Entscheidungsträgern eine konkrete Vorstellung davon geben, welche ökonomische Bedeutung den Pflanzen im Rahmen der Haushaltsökonomie zukommt. So werden Entscheidungen auf Grundlage von unvollständigen Kosten-Nutzen-Analysen getroffen, die den ökonomischen Wert der lokalen Pflanzenarten nicht abbilden und folglich den Erhalt derselben als Landnutzungsoption nicht in Betracht ziehen können. Vor diesem Hintergrund ist es daher dringend notwendig, entsprechende ökonomische Daten zu liefern, damit scheinbar profitablere Alternativen, wie z.B. Baumwollanbau, mit bestehenden Einkommensquellen adäquat verglichen werden können. Dieser Vergleich ist auch speziell dahingehend von enormer Bedeutung, da die Umwandlung von Savannenfläche in Kulturfläche immer auch einen Wechsel von ursprünglich kommunal verwalteten, und damit im Rahmen bestimmter Nutzungsregeln frei zugänglichen Ressourcen zu solchen bedeutet, deren Erträge nunmehr privat abgeschöpft werden. Dieser Verlust frei zugänglicher NTFPs trifft in der Regel die einkommenschwächsten Teile der Bevölkerung.

Die vorliegende Arbeit wurde durch das Anliegen motiviert, die ökonomische Bedeutung der NTFPs für die Haushaltsökonomie der ländlichen Bevölkerung in Westafrika zu untersuchen, um deren Rolle als Einkommensstrategie innerhalb verschiedener sozio-ökonomischer Gruppen besser zu verstehen. Ein solches verbessertes Verständnis ist Grundlage für die Entwicklung adäquater Managementstrategien, die die langfristige Erhaltung der Wildpflanzen und damit die Verfügbarkeit ihrer Produkte für die lokale Bevölkerung sicherstellen. Diese Arbeit ist die erste wissenschaftliche Untersuchung, die diesbezügliche Daten für die untersuchte Region in Nordbenin zur Verfügung stellt.

Meine erste Studie widmete sich der Fragestellung, welchen monetären Beitrag die Savannenprodukte zu einem typischen Haushaltseinkommen leisten und welchen Einfluss die Zugehörigkeit zu einer Einkommensgruppe oder einer Ethnie auf deren ökonomische Bedeutung hat (Kapitel 2). Durch den Vergleich mit den Erträgen aus anderen Einkommensquellen (Viehzucht, Ackerbau, Einkommen aus selbstständiger Arbeit) konnte ich den relativen Einkommensbeitrag der NTFPs an einem Haushaltseinkommen bestimmen: Im Durchschnitt werden 39 % des Gesamteinkommens eines Haushaltes durch NTFPs erzielt – die zweitgrößte Einnahmequelle nach dem Ackerbau. Dabei variiert dieser Beitrag deutlich mit dem Gesamteinkommen der Haushalte: Während ärmere Haushalte insgesamt stärker abhängig von Wildpflanzen sind, d.h. das Einkommen aus Savannenprodukten einen größeren Anteil an ihrem Einkommen ausmacht, erzielen reichere Haushalte höhere Erträge aus diesen Produkten. Letzteres lässt sich insbesondere darauf zurückführen, dass reichere Haushalte oft über einen größeren ‚privaten' Ressourcenzugang verfügen (Bäume auf Feldern), während ärmere mit zahlreichen anderen Nutzern um diese Allmendegüter konkurrieren müssen. Beim Vergleich zwischen den fünf wichtigsten ethnischen Gruppen im Untersuchungsgebiet (Fulbe, Ditammarie, Yom, Bariba und Kabiyé) ließ sich feststellen, dass die Viehzucht betreibenden Fulbe gegenüber den vier ackerbaulich wirtschaftenden Ethnien durchschnittlich ein um das Eineinhalbfache höhere Einkommen aus NTFPs erzielen. Ihre traditionelle Lebensgrundlage reflektierend, wird hiervon ein Drittel durch Futterpflanzen erbracht. Im Gegensatz dazu sammeln alle ethnischen Gruppen ähnlich große Mengen Savannenprodukte, die zur Befriedigung von Grundbedürfnissen dienen, z.B. im Bereich Ernährung und Feuerholz. Meine Untersuchungsergebnisse unterstreichen die hohe ökonomische Bedeutung der NTFPs bei gleichzeitiger Abhängigkeit der lokalen Bevölkerung von diesen, die eine entsprechende Reflexion in Landnutzungsentscheidungen unabdingbar macht.

In der zweiten Studie habe ich den Einfluss der ethnischen und örtlichen Zugehörigkeit auf die Bewertung von wichtigen, Savannenprodukte liefernden Gehölzpflanzen untersucht (Kapitel 3). Durch die Analyse der bereits genannten fünf Hauptethnien in zwei Vergleichsdörfern konnte ich Unterschiede in deren Nutzungspräferenzen für diese Arten in elf verschiedenen Nutzungskategorien (z.B. Ernährung, Feuerholz, medizinische Versorgung, Baumaterial) feststellen. Im Besonderen interessierte mich, welche Gehölzarten die ökonomisch wichtigsten für die jeweilige Ethnie darstellen. Die Ergebnisse dieser Studie lassen nur einen Schluss zu: Sozio-ökonomische Merkmale von NTFP-Nutzern prägen maßgeblich, welche Pflanzenarten für welche Nutzungszwecke eingesetzt werden und wie groß die ökonomische Bedeutung derselben ist. Während von den 90, insgesamt über alle Nutzungskategorien genannten Arten, insbesondere solche von allen Savannenbewohnern gleichermaßen, d.h. unabhängig von der Gruppenzugehörigkeit, genutzt werden, die elementare Grundbedürfnisse decken (z.B. Ernährungssicherung, Energieversorgung), werden im Bereich der traditionellen Heilkunst Gehölze und ihre Teile ethnienspezifisch eingesetzt. Die drei ökonomisch wichtigsten Arten sind indes unabhängig von ethnischer Zugehörigkeit für alle Bewohner die folgenden: *Vitellaria paradoxa* (Sheabutterbaum), *Parkia biglobosa* (Néré) und *Adansonia digitata* (Affenbrotbaum). Die hoch auflösenden Ergebnisse dieser Studie bieten eine ausgezeichnete Datengrundlage für die Anpassung bestehender bzw. die Entwicklung zukünftiger Managementstrategien, die darauf abstellen, die tatsächlichen Bedürfnisse und Nutzungspräferenzen der lokalen Bevölkerung zu berücksichtigen.

Die dritte Studie wurde in Zusammenarbeit mit meinem Kollegen Jonathan Heubes durchgeführt. Wir haben einen neuen methodischen Ansatz entwickelt, der die Auswirkungen von Klima- und Landnutzungsänderungen auf das Vorkommen bestimmter, NTFP-lieferender Gehölzpflanzen und damit den durch diese Arten erzielten ökonomischen Nutzen untersucht (Kapitel 4). Durch die Kombination aus einer Nischen-Modellierung, die die zukünftige Auftrittswahrscheinlichkeit der untersuchten Arten für das Jahr 2050 projiziert, und der Verknüpfung dieser Auftrittswahrscheinlichkeiten mit den ökonomischen Erträgen ebendieser Arten konnten wir Kartenmaterial erstellen, das die Regionen aufzeigt, in denen zukünftig mit einer Erhöhung der Erträge bzw. einem entsprechenden Verlust zu rechnen ist. Solcherart Informationen, die die zeitliche Dimension von Änderungsprozessen einbeziehen, komplettieren die in den beiden vorausgegangenen Studien erarbeitete Datengrundlage zur Entwicklung geeigneter, zukünftigen Umweltveränderungen angepasster Managementstrategien. Abgeleitet aus den Ergebnissen meiner zweiten Analyse wurden als Zielpflanzen für diese dritte Studie folgerichtig die drei Arten gewählt, die im Untersuchungsgebiet als ökonomisch wichtigste identifiziert wurden: *V. paradoxa*, *P. biglobosa* und *A. digitata*. Die Ergebnisse zeigen, dass die prognostizierten Umweltänderungen hauptsächlich negative Auswirkungen auf die Erträge aus diesen drei Arten haben werden. Dies trifft im Besonderen auf die Gehölzart mit der höchsten wirtschaftlichen Bedeutung *V. paradoxa* zu, für die die größten Verluste berechnet wurden. Insgesamt wurde modelliert, dass große Teile des Untersuchungsgebietes bis zu 50 % des bislang erzielten Ertrages aus den drei Gehölzarten verlieren werden. Hinsichtlich der in meiner ersten Studie deutlich herausgestellten Abhängigkeit von NTFPs ist daher mit einer erhöhten Vulnerabilität der lokalen Bevölkerung zu rechnen. Bedeutsam sind diese Ergebnisse darüber hinaus aber auch auf der Ebene der nationalen Ökonomie: In jüngster Zeit gewinnen insbesondere die Früchte bzw. Samen des Sheabutterbaums sowie das Fruchtpulver des Affenbrotbaumes aufgrund ihrer hervorragenden Qualitäten als Nahrungsfettersatz bzw. ihres hohen Vitamin-C-Gehaltes an internationaler Bedeutung, was sich auch in der entsprechenden Nachfrage auf den Märkten widerspiegelt: Derzeit exportiert Benin rund 35.000 Tonnen Sheanüsse nach Europa. Ein Verlust dieser wichtigen Arten wäre also auch volkswirtschaftlich folgenreich.

Zusammengefasst unterstreichen die Ergebnisse der vorliegenden Arbeit die unbedingte Notwendigkeit, lokale, NTFP-liefernde Pflanzen zur Sicherung der Subsistenzgrundlage sowie als Einkommensquelle für die Savannenbewohner Westafrikas langfristig zu sichern. Die durch diese Arbeit bereitgestellten ökonomischen Grunddaten zur Bedeutung der Wildpflanzen für lokale Haushalte können als wesentliche Orientierungswerte zur Verbesserung von Kosten-Nutzen-Analysen im Rahmen von Landnutzungsentscheidungen beitragen. In Kombination mit Studien zur ökologischen Leistungsfähigkeit der Fokusarten (Abundanzen, Populationsdynamiken) können daraus zukunftsfähige Managementstrategien abgeleitet werden.

REFERENCES

Adams, W.M., Hutton, J., 2007. People, parks and poverty: Political ecology and biodiversity conservation. Conservation and Society 5: 147-183.

Adhikari, B., Di Falco, S., Lovett, J.C., 2004. Household characteristics and forest dependency: evidence from common property forest management in Nepal. Ecological Economics 48: 245-257.

Adomou, A.C., 2005. Vegetation patterns and environmental gradients in Benin: implications for biogeography and conservation, University of Wageningen.

Agbahungba, G., Depommier, D., 1989. Aspects du parc à karité-nérés (Vitellaria paradoxa Gaertn. f. Parkia biglobosa Jaqu. Benth.) dans le sud du Borgou (Benin). Bois et Forêts des Tropiques, 41-54.

Albuquerque, U.P., Lucena R.F.P., Monteiro, J. M., Florentino, A.T.N., Almeida, C. F. C. B. R., 2006. Evaluating two quantitative ethnobotanical techniques. Ethnobotany Research & Applications 4: 51-60.

Anderson, J., Benjamin, C., Campbell, B., Tiveau, D., 2006. Forests, poverty and equity in Africa: New perspectives on policy and practice. International Forestry Review 8 (2): 44-53.

Angelsen, A. and Wunder, S., 2003. Exploring the forest-poverty link: key concepts, issues and research implications. CIFOR, Bogor, Indonesia, pp. viii, 58p.

Araújo, M.B., New, M., 2007. Ensemble forecasting of species distributions. Trends in Ecology and Evolution 22: 42-47.

Araújo, M.B., Whittaker, R.J., Ladle, R.J., Erhard, M., 2005. Reducing uncertainty in projections of extinction risk from climate change. Global Ecology and Biogeography 14: 529-538.

Arbonnier, M., 2004. Trees, Shrubs and lianas of West African dry zones. Centre de cooperation internationale en recherche agronomique pour le développement (CIRAD). Margraf Publishers GMBH. Muséum nationale histoire naturelle (MNHN).

Arbre de vie, Benin. Non-Governmental Organization. www.arbre-de-vie.org (access 11/2011).

Armsworth, P.R., Chan, K.M.A., Daily, G.C., Ehrlich, P.R., Kremen, C., Ricketts, T.H., Sanjayan, M.A., 2007. Ecosystem-Service Science and the Way Forward for Conservation. Conservation Biology 21: 1383-1384.

Arnold, J.E.M., Pérez, M.R., 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics 39: 437-447.

Auswärtiges Amt Berlin, 2010. (http://www.auswaertiges-amt.de/diplo/de/Laenderinformationen/Benin/Wirtschaft.html#t3)

Augusseau, X., Nikiéma, P., Torquebiau, E., 2006. Tree Biodiversity, Land Dynamics and Farmers' Strategies on the Agricultural Frontier of Southwestern Burkina Faso. Biodiversity and Conservation 15(2): 613-630.

Avocèvou-Ayisso, C., Sinsin, B., Adégbidi, A., Dossou, G., Van Damme, P., 2009. Sustainable use of non-timber forest products: Impact of fruit harvesting on Pentadesma butyracea regeneration and financial analysis of its products trade in Benin. Forest Ecology and Management 257:1930-1938.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., Mathijs, E., 2009. The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia. Forest Policy and Economics 11:109-117.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., Mathijs, E., 2008. Household livelihood strategies and forest dependence in the highlands of Tigray, Northern Ethiopia. Agricultural Systems 98:147-155.

Baddeley, A., Turner, R., 2005. Spatstat: an R package for analyzing spatial point patterns; www.jstatsoft.org. Journal of Statistical Software 12: 1-42.

Barbier, E.B., Burgess, J.C., 2001. The Economics of Tropical Deforestation. Journal of Economic Surveys 15: 413-433.

Baumgärtner, S., 2002. Der ökonomische Wert der biologischen Vielfalt. Bayerische Akademie für Naturschutz und Landschaftspflege (Hrsg.): Grundlagen zum Verständnis der Artenvielfalt und ihrer Bedeutung und der Maßnahmen, dem Artensterben entgegen zu wirken. Laufener Seminarbeiträge 2/02. Laufen/Salzach.

Belcher, B.M., 2003. What isn't an NTFP? International Forestry Review 5:161-162.

Belem, B., Nacoulma, B. M. I., Gbangou, R.,Kambou, S.,Hansen, H.H., Gausset, Q., 2009. Use of non wood forest products by local people bordering the "Parc National Kaboré Tambi", Burkina Faso. The Journal of Transdisciplinary Environmental Studies 6(1).

Berkes, F., J. Colding, et al., 2000. Rediscovery of Traditional Ecological Knowledge as Adaptive Management. Ecological Applications 10(5): 1251-1262.

Berkes, F. and C. Folke, 2002. Back to the Future: Ecosystem Dynamics and Local Knowledge. Panarchy: Understanding Transformation in Human and Natural Systems. L. H. Gunderson and C. S. Holling. Washington, D.C., Island Press: 121-146.

Besco, E., Braccioli, E., Vertuani, S., Ziosi, P., Brazzo, F., Bruni, R., Sacchetti, G.,

Manfredini, S., 2007. The use of photochemiluminescence for the measurement of the integral antioxidant capacity of baobab products. Food Chemistry 102: 1352-1356.

Boffa, J. M., 1999. Agroforestry Parklands in Sub-Saharan Africa. Rome, Food and Agriculture Organization of the United Nations.

Boffa, J. M., 2000. West African agroforestry parklands: keys to conservation and sustainable management. Unasylva 51(200): 11-17.

Bolwig, S., Paarup-Laursen, B., 1999. Nature, work, culture: labour utilisation in agriculture and off-farm employment among the Fulani in nothern Burkina Faso. Danish Journal of Geography (2): 27-41.

Borgatti, S. P., Halgin, D.S., 2010. Mapping culture: Freelists, pilesorting, triads and consensus analysis. The Ethnographer's Toolkit 3.

Breman, H., Kessler, J.J., 1995. Woody plants in agro-ecosystems of semi-arid regions.

Brink, A.B., Eva, H.D., 2009. Monitoring 25 years of land cover change dynamics in Africa: A sample based remote sensing approach. Applied Geography 29: 501-512.

Business Times, 2010. Bright Light Shines Over Ghana’s Shea-Nut Industry, Business Times Magazine Africa, Accra, Ghana.

Bussmann, R.W., 2006. Ethnobotany of the Samburu of Mt. Nyiru, South Turkana, Kenya. Journal of Ethnobiology and Ethnomedicine 2:35.

Bussmann, R.W., Gilbreath, G.G., Solio, J., Lutura, M., Lutuluo, R., Kunguru, K., Wood, N., Mathenge, S.G., 2006. Plant use of the Maasai of Sekenani Valley, Maasai Mara, Kenya. Journal of Ethnobiology and Ethnomedicine 2:22.

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.r.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.v.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H.n., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Via, J.-C., Watson, R., 2010. Global Biodiversity: Indicators of Recent Declines. Science 328, 1164-1168.

Byron, N., Arnold, M., 1999. What Futures for the People of the Tropical Forests? World Development 27:789-805.

Calibre consultants and the Statistical Services Centre, 2000. Numbers of Forest Dependent People. A Feasibility Study. DFID Forestry Research Programme.

Caluwé, E. D., Smedt, S. D., Assogbadjo, A. E., Samson, R., Sinsin, B., van Damme, P., 2009. Ethnic differences in use value and use patterns of baobab (Adansonia digitata L.) in northern Benin. African Journal of Ecology 47(3): 433-440.

Campbell, M.B., Luckert, K.M.E., 2002. Uncovering the Hidden Harvest: Valuation Methods for Woodland and Forest Resources. Earthscan Publications Ltd., London.

Cavendish, W., 1997. The economics of natural resource utilisation by communal area farmers of Zimbabwe, University of Oxford, Oxford.

Cavendish, W., 2000. Empirical Regularities in the Poverty-Environment Relationship of Rural Households: Evidence from Zimbabwe. World Development 28:1979-2003.

Cavendish, W., 2002. Quantitative methods for estimating the economic value of resource use to rural households. Uncovering the Hidden Harvest: Valuation Methods for Woodland and Forest Resources. Earthscan publications Ltd., London.

CIFOR, 2011. Forests and non-timber forest products. CIFOR fact sheets, http://www.cifor.cgiar.org/publications/corporate/factSheet/NTFP.htm.

Chatelain, C., Aké Assi, L., Gautier, L., Spichiger, R., 2011. Atlas des plantes de Côted'Ivoire. Boissiera 64: 1-250.

Chen, N., Li, H., Wang, L., 2009. A GIS-based approach for mapping direct use value of ecosystem services at a county scale: Management implications. Ecological Economics 68: 2768-2776.

Chileshe, R.A., 2005. Land tenure and rural livelihoods in Zambia: case studies of Kamena and St. Joseph. University of the Western Cape, South Africa.

Clark, S., Bolt, K., Campbell, A., 2008. Protected areas: an effective tool to reduce emissions from deforestation and forest degradation in developing countries? Working Paper, UNEP World Conservation Monitoring Centre, Cambridge, UK.

Cocks, M.L., Bangay, L., Shackleton, C.M. and Wiersum, K.F., 2008. 'Rich man poor man' - inter-household and community factors influencing the use of wild plant resources amongst rural households in South Africa. International Journal of Sustainable Development and World Ecology 15: 198-210.

Convention on Biological Diversity (CBD), 2006. www.cbd.int.

Costanza, R., Daly, H.E., 1992. Natural Capital and Sustainable Development. Conservation Biology 6: 37-46.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., Oneill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., D'Agostino, J., 2006. The Value of New Jersey's Ecosystem Services and Natural Capital. Gund Institute for Ecological Economics, University of Vermont.

Coulibaly-Lingani, P., Tigabu, M., Savadogo, P., Oden, P.-C. and Ouadba, J.-M., 2009. Determinants of access to forest products in southern Burkina Faso. Forest Policy and Economics 11:516-524.

Cunningham, A.B., 1996. People, park and plant use. Recommendations for multiple use zones and development alternatives around Bwindi Impenetrable National Park, Uganda., UNESCO, Paris.

Dah-Dovonon, J.Z., Gnangle, C.P., 2006. Evaluation des potentialités de développement de la filière karité dans les départements de l'Atacora et de la Donga: Rapport définitif. ProCGRN, GTZ, Natitingou, Benin.

Daily, G.C., 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C.

Das, N., Sarker, D., 2008. Study on Forest Dependent Households under a Household Model Framework, MPRA Archive, Munich.

Dasgupta, P., 2008. Discounting climate change. Journal of Risk and Uncertainty 37: 141-169.

de Beer, J.H., McDermott, M., 1989. The Economic Value of Non-Timber Forest Products in South East Asia, Amsterdam.

de Berg, M., Cheong, O., van Kreveld, M., Overmars, M., 2008. Computational Geometry: Algorithms and Applications, 3 ed. Springer, Berlin, Heidelberg, New York.

de Bruijn, M.E., Dijk, J.W.M.v., 1994. Drought and coping strategies in Fulbe Society in the Hayre (Central Mali): a historical perspective. Cahiers d'Etudes africaines 34 (1-3).

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7: 260-272.

de Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393-408.

de Merode, E., Homewood, K., Cowlishaw, G., 2004. The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. Biological Conservation 118:573-581.

Deaton, A., 1982. Inequality and needs – some experimental results for Sri Lanka. Population and Development Review 8: 35-49.

Deaton, A., 1997. The analysis of household surveys: a microeconometric approach to development policy / Angus Deaton. Published for the World Bank [by] Johns Hopkins University Press, Baltimore, MD, p. 139

Dewi, S., Belcher, B., Puntodewo, A., 2005. Village economic opportunity, forest dependence, and rural livelihoods in East Kalimantan, Indonesia. World Development 33: 1419-1434.

Donovan, D. G. and R. K. Puri, 2004. Learning from Traditional Knowledge of Non-timber Forest Products: Penan Benalui and the Autecology of Aquilaria in Indonesian Borneo. Ecology and Society 9(1).

Dormann, C.F., 2007. Promising the future? Global change projections of species distributions. Basic and Applied Ecology 8 387-397.

Dove, M.R., 1993. A Revisionist View of Tropical Deforestation and Development. Environmental Conservation 20:17-24.

Dove, M.R., 1994. Marketing the Rainforest: 'Green' Panacea or Red Herring? Analysis from the East-West Center: 13.

Eade, J.D.O., Moran, D., 1996. Spatial economic valuation: Benefits transfer using geographical information systems. Journal of Environmental Management 48, 97-110.

EarthTrends and Portal, T.E.I., 2003. Forests, Grasslands, and Drylands. Benin. World Resources Institute, Washington, D.C., http://earthtrends.wri.org/pdf_library/country _profiles/for_cou_204.pdf

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C., van Jaarsveld, A.S., 2008. Mapping ecosystem services for planning and management. Agriculture Ecosystems & Environment 127: 135-140.

Ehrlich, P.R., Ehrlich, A.H., 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York.

Eigenbrod, F., Armsworth, P.R., Anderson, B.J., Heinemeyer, A., Gillings, S., Roy, D.B.,
Thomas, C.D., Gaston, K.J., 2010. The impact of proxy-based methods on mapping the distribution of ecosystem services. Journal of Applied Ecology 47: 377-385.

Ellenberg, L., 1993. Naturschutz und Technische Zusammenarbeit. Geographische Rundschau 45.

Elliman, K., Berry, N., 2007. Protecting and restoring natural capital in New York City's Watersheds to safeguard water, in: Aronson, J., Milton, S., Blignaut, J. (Eds.), Restoring Natural Capital: Science, Business and Practice. Island Press, Washington, D.C.

Ellis, F., 1998. Household Strategies and Rural Livelihood Diversification. The Journal of Development Studies 35:1-38.

Emerton, L., 2003. Tropical Forest Valuation: Has it all bee a futile exercise?, World Forestry Congress. FAO, Québec, Canada.

Emerton, L., 2005. Making the Economic Links between Biodiversity and Poverty Reduction: The Case of Lao PDR. IUCN - The World Conservation Unit. Ecosystems and Livelihood Group Asia. Colombo.

Emerton, L., Mogaka, H., 1996. Participatory environmental valuation of forest resources in the Aberdares, Kenya. PLA Notes.

Fandohan, B., Assogbadjo, A., Kakai, R., Kyndt, T., Caluwé, E., Codjia, J., Sinsin, B., 2010. Women's Traditional Knowledge, Use Value, and the Contribution of Tamarind (<i>Tamarindus indica</i> L.) to Rural Households' Cash Income in Benin. Economic Botany 64(3): 248-259.

FAO, 1999a. Non-wood Forest Products and Income Generation, FAO (Food and Agriculture Organization of the United Nations).

FAO, 1999b. Afgroforestry parklands in sub-Saharan Africa, in: FAO (Ed.), FAO Conservation Guide. FAO, p. 230.

FAO, 1999c. Agroforestry parklands in sub-Saharan Africa. FAO, p. 230.

Farber, S.C., Costanza, R., Wilson, M.A., 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics 41 : 375-392.

Faye, M. D., Weber, J. C., Mounkoro, B., Dakouo, J-M., 2010. Contribution of parkland trees to farmers livelihoods: a case study from Mali. Development in Practice 20(3): 428 - 434.

Fielding, A.H., Bell, J.F., 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24: 38-49.

Fisher, M., 2004. Household welfare and forest dependence in Southern Malawi. Environment and Development Economics 9:135-154.

Fisher, M., Chaudhury, M., McCusker, B., 2010. Do Forests Help Rural Households Adapt to Climate Variability? Evidence from Southern Malawi. World Development 38 : 1241-1250.

Folke, C., 2006. The Economic Perspective: Conservation against Development versus Conservation for Development. Conservation Biology 20: 686-688.

Ford, J., 2001. The relevance of indigenous knowledge for contemporary sustainability. Northwest Science 75(1): 183-188.

Fordham, D., Wigley, T., Brook, B.W., 2011. Multi-model climate projections for biodiversity risk assessments. Ecological Applications in press, doi:http://dx.doi.org/10.1890/1811-0314.1891.

Gadgil, M., Berkes, F., Folke, C., 1993. Indigenous Knowledge for Biodiversity Conservation. Ambio 22(2/3): 151-156.

Gallai, N., Salles, J.-M., Settele, J., Vaissière, B.E., 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics 68: 810-821.

Gaoue, O., Ticktin, T. 2009. Fulani Knowledge of the Ecological Impacts of Khaya senegalensis (Meliaceae) Foliage Harvest in Benin and its Implications for Sustainable Harvest. Economic Botany 63(3): 256-270.

Gebauer, J., El-Siddig, K., Ebert, G. 2002. Baobab (Adansonia digitata L.): a review on a multipurpose tree with promising future in the Sudan. Gartenbauwissenschaft 67: 155-160.

Glèlè Kakaï, R., Akpona, T.J.D., Assogbadjo, A.E., Gaoué, O.G., Chakeredza, S., Gnanglè, P.C., Mensah, G.A., Sinsin, B., 2011. Ecological adaptation of the shea butter tree (Vitellaria paradoxa C.F. Gaertn.) along climatic gradient in Bénin, West Africa. African Journal of Ecology 49(4): 440-449.

Godoy, R., Bawa, K., 1993. The economic value and sustainable harvest of plants and animals from the tropical forest: Assumptions, hypotheses, and methods. Economic Botany 47:215-219.

Godoy, R., Wilkie, D., Overman, H., Cubas, A., Cubas, G., Demmer, J., McSweeney, K., Brokaw, N., 2000. Valuation of consumption and sale of forest goods from a Central American rain forest. Nature 406: 62-63.

Goklany, I.M., 2009. Discounting the Future. Regulation (Spring) 36-40.

Gómez-Baggethun, E., de Groot, R., Lomas, P.L., Montes, C., 2009. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Ecological Economics 69: 1209-1218.

Gómez-Baggethun, E., Ruiz-Pérez, M., 2011. Economic valuation and the commodification of ecosystem services. Progress in Physical Geography 35: 613-628.

Gouwakinnou, G., Lykke, A., Assogbadjo, A., Sinsin, B., 2011. Local knowledge, pattern and diversity of use of Sclerocarya birrea. Journal of Ethnobiology and Ethnomedicine 7(1): 8.

Gram, S., 2001. Economic valuation of special forest products: an assessment of methodological shortcomings. Ecological Economics 36: 109-117.

Gubbi, S., MacMillan, D.C., 2008. Can non-timber forest products solve livelihood problems? A case study from Periyar Tiger Reserve, India. Oryx 42: 222-228.

Guisan, A., Thuiller, W., 2005. Predicting species distribution: offering more than simple habitat models. Ecology Letters 8: 993-1009.

Guisan, A., Zimmermann, N.E., 2000. Predicitive habitat distribution models in ecology. Ecological Modelling 135: 147-186.

Gustad, G., S. Dhillion, et al., 2004. Local use and cultural and economic value of products from trees in the Parklands of the municipality of Cinzana, Mali. Economic Botany 58(4): 578-587.

Hagenaars, A., de Vos, K., Zaidi, M.A., 1994. Poverty Statistics in the Late 1980s: Research Based on Micro-data, Office for Official Publications of the European Communities, Luxembourg.

Hahn-Hadjali, K., Thiombiano, A., 2000. Perception des espèces en voie de disparition en milieu gourmantché (Est du Burkina Faso). Berichte des Sonderforschungsbereich 68: 285-297.

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being, in: Raffaelli, D.G., Frid, C.L.J. (Eds.), Ecosystem Ecology: a new synthesis. Cambridge University Press, Cambridge: 110-139.

Hassan, R.M., Mbuli, P., Dlamini, C., 2002. Natural Resource Accounts for the State and Economic Contribution of Forests and Woodland Resources in Swaziland, in: Center for Environmental Economics and Policy in Africa (CEEPA) (ed.).

Heikkinen, R.K., Luoto, M., Araújo, M.B., Virkalla, R., Thuiller, W., Sykes, M.T., 2006. Methods and uncertainties in bioclimatic envelope modelling under climate change. Progress in Physical Geography 30: 751-777.

Hein, L., van Koppen, K., de Groot, R.S., van Ierland, E.C., 2006. Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics 57: 209-228.

Heubach, K., R. Wittig, Nuppenau, E.-A., Hahn, K., 2011. The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural west African communities: A case study from northern Benin. Ecological Economics 70(11): 1991-2001.

Heubes, J., Kühn, I., König, K., Wittig, R., Zizka, G., Hahn, K., 2011. Modelling biome shifts and tree cover change for 2050 in West Africa. Journal of Biogeography, in press.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A., 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Illukpitiya, P., Yanagida, J., 2008. Role of income diversification in protecting natural forests: evidence from rural households in forest margins of Sri Lanka. Agroforestry Systems 74:51-62.

Illukpitiya, P., Yanagida, J.F., 2010. Farming vs forests: Trade-off between agriculture and the extraction of non-timber forest products. Ecological Economics 69:1952-1963.

INSAE, 2000. Evolution des filières d'explortation au Benin: cas de quatre produits. Institut National de la Statistique et de l'Analyse Economique, Cotonou, Benin.

INSAE, 2008. Tableau de bord social 2008. Profils socio-économiques et indicateurs de développement. Institut National de la Statistique et de l'Analyse Economique, Cotonou, Benin.

IPCC, 2007. Climate Change 2007: The Physical Science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge.

IUCN, 2003. Recommendations of the Vth IUCN World Parks Congress, in: Union), I.T.W.C. (Ed.). IUCN, Gland.

Janßen, T., Schmidt, M., Dressler, S., Hahn-Hadjali, K., Hien, M., Konaté, S., Lykke, A.M., Mahamane, A., Sambou, B., Sinsin, B., Thiombiano, A., Wittig, R., Zizka, G., 2011. Addressing data property rights concerns and providing incentives for collaborative data pooling: the West African Vegetation Database approach. Journal of Vegetation Science 22: 614-620.

Jetz, W., Wilcove, D.S., Dobson, A.P., 2007. Projected Impacts of Climate and Land-Use Change on the Global Diversity of Birds. PLoS Biology 5: 1211-1219.

Kamanga, P., Vedeld, P. and Sjaastad, E., 2009. Forest incomes and rural livelihoods in Chiradzulu District, Malawi. Ecological Economics 68:613-624.

Kasina, J.M., Mburu, J., Kraemer, M., Holm-Mueller, K., 2009. Economic Benefit of Crop Pollination by Bees: A Case of Kakamega Small-Holder Farming in Western Kenya. Journal of Economic Entomology 102: 467-473.

Kepe, T., 2008. Beyond the numbers: Understanding the value of vegetation to rural livelihoods in Africa. Geoforum 39: 958-968.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H., Fischer-Kowalski, M., 2009. Growth in global materials use, GDP and population during the 20th century. Ecological Economics 68: 2696-2705.

Kristensen, M., Balslev, H., 2003. Perceptions, use and availability of woody plants among the Gourounsi in Burkina Faso. Biodiversity and Conservation 12: 1715-1739.

Kristensen, M., Lykke, A.M., 2003. Informant-Based Valuation of Use and Conservation Preferences of Savanna Trees in Burkina Faso. Economic Botany 57: 203-217.

Krohmer, J., 2004. Umweltwahrnehmung und -klassifikation bei Fulbegruppen in verschiedenen Naturräumen Burkina Fasos und Benins (Westafrika). Ethnoökologische, ethnobotanische und pflanzensoziologische Untersuchungen in Sahel-, Nord- und Südsudanzone., Goethe-University, Frankfurt.

Lamien, N., S. J. Ouédraogo, Diallo, O. B., Guinko, S., 2004. Productivité fruitière du karité (Vitellaria paradoxa Gaertn. C.F., Sapotaceae) dans les parcs agroforestiers traditionnels au Burkina Faso. EDP Sciences, CIRAD.

Lykke, A. M. (2000). Local perceptions of vegetation change and priorities for conservation of woody-savanna vegetation in Senegal. Journal of Environmental Management 59(2): 107-120.

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(10): 1961-1990.

MA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-Being: A Framework for Assessment, Washington, D.C.

Maranz, S., Kpikpi, W., Wiesman, Z., De Saint Sauveur, A., Chapagain, B., 2004. Nutritional Values and Indigenous Preferences for Shea Fruits (Vitellaria Paradoxa C.F. Gaertn. F.) in African Agroforestry Parklands. Economic Botany 58: 588-600.

Mayaux, P., Cabral, E. B., Cherlet, A. M., Defourny, P., Di Gregorio, A., Diallo, O., Massart, M., Nonguierma, A., Pekel, J.-F., Pretorius, C., Vancutsem, C., Vasconcelos, M., 2003. The Land Cover Map for Africa in the Year 2000. GLC2000 database, European Commission Joint Research Centre.

McCune, B., M. J. Mefford, 2006. PC-ORD. Multivariate Analysis of Ecological Data. Gleneden Beach, Oregon.

Mkanta, W.N., Chimtembo, M.M.B., 2002. Towards Natural Resource Accounting in Tanzania: A Study on the Contribution of Natural Forests to national Income. Center for Environmental Economics and Policy in Africa (CEEPA).

Mooney, H.A., Ehrlich, P.R., 1997. Ecosystem Services: A Fragmentary History, in: Daily, G.C. (Ed.), Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C., pp. 11-19.

Myers, J.P., Reichert, J.S., 1997. Perspectives on Nature's Services, in: Daily, G.C. (Ed.), Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T.R., Ricketts, T.H., 2008. Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences 105: 9495-9500.

Neumann, R.P., Hirsch, E., 2000. Commercialisation of non-timber forest products: review and analysis of research. CIFOR, Bogor, Indonesia, 176 pp.

Neumayer, E., 1999. Weak versus strong sustainability, Cheltenham.

Newell, R.G., Pizer, W.A., 2003. Discounting the distant future: how much do uncertain rates increase valuations? Journal of Environmental Economics and Management 46: 52-71.

Newton, A. C., 2008. Conservation of tree species through sustainable use: how can it be achieved in practice? Fauna & Flora International, Oryx 42(2): 195-205.

Ouédraogo, I., Tigabu, M., Savadogo, P., Compaoré, H., Odén, P.C., Ouadba, J.M., 2010. Land cover change and its relation with population dynamics in Burkina Faso, West Africa. Land Degradation and Development 21: 453-462.

Opschoor, J.B., 2003. Biodiversity, Sustainable Development and Economic Analysis, Public Lectures Series. Institute of Development Studies, Kerala.

Paré, S., Savadogo, P., Tigabu, M., Ouadba, J., Odén, P., 2010. Consumptive values and local perception of dry forest decline in Burkina Faso, West Africa. Environment, Development and Sustainability 12(2): 277-295.

Peters, C.M., 1994. Sustainable harvest of non-timber plant resources in tropical moist forest: an ecological primer, USAID Biodiversity Support Programme, Washington DC.

Phillips, O., A. Gentry, 1993. The useful plants of Tambopata, Peru: I. Statistical hypotheses tests with a new quantitative technique. Economic Botany 47(1): 15-32.

Plummer, M.L., 2009. Assessing benefit transfer for the valuation of ecosystem services. Frontiers in Ecology and the Environment 7: 38-45.

Polasky, S., Nelson, E., Pennington, D., Johnson, K., 2011. The Impact of Land-Use Change on Ecosystem Services, Biodiversity and Returns to Landowners: A Case Study in the State of Minnesota. Environmental and Resource Economics 48: 219-242.

ProCGRN, 2011. Stratégie ProCGRN 3. Filière karité - Changements structurels durables visés (Institutions, Services, OPA etc.). ProCGRN, GTZ, Natitingou, Benin.

Przyrembel, T., 2011. Benin: Landesübersicht und Naturraum, in: GIZ (Ed.). GIZ.

Ræbild, A., Hansen, H., Dartell, J., Ky, J. M., Sanou, L., 2007. Ethnicity, land use and woody vegetation: a case study from south-western Burkina Faso. Agroforestry Systems 70(2): 157-167.

Ramirez, J., Jarvis, A., 2008. High resolution statistically downscaled future climate surfaces. International Centre for Tropical Agriculture, CIAT.

R Development Core Team, 2011. R: A language and environment for statistical computing (http://www.R-project.org). R Foundation for Statistical Computing, Vienna, Austria.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R., Michener, C.D., 2004. Economic value of tropical forest to coffee production. Proceedings of the National Academy of Science U.S.A. 101: 12579-12582.

Rothman, D.S., Agard, J., Alcamo, J., 2007. Chapter 9: The Future Today, in: Schomaker, M., Keating, M., Chenje, M. (Eds.), Global Environmental Outlook 4 (GEO-4) environment for development. United Nations Environment Programme (UNEP), Valletta, Malta, pp. 395-454.

Sala, O.E., Chapin III, F.S.C., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D., 2000. Global Biodiversity Scenarios for the Year 2100. Science 287: 1770-1774.

Schaldach, R., Alcamo, J., Koch, L., Kölking, C., Lapola, D.M., Schüngel, J., Priess, J., 2011. An integrated approach to modelling land-use change on continental and global scales. Environmental Modelling & Software 26: 1041-1051.

Scheiter, S., Higgins, S.I., 2009. Impacts of climate change on the vegetation of Africa: an adaptive dynamic vegetation modelling approach. Global Change Biology 15: 2224-2246.

Scholes, R.J., 1997. Savanna, in: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.), Vegetation of southern Africa. Cambridge University Press, Cambridge.

Schreckenberg, K., 1996. Forests, fields and markets: A study of indigenous tree products in the woody savannas of the Bassila region, Benin. University of London, London.

Schreckenberg, K., 1999. Products of a managed landscape: non-timber forest products in the parklands of the Bassila region, Benin. Global Ecology & Biogeography 8:279-289.

Schreckenberg, K., 2004. The contribution of shea butter (Vitellaria paradoxa C.F. Gaertner) to local livelihoods in Benin, in: Sunderland, T., Ndoye, O. (Eds.), Forest Products, Livelihoods and Conservation. Case Studies of Non-Timber Forest Product Systems. Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Schreckenberg, K., Awono, A., Degrande, A., Mbosso, C., Ndoye, O., Tchoundjeu, Z., 2006. Domesticating indigenous fruit trees as a contribution to poverty reduction. Forest, Trees and Livelihoods 16: 35-51.

Schröter, D., Cramer, W., Leemans, R., Prentice, I.C., Araújo, M.B., Arnell, N.W., Bondeau, A., Bugmann, H., Carter, T.R., Gracia, C.A., de la Vega-Leinert, A.C., Erhard, M., Ewert, F., Glendining, M., House, J.I., Kankaanpää, S., Klein, R.T.J., Lavorel, S., Lindner, M., Metzger, M.J., Meyer, J., Mitchell, T.D., Reginster, I., Rounsevell, M., Sabaté, S., Sitch, S., Smith, B., Smith, J., Smith, P., Sykes, M.T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S., Zierl, B., 2005. Ecosystem Service Supply and Vulnerability to Global Change in Europe. Science 310: 1334-1337.

Schumann, K., Wittig, R., Thiombiano, A., Becker, U., Hahn, K., 2010. Impact of land-use type and bark- and leaf-harvesting on population structure and fruit production of the baobab tree (Adansonia digitata L.) in a semi-arid savanna, West Africa. Forest Ecology and Management 260: 2035-2044.

Schumann, K., 2011. Impact of Land-Use on Savanna: Vegetation and Populations of Non-Timber Forest Product-Providing Tree Species in West Africa. Diss., Department of Ecology and Geobotany, FB 15, Goethe-University, Frankfurt/Main,

Shackleton, C., Shackleton, S., 2004. The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. South African Journal of Science 100:658-664.

Shackleton, C.M., Shackleton, S.E., 2006. Household wealth status and natural resource use in the Kat River valley, South Africa. Ecological Economics 57:306-317.

Shackleton, C.M., Shackleton, S.E., Buiten, E., Bird, N., 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. Forest Policy and Economics 9:558-577.

Shone, B.M., Caviglia-Harris, J.L., 2006. Quantifying and comparing the value of non-timber forest products in the Amazon. Ecological Economics 58:249-267.

Sidibé, M., Williams, J.T., 2002. Baobab (Adansonia digitata). Southhampton, International Centre for Underutilised Crops.

Sieglstetter, R., 2002. Wie die Haare der Erde. Vegetationsökologische und soziokulturelle Untersuchungen zur Savannenvegetation der Südsudanzone Westafrikas und ihrer Nutzung und Wahrnehmung durch die ländliche Bevölkerung am Beispiel der Region Atakora im Nordwesten Benins., Johann Wolfgang Goehe-Universität, Frankfurt.

Sieglstetter R., Hahn K., Wittig R (2011): The use of non timber forest products in northern Benin. Flora et Vegetatio Sudano-Sambesica 14 (in press).

Sitch, S., Smith, B., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplans, J.O., Levis, S., Lucht, W., Sykes, M.T., K., T., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrical carbon cycling in the LPJ dynamic global vegetation model. Global Change Biology 9: 161-185.

SPSS (2011). PASW Statistics. Chicago, IL, USA, SPSS Inc.

Steffen, W., Rockström, J., Costanza, R., 2011. How Defining Planetary Boundaries Can Transform Our Approach to Growth. Solutions 2.

Steffen, W., Sanderson, A., Tyson, P.D., Jäger, J., Matson, P.A., Moore, B., 2004. Global Change and the Earth System: A Planet Under Pressure. Springer, Heidelberg.

Stern, N., 2006. Stern Review on the Economics of Climate Change. Cambridge University Press, UK.

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., Wunder, S., 2005. Livelihoods, forests, and conservation in developing countries: An Overview. World Development 33: 1383-1402.

Swets, J.A., 1988. Measuring the accurcay of diagonostic systems. Science 240: 1285-1293.

Tear, T.H., Karieva P., Angermeier, P.L., 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. BioScience 55: 835-849.

TEEB, 2008. TEEB – The Economics of Ecosystems and Biodiversity.

TEEB, 2010: The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Taita, P., 2003. Use of woody plants by locals in Mare aux Hippopotames Biosphere Reserve in western Burkina. Biodiversity and Conservation 6: 1205-1217.

Teklehaimanot, Z., 2004. Exploiting the potential of indigenous agroforestry trees: Parkia biglobosa and Vitellaria paradoxa in sub-Saharan Africa. Agroforestry Systems 61(2): 207-220.

Thomas, R.J., 2008. Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. Agriculture Ecosystems & Environment 126: 36-45.

Thornthwaite, C.W., 1948. An approach toward a rational classification of climate. Geographic Review 38: 55-94.

Thuiller, W., 2004. Patterns and uncertainties of species' range shifts under climate change. Global Change Biology 10: 2020-2027.

Thuiller, W., Lafourcade, B., Engler, R., Araújo, M.B., 2009. BIOMOD - a platform for ensemble forecasting of species distributions. Ecography 32: 369-373.

Ticktin, T., 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology 41(1): 11-21.

Ticktin, T., P. Nantel, et al., 2002. Effects of Variation on Harvest Limits for Nontimber Forest Species in Mexico. Efectos de la Variación Sobre los Límites de Cosecha de Especies Forestales No Maderables en México. Conservation Biology 16(3): 691-705.

Timko, J.A., Waeber, P.O. and Kozak, R.A., 2010. The Socio-Economic Contribution of Non-Timber Forest Products to Rural Livelihoods in Sub-Saharan Africa: Knowledge Gaps and New Directions. International Forestry Review 12:284-294.

Toman, M., 1998. SPECIAL SECTION: FORUM ON VALUATION OF ECOSYSTEM SERVICES: Why not to calculate the value of the world's ecosystem services and natural capital. Ecological Economics 25: 57-60.

Torras, M., 2000. The total economic value of Amazonian deforestation, 1978-1993. Ecological Economics 33: 283-297.

Troy, A., Wilson, M.A., 2007. Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. Ecological Economics 60: 852-853.

UNDP, 2010. The Human Development Report, New York.

UNECA, 2005. Striving for good governance in Africa: Synopsis of the African Government report 2005. United Nations Economic Comission for Africa.

UNEP, 2010. Global Honey Bee Colony Disorder and Other Threats to Insect Pollinators, merging Issues. Nairobi.

Vadez, V., Reyes-García, V., Godoy, R. A., Apaza, V. L., Byron, E., Huanca, T., Leonard, W. R., Pérez, E., Wilkie, D., 2004. Brief Communication: Does Integration to the Market Threaten Agricultural Diversity? Panel and Cross-Sectional Data From a Horticultural-Foraging Society in the Bolivian Amazon. Human Ecology 32(5): 635-646.

Valdivia, C., Dunn, E.G., Jettä, C., 1996. Diversification as a Risk Management Strategy in an Andean Agropastoral Community. American Journal of Agricultural Economics 78: 1329-1334.

Vassiliou, A., 2008. Commission Decision of 27 June 2008 authorising the placing on the market of Baobab drird fruit pulp as a novel food ingredient under Regulation (EC) No 258/97 of the European Parliament and the Council, in: Parliament, E. (Ed.).

Vedeld, P., Angelsen, A., Bojö, J., Sjaastad, E., Kobugabe Berg, G., 2007. Forest environmental incomes and the rural poor. Forest Policy and Economics 9: 869-879.

Viet Quang, D., Nam Anh, T., 2006. Commercial collection of NTFPs and households living in or near the forests: Case study in Que, Con Cuong and Ma, Tuong Duong, Nghe An, Vietnam. Ecological Economics 60: 65-74.

Vodouhê, F., Coulibaly, O., Greene, C. and Sinsin, B., 2009. Estimating the Local Value of Non-Timber Forest Products to Pendjari Biosphere Reserve Dwellers in Benin. Economic Botany 63:397-412.

Vodounou, C., 2008. Projections Départementales 2002 - 2030. Institute National de la Statistique et de l'Analyse économique du Benin.

WBGU, 1999. Umwelt und Ethik. Sondergutachten, in: WBGU (Ed.), Welt im Wandel, Marburg.

Wezel, A., Lykke, A., 2006. Woody vegetation change in Sahelian West Africa: evidence from local knowledge. Environment, Development and Sustainability 8(4): 553-567.

Wittig, R., Hahn-Hadjali, K., Krohmer, J., Müller, J., 2000. Nutzung, Degradation und Regeneration von Flora und Vegetation in westafrikanischen Savannenlandschaften. Berichte der Reinhold-Tüxen Gesellschaft 12: 263-281.

Wittig, R., König, K., Schmidt, M., Szarzynski, J., 2007. A study of climate change and anthropogenic impacts in West Africa. Environmental Science and Pollution Research 14: 182-189.

World Bank, 2001. A revised forest strategy for the World Bank group. Washington, D.C.

World Bank, 2004. Sustaining Forests: A Development Strategy, Washington, D.C.

World Bank, FAO, 2009. The sunken billions: The economic justification for fisheries reform. Washington, D.C.

World Resources Institute (WRI), 1998. Valuing Ecosystem Services, in: Institute, W.R. (Ed.).

WWF, 2004. How effective are protected areas? A preliminary analysis of forest protected areas by WWF - the largest ever global assessment of protected area management effectiveness. WWF, Gland.

Yatich, T., A. Kalingánire, Alinon, K., Weber, J. C., Dakouo, J. M., Samaké, O., Sangaré, S., 2008. Moving Beyond Forestry Law in Sahelian Countries. Policy Brief. World Agroforestry Centre, Nairobi.

Yazzie, D, Vanderjagt, D. J., Pastuszyn, A. O., Glew, R. H., 1994. The Amino Acid and Mineral Content of Baobab (Adansonia digitata L.) leaves. Journal of Food Composition and Analysis 7: 189-193.

ACKNOWLEDGEMENTS

I am very grateful to an uncountable number of people who bestowed me invaluable trust and advice not only for this work itself but for the entire path to finally achieve this written document.

First and foremost, I would like to truly thank Prof. Dr. Rüdiger Wittig for dedicating me the presented issue in the area of ecological economics being both a major challenge and an even greater pleasure for me to elaborate. Particularly, I am very honored by the trust you have put in me since day one of this thesis.

Sincere thanks go to Prof. Dr. Ernst-August Nuppenau who introduced me firmly and with great success into the world of economic sciences. Without your great willingness to educate and guide me in this scientific area this thesis would not have advanced like it did.

I am exceedingly grateful to Dr. Karen Hahn, the very heart of the Africa-related research within the professorship of Prof. Wittig. Your commitment for this work went far beyond conventional boundaries and your personal care was priceless – especially with regard to my first scientific steps in Benin. Moreover, I would like to sincere thank you for giving me so much confidence.

I owe my deepest gratitude Prof. Dr. Brice Sinsin for his great scientific, logistic and personal support in Benin that allowed me to conduct this research in the first place.

This thesis would not exist without the true commitment of my colleagues in Benin, Frankfurt and elsewhere. In particular, I am honestly grateful to Gnanando Saidou with whom I conducted the fieldwork in Benin, and Dr. Julia Krohmer whose dedicated love for this charming region of the world took me completely, forming the fundament of my work.

Furthermore, I would like to deeply thank Katrin Jurisch for her friendship: I admire your strong heart, your loyalty and the many moments of deep mutual understanding.

My very heartfelt thanks go to Dr. Lasse Loft who I boundlessly treasure for his great mind. I learned invaluably much from you, not only regarding this subject and the necessary patience aiming at addressing it appropriately, but especially with regard to the scientific and personal opportunities life has to offer.

I would like to thank all other colleagues of our department, especially Katharina Schumann, Daniela Haarmeyer, Svenja Meierfrankenfeld, Yvonne Bachmann, Marion Leiblein as well as Cornelia Anken for a powerful team play and the cheerful atmosphere.

Finally, my greatest thanks go to the Biodiversity and Climate Research centre that funded this research giving me the opportunity to explore an inspiring and greatly exciting scientific area.

This thesis is, first of all, dedicated to my parents, Gisela and Tobias Heubach. It is impossible to reward you for at least even a tiny part of the things you have been giving to me, especially your faith in me. However, this work might be a start. This thesis is also dedicated to my brother Markus and my beloved grandmother Helga as well as the entirety of my true friends: Josefine, Sonja, Onno, Yvonne, Denise, George, Jenny, René, Soni, Julia, Axel, Vera, Ingo, Angie, Jo, Steffen and Frederik. I owe you everything.

CURRICULUM VITAE

Personal information

First name(s) / Surname(s)	**Katja Heubach**
Place of Birth	Apolda, Germany

Current position held

Dates	January 2009 onwards
Position	PHD CANDIDATE
	Biodiversity and Climate Research Centre Frankfurt (BiK-F), D-60325 Frankfurt, European research institute
Main activities and responsibilities	Interdisciplinary research focussing on the economic valuation of ecosystem services in West African communities elaborating a case study in Benin Thesis title: "The socio-economic importance of non-timber forest products for rural livelihoods in West African savanna ecosystems: current status and future trends." First supervisor: *Prof. Dr. Rüdiger Wittig*, Frankfurt Second supervisor: *Prof. Ernst-August Nuppenau*, Gießen Member of *GRADE Goethe Graduate Academy* (graduate School) Member of *SciMento-hessenweit* (mentoring programme, completed)

Work experience

Dates	February 2009 onwards
Position	OFFICE MANAGER
	BUND (Friends of the Earth Germany) Frankfurt, D-60314 Frankfurt; German NGO
Main activities and responsibilities	• Citizen advisory service for questions regarding nature conservation and environmental protection • Establishment of new BUND groups (e.g. academic student association); development of own projects (e.g. urban ecological gardening) • Organisation, administration and implementation of BUND projects • Development and implementation of a volunteer management

Dates	May 2007 – December 2008
Position	CONSULTANT FOR PROJECT GRANTS IN THE AREA OF NATURE CONSERVATION, ENVIRONMENTAL PROTECTION AND DEVELOPMENT COOPERATION *Umweltkontor Nord, Büro für Umwelt und Entwicklung*, D-26653 Dornum, German SME
Main activities and responsibilities	• Professional and financial examination of applications under concerns of nature conservation and development cooperation; development of sponsorship proposals • Applicant advisory service and internal communication with board of foundation and award committee as well as authorities, institutions and media • Training and leading new colleagues within the internal trainee programme

Education and training

Dates	October 2007 – November 2008
Title of qualification awarded	Distance Learning Course at *Technische Universität Kaiserslautern*, Germany, "Nachhaltige Entwicklungszusammenarbeit", Certificate (good: 1.7)
Principal subjects/occupational skills covered	• Theoretical background of development cooperation (economics and social sciences) • Strategies and concepts for sustainable development cooperation • Sustainable project management
Dates	October 2001 – August 2006
Title of qualification awarded	Diploma Biologist at *Goethe-Universität Frankfurt*, Germany (very good: 1.3) Diploma thesis title: "Saisonale Populationsdynamik eines Daphnia-Artenkomplexes: Genetik und life-history-Variation" Supervisor: *Prof. Dr. Bruno Streit*, Frankfurt
Principal subjects/occupational skills covered	• Ecology, evolution and diversity of plants and animals • Molecular ecology of freshwater arthropods • Plant physiology

Personal skills & competences

Mother tongue(s)	German
Foreign Languages	English (C1), French (B1)

Social skills and competences

Intercultural skills:

- 8-month field work and research in West Africa (Benin, Burkina Faso); close collaboration with local assistants and NGOs
- Internships in the US (nature conservation in National Parks) and the UK (*Cambridge Certificate of Work Experience*)

Team skills:

- Involved in an international research team in BiK-F including partners in Africa
- Member of various NGOs (e.g. BUND e.V., Afrika-Projekt Frankfurt)
- For two years member of the students council biology of Goethe-University, Frankfurt

Mediating skills:

- Group leader of the BUND academic student association Frankfurt
- Member of the PhD committee in BiK-F

Organisational skills and competences

During my PhD I organized an international workshop with scientist from 7 European countries dealing with the economic valuation of biodiversity and ecosystem services. Within my position at BUND Frankfurt I have been constantly developing, organising and implementing projects, e.g. seminars for volunteers or experience-oriented environmental education events for children.

Scientific record (extract)

Heubach, K., Wittig, R., Nuppenau, E.-A., Hahn, K. (2011): “The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural west African communities: A case study from northern Benin.” *Ecological Economics* 70(11): 1991-2001

Heubach, K., Wittig, R., Nuppenau, EA, Hahn, K. (2011): More than just fruits, bulbs, leaves and stems: Wild plant products are essential ecosystem services helping to sustain livelihoods in rural West African communities. *Poster* at the Evaluation of the Biodiversity and Climate Research Centre, Frankfurt, 14 – 15 Mar 2011; awarded first prize.

Heubach, K., Wittig, R., Hahn-Hadjali, K. (2009): How much "costs" the savanna? - The economic contribution of Non-Timber-Forest-Products (NTFPs) to livelihood maintenance of rural communities in Westafrican savannas: A case study from Benin. *Talk* at the Conference Diversitas OSC2 “Biodiversity and society: understanding connections, adapting to change”, Cape Town, 14 Oct 2009.

ERKLÄRUNG

Die dritte der in dieser Arbeit vorgelegten Studien *(“Impact of future climate and land use change on Non-Timber Forest Product provision in Benin, West Africa: Linking niche-based modelling with ecosystem service values”,* Kapitel 4) ist in Zusammenarbeit mit meinem Kollegen Jonathan Heubes entstanden. Diese Studie ist eine Zusammenführung von ökonomischen Haushaltsdaten mit Modellierungsdaten hinsichtlich der drei untersuchten Gehölzarten *Vitellaria paradoxa*, *Parkia biglobosa* und *Adansonia digitata*.

Ich erkläre hiermit, den ökonomischen Anteil der Studie sowohl im Hinblick auf die Datenaufnahme und –analyse (haushaltsökonomische Umfragen und GPS-Aufnahmen in Benin) als auch die hier vorgelegte schriftliche Abfassung vollständig selbstständig erstellt zu haben. Gemeinsam mit Herrn Heubes habe ich die Verbindung zu dessen Modellierung erarbeitet.

Frankfurt am Main, den Katja Heubach