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ORIGINAL ARTICLE

Usable wild plant species in relation to elevation and land use at Mount Kilimanjaro, Tanzania

Neduvoto Piniel Mollel[1,2] · **Markus Fischer**[2,3,4] · **Andreas Hemp**[5]

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Abstract We used the broad elevational gradient of Kilimanjaro ranging from warm tropical lowland to cold Afro-alpine temperature regimes and the occurrence of natural, nearly untouched as well as of anthropogenic and heavily disturbed habitats to study how elevation and disturbance by humans affect the proportion of useful plant species in different habitat types. Of the 962 vascular plant species recorded in our 60 study plots, 563 species turned out to be listed as useful in the literature. We classified these species into six usage categories. With linear models we tested for relationships between the proportion of useful species per plot and elevation for natural habitats, and with analysis of variance we compared the proportion of useful species between plots in disturbed and natural habitats at similar elevation. The proportion of useful species for all usage categories increased from 860 to 2500 m asl and decreased with higher elevation. We also found an overall positive correlation between the number of useful plants and the species richness of our plots. Human-influenced habitats had higher proportions of useful species for all usage categories, except for construction and fuel wood usage which were higher in natural savanna and lower montane forest than in used habitats at these elevations. Given the high proportions of useful species, we conclude that preserving the biodiversity of Kilimanjaro ecosystems is indispensable for maintaining the diversity of useful plants species for the local people who rely on it for food, sustainable access to medicinal, fuel, construction and forage material.

Keywords Ethnobotany · Elevation gradient · Land use

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✉ Andreas Hemp
andreas.hemp@uni-bayreuth.de

Neduvoto Piniel Mollel
nmollel@tpri.or.tz

Markus Fischer
markus.fischer@ips.unibe.ch

1 Tropical Pesticides Research Institute, P O Box 3024, Arusha, Tanzania

2 Institute of Plant Sciences and Botanical Garden, University of Bern, Altenbergrain 21, 3013 Bern, Switzerland

3 Oeschger Centre for Climate Change Research, University of Bern, Falkenplatz 16, 3012 Bern, Switzerland

4 Senckenberg Biodiversity and Climate Research Centre BiK-F, Georg-Voigt-Straße 14-16, 60325 Frankfurt am Main, Germany

5 Department of Plant Systematics, University of Bayreuth, 95440 Bayreuth, Germany

Introduction

There has been increasing scientific interest in the difference between types and characteristics of habitats and their provision to humans in terms of ecosystem services (Wall and Nielsen 2012). In spite of the growing interest and awareness of the general importance of ecosystems and biodiversity for human welfare, loss of biodiversity due to degradation of ecosystems still continues at a large scale, potentially resulting in a decline of ecosystem services, especially of wild foods, timber, wood-fuel, genetic resources, medicine and fodder (MEA 2005).

In rural areas, wild plants are an important source of edible fruits, leafy vegetables and herbs, and are particularly important in ensuring food security (Ndangalasi et al. 2007). Moreover, it is indicated that 70–80% of the world population use plants for treatment of basic medical ailments (Farnsworth and Soejarto 1991) and that 25,000–75,000 species of vascular plants have been used in traditional medicine worldwide (Farnsworth 1985).

Previous studies by Hemp (1989/90; 1999), Lyaruu (2002), Misana et al. (2003), Hemp and Hemp (2009) focused on a general compilation of vernacular nomenclature and traditional usage of plant species at Kilimanjaro. Usable species might be most frequent at intermediate elevations, where the highest diversity of plant growth forms is found in multilayered forests (Hemp 2010). The proportion of usable species may also depend on land cover type. Human use of habitats may either lead to a depletion or an enrichment in usable species. However, a study of the relationship between the occurrence of usable plants and environmental conditions (elevation, climate, anthropogenic influence) is still lacking. The huge gradient of such parameters at Kilimanjaro ranging from hot and dry savanna at the foothills, to montane rain forest and alpine heath lands and covering a high variety of human-impacted habitats at different elevations offer an ideal opportunity for addressing the effect of elevation and anthropogenic impacts on usable plants. Within the frame of the DFG-funded research unit FOR 1246, we established research plots within all major land use and vegetation types (6 mainly undisturbed and 6 anthropogenic or heavily disturbed) ranging from 860 to 4550 m on the southern slope of Kilimanjaro, where we recorded the whole species composition of vascular plants, capturing about one-third of the 3000 plant species occurring on Kilimanjaro (Hemp 2006c). Based on this dataset, we calculated the proportion of useful plant species in the various ecosystems along elevation and in natural and heavily disturbed habitats. Furthermore, we asked whether the number of useful species is a function of overall biodiversity.

Hemp (1999) reported that knowledge about useful plants is largely found among the older people, while younger people tend to disdain such "traditional" resources, preferring "modern" industrial products. Thus, such traditional knowledge may well be lost in the near future. This is likely accelerated by increasing land use intensification and land cover changes degrading natural habitats where these plants occur (Hemp 1999). Therefore, our study not only aims at complementing previous ethnobotanical studies, but also at highlighting the consequences of human interference for usable species.

Methods

Study area

Due to strong climatic gradients, several vegetation zones are apparent on the southern slopes of Mt. Kilimanjaro which range from the colline savanna in the plains at 800 m asl to the alpine *Helichrysum* scrub up to 4600 m asl. In the colline zone between 800 and 1100 m asl, natural *Acacia*–*Commiphora* woodlands are mainly replaced by crop fields, and the lower montane vegetation zone below 1800 m asl is densely populated as well. Here, on the southern and eastern slopes of Kilimanjaro, the Chagga, a Bantu-tribe, have continuously settled since several hundred years where they are living within their home gardens in single houses and not in closed villages (Hemp 2006a). The first census by the German colonial government in 1914 counted 0.1 million Chagga people living at Kilimanjaro, while by 2012 the population had increased at a rapid rate to over 1.2 million (Hemp 2006a, Tanzanian National Bureau of Statistics 2003 and 2013). Most of the southern and south-eastern slopes of Kilimanjaro are covered by traditional Chagga home gardens, followed by commercial coffee plantations and grasslands used for fodder collection (Hemp 2006a, b). Remnants of the former forest occur only in deep and inaccessible river valleys and in the upper part of the lower montane zone above 1800 m.

The middle montane zone between 2200 and 2800 m asl is the main habitat of *Ocotea usambarensis*. In this zone, commercial logging targeting *O. usambarensis* took place until 1984 when commercial logging was banned (Agrawala et al. 2003). Therefore, this zone is untouched and formerly logged forests exist which are nowadays protected by the National Park (Rutten et al. 2015a). With increasing elevation between 2800 and 3200 m asl, *Podocarpus latifolius* dominates the forest in the upper montane vegetation zone. During the last three decades, a considerable area of this *Podocarpus* forest has been destroyed by fire resulting in a mosaic of undisturbed *Podocarpus* forests and fire regenerating stages with monodominant *Erica excelsa* in the tree layer (Hemp 2005, 2009). In the subalpine zone between 3200 and 4000 m asl, most of the former *Erica* forest is destroyed by fire and replaced by ericaceous shrubland. Higher up, in the alpine zone, cushions of the genus *Helichrysum* and grasses dominate the vegetation up to 4600 m and the higher elevations are bare of vegetation (Hemp 2001). The studied vegetation and land use types as well as the types of disturbance are listed in Table 1.

Vegetation records

Along the altitudinal gradient of the southern and south-eastern slope of Mt. Kilimanjaro, 60 study plots (20 × 50 m) representing the 12 major habitat types (six natural, i.e. mainly undisturbed and six severely disturbed or anthropogenic) as explained above and in Table 1 were established. In each of the 12 habitat types, five replicate study plots were established, distributed over an east–west gradient and covering the elevational distribution and

Table 1 The studied natural vegetation with their type of disturbance/land use along elevational zones at the southern slopes of Mt. Kilimanjaro

Elevation (m)	Vegetation zone	Natural vegetation	Disturbance or land use
4000–4600	Alpine	*Helichrysum* vegetation	No land use
3200–4000	Subalpine	Erica forest	Burned[a]
2800–3200	Upper montane	*Podocarpus* forest	Burned
2200–2800	Middle montane	*Ocotea* (Camphor) forest	Logged
1100–2200	Lower montane	Lower montane forest	Chagga home gardens, Coffee plantations and grasslands
700–1100	Colline	Savanna woodlands	Maize fields

[a] This land cover type was not studied

variability within each habitat type and vegetation zone. The location of the plots was chosen according to its representativeness for the respective habitat type, and according to accessibility and security. Plot positions were recorded with GPS and permanently marked with subterranean iron nails. The distances between the plots ranged from 0.3 to 54 km.

We recorded all vascular plant species (herbs, shrubs, trees, lianas, epiphytes) in all study plots between 2010 and 2011 using the method of Braun-Blanquet (1964). Species were identified mainly in the field or collected and compared with the herbarium specimens at the research station of the Kili-project in Kidia (Old Moshi) collected by A. Hemp during the last 27 years. In difficult cases, vouchers were collected and compared and deposited at the herbaria of Arusha (Tanzania), Nairobi (Kenya), Kew (England), Berlin (Germany), Copenhagen (Denmark), Stockholm (Sweden), Paris (France) and Vienna (Austria). The nomenclature follows FTEA (1952–2012).

Occurrence of usable plant species

For all 962 species occurring in the 60 plots, we assessed whether they are useful for humans and, if so, for which purpose (six categories of usage were differentiated: traditional medicine, cattle forage, construction material, food, fuel wood and shading/ornamental usage). The assessment involved several plant use databases and publications [Prelude Medicinal plants database; Kokwaro (1976, 2009); PROTA database; Beentje (1994); Ruffo et al. (2002)], including information compiled by Hemp (1990, 1999) and Hemp and Hemp (2009), who had extensively interviewed local people with comprehensive knowledge on useful wild plant species at Mt. Kilimanjaro. The useful species were calculated for each plot, in total and per category of usage, considering that the same species can be used for different purposes.

Analysis

Linear models were tested for the proportions of useful species over an elevation gradient in the 30 plots of the natural habitats. We compared linear and quadratic models with a likelihood ratio test. Analysis of variance (ANOVA) was applied to compare the proportion of useful species between human-used/disturbed and natural habitat types for four different elevational zones, except the subalpine and alpine zones, where only undisturbed natural vegetation was studied (i.e. subalpine *Erica* forest and alpine *Helichrysum* vegetation, Table 1). In these comparisons, plot elevation was used as covariate to account for elevational differences between plots of the same vegetation zone. Post hoc tests (Tukey's 'honest significant difference' method) were used to test for significant differences of the proportion of used plant species between the four habitat types in the lower montane zone. All analyses were performed using R version 3.0.1 (R Core Team, 2014).

Results

Usable plants

Altogether, 563 of the 962 species recorded in all study plots were known to be usable by local people. These species belonged to 346 genera and 119 families. The most represented families across all categories for usage were the Poaceae (75 species), followed by the Fabaceae (55 species), Asteraceae (42 species), Rubiaceae (28 species), Euphorbiaceae (20 species), Lamiaceae (18 species), Aspleniaceae (15 species), Acanthaceae and Cyperaceae (each 13 species). 110 further families were represented by less than ten species, among them 45 families by just one species (Online Resource 1). The highest share of useful plants within the ten most important families was found in the Poaceae and Rubiaceae with 79 and 75% (Online Resource 1). There was a strong positive correlation between the number of useful plants and species richness of our plots, for both natural and human-influenced ones (Fig. 1).

Of all 563 useful species, 385 or 68% belonged to the category of traditional medicine. The second most frequent category was use for forage with 324 (57.5%) species. 112 species (19.9%) were used for fuel either as firewood and/or charcoal. 103 species (18.3%) in 84 genera and 49 families were material for construction and making tools. 89 plant species (15.8%) were edible, while the smallest group consisted of 38 species (6.7%) from 35 genera and 28 families which were either preferred as shade trees in coffee and banana gardens or as ornamentals around homesteads.

Usable plants from natural habitats in relation to elevation

The proportions of useful plant species per plot followed a strong quadratic relationship with elevation forming a unimodal pattern peaking in the lower to middle zones of the mountain ($F_{2,27} = 70.1$, $R^2 = 0.84$, $P < 0.001$; peak at 1900 m asl; Fig. 2). Individual usage categories followed the same pattern with varied strengths: forage ($F_{2,27} = 35.85$, $R^2 = 0.72$, $P < 0.001$; peak at 1800 m asl; Fig. 3a); medicine ($F_{2,27} = 49.99$, $R^2 = 0.77$, $P < 0.001$; peak at 1000 m asl; Fig. 3b); fuel wood ($F_{2,27} = 25.28$, $R^2 = 0.65$, $P = 0.004$; peak at 1200 m asl; Fig. 3c); food ($F_{2,27} = 23.07$, $R^2 = 0.63$, $P < 0.001$; peak at 1000 m asl; Fig. 3d); construction ($F_{2,27} = 26.53$, $R^2 = 0.66$, $P = 0.01$; peak at 1000 m asl; Fig. 3e); shade and ornamental use ($F_{1,28} = 17.84$, $R^2 = 0.39$, $P < 0.001$; linear decline; Fig. 3f; Table 2).

Usable plants in relation to human impact

The proportion of useful plant species and their absolute number per zone differed strongly between natural and human-impacted habitats at lower elevations (Fig. 4, Online Resource 2). Below, we describe human impact on the occurrence of usable plants for each of the four vegetation zones separately. In the savanna zone, there were no significant differences between the proportions of species for traditional medicine, forage, shade and ornamental use between maize fields and natural savanna (Fig. 4a, b, d). However, the proportion of food species was higher

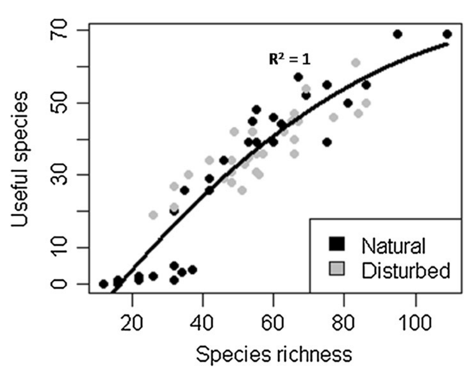

Fig. 1 Correlation between number of useful species and overall species richness of the research plots. $F1,57 = 57$; $R^2 = 1$; $^{***}P < 0.001$

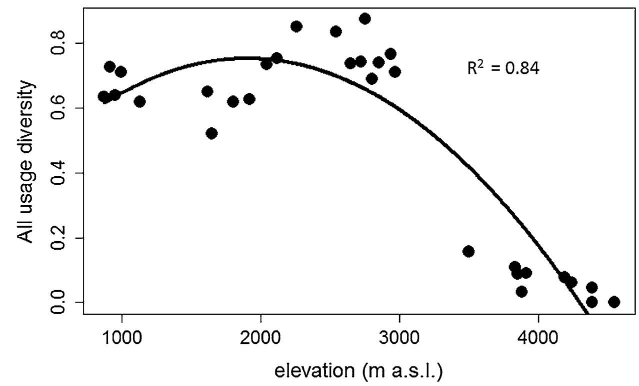

Fig. 2 Proportion of species of any usage category for the 30 plots in natural habitats along the elevation gradient at Mt. Kilimanjaro: $F_{2,27} = 70.1$, $^{***}P < 0.001$. The fitted line represents the significant quadratic function. R^2 indicates the variation explained

($F_{1,6} = 11.6$; $P = 0.01$) in maize fields (Fig. 4c), while the proportions of species for fuel wood ($F_{1,6} = 8.34$; $P = 0.02$) and for construction ($F_{1,6} = 8.4$; $P = 0.02$) were higher in natural savanna than in maize fields (Fig. 4e, f).

In the lower montane zone, the proportions of plant species potentially used for traditional medicine, food, shading and for ornamental use were increased in human-used habitats. The proportion of forage species was not significantly different between natural and human-used habitats, while the proportions of species for construction and fuel wood were highest in the natural habitats (Table 3; Fig. 4e, f).

Tukey's HSD tests for the lower montane zone revealed that the proportions of species of the usage categories forage and traditional medicines were significantly higher in coffee plantations than in natural habitats or home gardens, whereas proportions in grasslands were intermediate (Fig. 4a, b). Moreover, the proportions of food and shade species were highest in the home gardens and differed significantly from the ones of natural habitats, but not from coffee plantations or grasslands (Fig. 4c, d). Finally, the proportion of species for fuel wood and construction, which was highest in the natural habitats of the lower montane zone, was significantly higher in natural forests than in coffee plantations or grasslands, whereas home garden proportions were intermediate (see letters above columns in Fig. 4e, f).

In the *Ocotea* zone, the proportions of species of the categories traditional medicine, food, construction, fuel, shade and ornamental use were not significantly different between natural and logged *Ocotea* forests (Fig. 4a, c–f). In contrast, the proportion of forage species was higher in the natural *Ocotea* forests ($F_{1,8} = 9.9$; $P = 0.01$; Fig. 4b; Table 3).

In the *Podocarpus* zone, the proportion of medicinal species ($F_{1,8} = 14$; $P = 0.005$) and forage ($F_{1,8} = 12.5$;

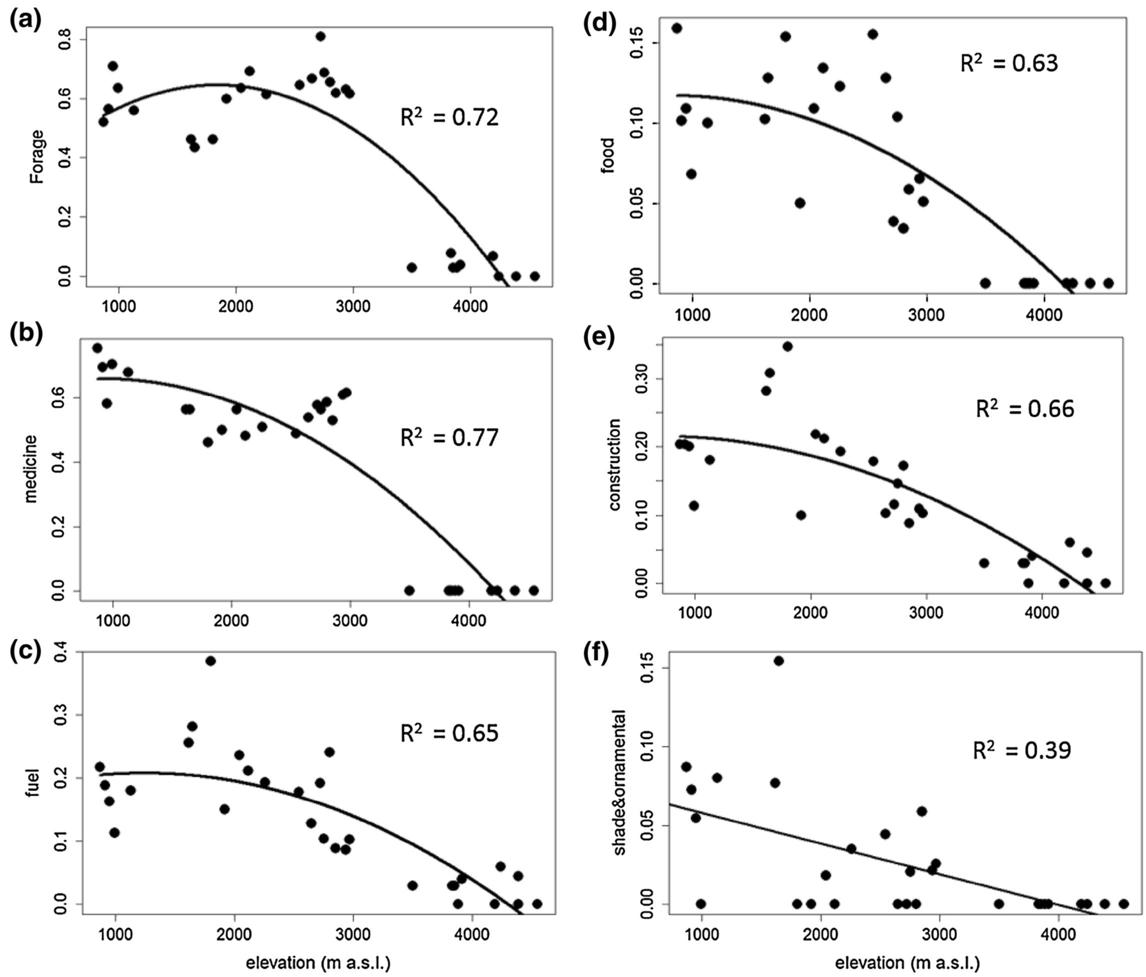

Fig. 3 Proportion (%) of used plant species per plot for 30 natural habitats along the elevation gradient at Kilimanjaro: **a** forage: $F_{2,27} = 35.87$, $P < 0.001$; **b** traditional medicine: $F_{2,27} = 49.99$, $P < 0.001$; **c** fuel wood: $F_{2,27} = 25.28$, $P = 0.04$; **d** food plants: $F_{2,27} = 23.07$, $P = 0.01$; **e** construction: $F_{2,27} = 26.53$, $P = 0.01$; **f** shade and ornamental use: $F_{1,28} = 17.84$, $P < 0.001$. The fitted lines represent the significant quadratic or linear function. R^2 indicates the variation explained. Note the different scales of the *y* axis

Table 2 Parameters of the quadratic regressions of the proportion of used plants per usage category on elevation for 30 plots of natural habitat types at Mount Kilimanjaro

Use category	*df*	*F*	*P*	R^2
Medicinal	2; 27	49.99	<0.001	0.77
Forage	2; 27	35.87	<0.001	0.72
Fuel wood	2; 27	25.28	<0.004	0.65
Construction	2; 27	26.53	<0.01	0.66
Food (edible)	2; 27	23.07	0.01	0.63
Shade and ornamental use	1; 28	17.84	<0.001	0.39

$P = 0.007$) was higher in undisturbed *Podocarpus* forests than in previously burned ones (Fig. 4a, b). In contrast, the proportions of species of the usage categories fuel wood, construction, food, shade and ornamentals were not significantly different between the unburned and previously burned *Podocarpus* forests (Fig. 4c–f; Table 3).

Discussion

Plant usage

The majority of the usable species in our study area was in the category of traditional medicines (68%). Medicinal

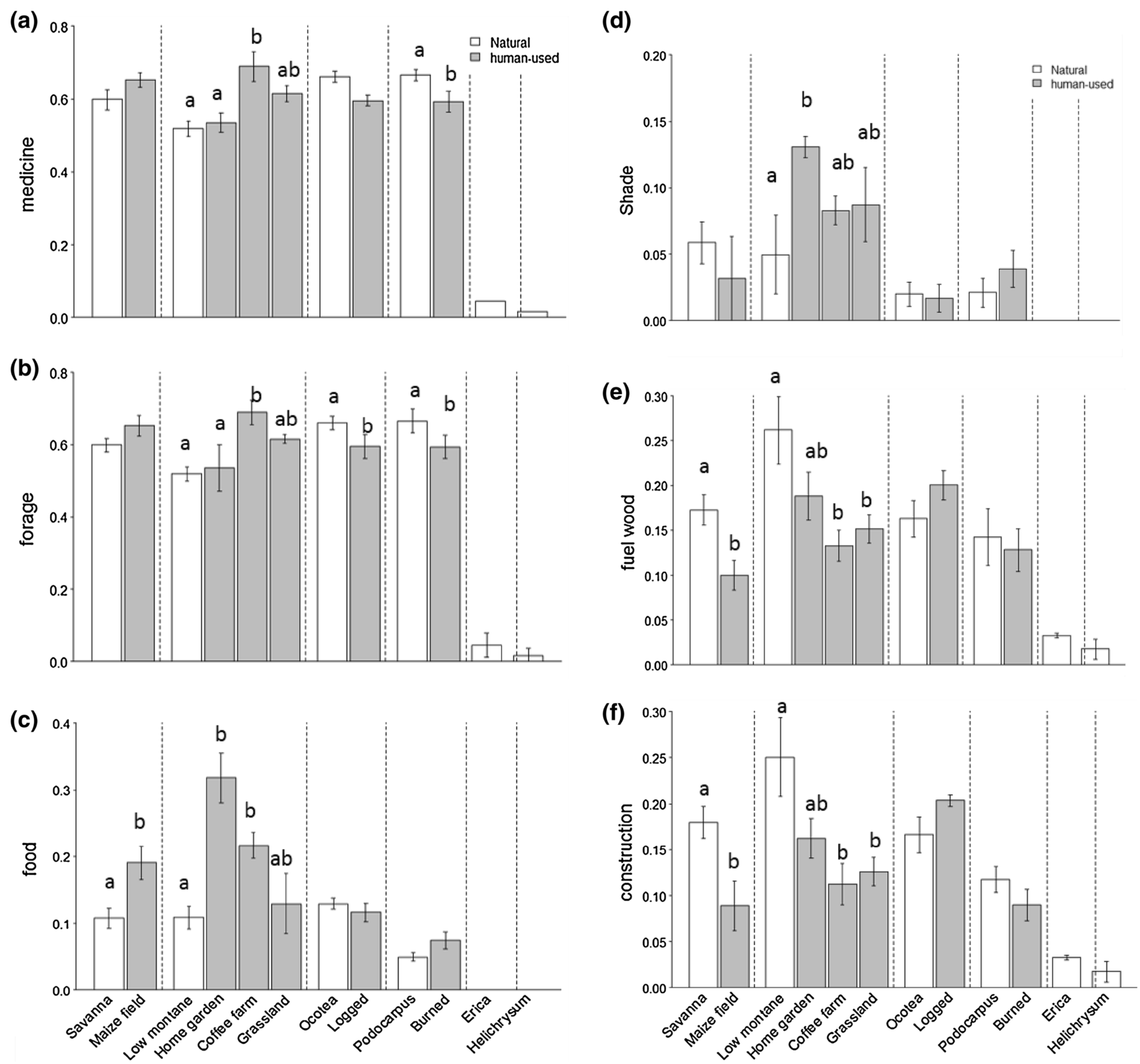

Fig. 4 ANOVA results. The mean proportion of used plant species (%) for each of the 12 habitat types studied at Mt. Kilimanjaro (savanna vs. maize fields, lower montane forests vs. home gardens vs. coffee farms vs. grassland, natural vs. previously selectively logged *Ocotea* forests, and natural vs. previously burned *Podocarpus* forests). *Bars* indicate means (±SE) for the six natural (*white bars*) and the six human-used habitat types (*grey bars*). *Dashed lines* separate different elevation belts. *Bars not sharing a character* are significantly different at $P < 0.05$. The usage categories are: **a** traditional medicines, **b** cattle forage, **c** food, **d** shading and ornamental plants, **e** fuel wood, **f** construction. In the *Erica* and *Helichrysum* zones, only undisturbed natural vegetation was studied

plants constitute an important alternative to conventional medicine, especially for communities in rural areas (Kareru et al. 2008; Andriamparany et al. 2014). All over the world, indigenous people discovered and developed the medicinal uses of native plants, whereas, about 65–80% of the population of the world depends on traditional medicine, mostly herbal remedies for their primary health care needs (WHO 1991; Simbo 2010). The African continent has a long history with the use of wild plants and in some African countries up to 90% of the population relies on medicinal plants as a source of drugs (Hostettmann et al. 2000). Common disorders and diseases treated with herbal medicines prepared from wild plants at Mt. Kilimanjaro include gastrointestinal tract problems, persistent coughs, wounds, dental problems and veterinary problems of both livestock and chicken (Hemp 1999; Misana et al. 2003).

As already mentioned by Hemp (1999) the second largest usage group on Kilimanjaro is for cattle forage (57.5%). The

Table 3 ANOVA summaries of comparisons of the proportions of used plant species between natural and human-impacted habitat types in the lower four elevational zones of Mount Kilimanjaro

Usage	Colline zone			Lower montane zone			Middle montane zone			Upper montane zone		
	df	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*	*df*	*F*	*P*
Medicinal	1; 6	0.01	0.9	1;19	10	**0.005**	1; 8	0.19	0.66	1; 8	14	**0.005**
Forage	1; 6	3.2	0.1	1;19	2.6	0.12	1; 8	9.9	**0.01**	1; 8	12	**0.007**
Fuel wood	1; 6	8.3	**0.02**	1;19	10	**0.005**	1; 8	0.9	0.3	1; 8	1	0.34
Construction	1; 6	8.3	**0.02**	1;19	11.9	**0.002**	1; 8	1.2	0.3	1; 8	4.9	**0.05**
Food	1; 6	11.5	**0.04**	1;19	6.3	**0.02**	1; 8	2.5	0.14	1; 8	0.9	0.3
Shade and ornamental use	1; 6	0.6	0.4	1;19	6.3	**0.02**	1; 8	0.07	0.7	1; 8	0.5	0.5

Colline zone: natural savanna woodlands vs. maize fields; lower montane zone: natural lower montane forests vs. home gardens, vs. coffee farms, vs. grass lands; middle montane zone: natural vs. previously selectively logged *Ocotea* forests; upper montane zone: natural vs. previously burned *Podocarpus* forests. In the subalpine and alpine zones, only undisturbed natural vegetation was studied. Significant differences are shown in bold

commonly domesticated animals are cows, goats, sheep, pigs, chicken and rabbits. Another usage category was wood fuel, either as firewood or charcoal (19.9%). The demand for fuel from plant material for cooking and heating has been raised by the increases in the price and inadequate supply of liquefied gas and electricity (Winter 2009). People enter the natural lower montane forest to collect dead branches of trees and shrubs for firewood.

Another usage category was wild food plants; these are those plant species with edible parts which are found in natural forests and woodlands, in the forest like home gardens and on farm fallows. Local communities have utilized indigenous plants for food as an important option during famine and maintenance of nutritional balance in local diets (Ruffo et al. 2002; Ndangalasi et al. 2007). Fresh or dried leaves of some species (e.g. *Launea cornuta*, *Galinsoga parviflora* and *Vigna unguiculata* are eaten and fruits of *Sclerocarya birrea* are also edible. Moreover, roots and tubers of *Dioscorea bulbifera* were reported to be highly valued food among the Chagga people. The extract from the bark of *Albizia schimperiana* and *Rauvolfia caffra*, the common trees in the home gardens, are added to a traditional Chagga banana beer to increase flavour and alcohol content (Hemp and Hemp 2009).

18.3% of useful species were used for construction and making tools. Species such as *Pauridiantha paucinervis*, *Olea capensis*, *Macaranga kilimandscharica*, *Cyathea manniana* and *Dracaena fragrans* were used to erect traditional Chagga huts (Hemp and Hemp 2009). Material from *Cymbopogon caesius, Themeda triandra, Cyperus* ssp. and banana leaves were used for roofing. Making wooden cups, spoons, bowls and digging tools is a common practice among the Chagga (Winter 2009). Until now trees or shrubs are used as the main source of building material. Indigenous trees and shrubs are also used by Chagga people as boundary markers, ornamentals and wind breakers and to provide shading around homesteads. Trees such as *Albizia schimperiana*, *Rauvolfia caffra* and the beautiful flowering *Cordia africana* are good shade species and ornamentals on coffee farms and at homesteads. Overall, 6.7% of the useful plant species served for shading and as ornamental plants in coffee farms and homestead.

Occurrence of usable plants with elevation at Mount Kilimanjaro

As on Mt. Kinabalu (Salick et al. 1999) we found a strong correlation between useful plants and biodiversity (Fig. 1). However, the proportion of useful species varied strongly along elevation in contrast to the findings of Salick et al. (1999), who found no major variation. Our findings are also different from Lyaruu (2002), who detected a decreasing trend with elevation on Kilimanjaro. In our study, the proportion of useful species was highest between 1000 and 2800 m asl for all categories, but decreased higher up in a linear or quadratic manner (Figs. 2, 3). This supports and extends previous findings regarding the diversity of medicinal and forage plant species at Mount Kilimanjaro (Hemp 1999, Misana et al. 2003; Hemp and Hemp 2009). The observed quadratic hump-shaped pattern around 1000–2800 m asl (Fig. 2) suggests that vegetation zones at this elevation have a relatively high diversity of useful plant species. However, the Chagga formerly avoided these elevations much higher than their settlements, which are situated up to 1700 m, because they were difficult to reach. Therefore, their knowledge of the highland flora is probably more limited than that of the lowland flora. More recently, activities in the forest belt were additionally restricted with the establishment of the National Park, which ranges down to about 1700 m, possibly further reducing future traditional knowledge on usable plants. Nevertheless, in addition to illegal logging activities and poaching in the protected forests of Kilimanjaro (Lambrechts et al. 2002, Strangeland et al. 2008), also collecting of useful plants still plays an important role up to 2800 m (Figs. 2, 3).

Generally, since savanna forms 40% of Africa's land surface, it is of great importance for livelihood and the main source of useful species for African people (Blösch 2008). The comparatively low importance of the savanna foothills of Kilimanjaro in their knowledge of useful plants might be partly due to the fact that the Chagga are mountain people originally cultivating and living in (sub) montane (forest) environments, avoiding the lowlands for different reasons (e.g. in fear of the Massai, Hemp 1999; Winter 2009). This limited knowledge of traditional plant uses is further decreasing since natural savanna woodlands have become very rare, because it is the most rapidly declining land cover type at the mountain (Hemp 2006c). It is expected to disappear in the near future due to rapid increase in population growth which demands land for agricultural and settlements and construction and fuel wood material from the wild. According to the 2012 National Census, the Kilimanjaro region is one of the regions with the highest population increases in Tanzania (National Bureau of Statistics 2013).

Plots with the highest diversity of usable plants are highly structured, multilayered montane forests. These forests consist of several distinct layers with different niches, life forms and functional groups such as herbs, shrubs, trees, epiphytes and lianas and are also very rich in the numbers of species. These functionally very different groups provide a huge source of different usage types, e.g. different kinds of building material such as poles, lianas (for ropes), hollow trunks as beehives, sticky latex as glue, manufacturing of fibres and fodder (Hermansen et al. 2008). However, it is noteworthy to mention that the share as well as the absolute number of medicinal plants is still highest in the savanna plots (Fig. 3b, Online Resource 2a). This agrees with findings of Hemp (1999) but stays in contrast to observations by Strangeland (2008), who found that in Tanzania most of the medicinal plants occurred in the moist forests, including lowland woodlands, thickets and grasslands. A possible explanation could be that plant species have a higher content of phytochemicals (secondary plant substances) in warmer climates (Frohne and Fensen 1998).

Occurrence of usable plants in human-disturbed compared to natural habitats

Increased diversity of species for construction and fuel usage in natural habitats of the lower zones (Fig. 4e, f) is probably due to the presence of hardwood shrubs and trees of *Acacia*, *Balanites*, *Combretum*, *Lannea* and *Terminalia* species in savanna woodlands and *Syzygium guineense*, *Olea capensis* and *Ilex mitis* in lower montane forests which are preferred for construction and charcoaling. In disturbed habitats of these zones this usage category is represented by fewer species, most likely because the respective species were already erased due to overexploitation. The diversity of edible plants was increased in maize field suggesting that, together with the crops grown for food, annual herbaceous weed species, many of them being introduced species, are also used for food. For instance, leaves of *Bidens pilosa*, *Trichodesma zeylanicum* and *Solanum nigrum* are eaten as vegetables (Fig. 4c). In contrast to a previous study by Lyaruu (2002) at Kilimanjaro who found that natural savanna had significantly higher diversity of medicinal plant species than human-used savanna, we could not find significant differences in species used for medicines, forage, shade and as ornamental plants between maize fields and natural savanna habitats (Fig. 4a, b, d). The reason could be that we revisited our plots during several seasons to record the full array of species; in particular, after harvest during the dry season the maize fields are nearly completely bare of their (mainly annual) weeds.

The proportion of useful plants in the lower montane zone, except for the category of fuel wood and construction, was generally higher in human-used habitats than in natural habitats (Fig. 4a–d). This suggests that the managed home gardens and coffee farms include in addition to crops and fruits many wild species, which are suitable for human daily use such as food, medicines and forage. Our results are in agreement with other studies which found that managed habitats such as home gardens and coffee farms are a strategic and ideal farming system for conservation, production and enrichment of useful plant species (Fernandes et al. 1984; Hemp and Hemp 2008; Winter 2009).

In the *Ocotea* zone, there was generally no significant difference in proportion of useful species between the selectively logged and undisturbed *Ocotea* forest except for forage category which was higher in the natural forest. Selective logging of *Ocotea* forest has resulted in particular on the (south) eastern slope of Kilimanjaro in forests free of *Ocotea* trees but otherwise with the same species composition (Hemp 2006b, c). On the central southern slope *Ocotea* trees were able to recover after selective logging which occurred 30–40 years ago (Rutten et al. 2015a). In a parallel study, using the same study plots, the natural and the previously selectively logged forests were also similar in biomass (Ensslin et al. 2015) and vegetation structure (Rutten et al. 2015b). The lower share of medicine and forage usage categories (Fig. 4a, b) in burnt compared to unburnt *Podocarpus* forest could be related to the significant change in species composition due to fire (Hemp 2005).

Conclusion

The Chagga make use of their plant environment in a great variety of ways. In our study plots, we investigated one-third of the 3000 vascular plant species of Kilimanjaro. We found that more than half of them are useful in many respects of human life. The proportion of useful species did not linearly decrease with elevation, but varied strongly over elevation peaking in mid elevations. The highly structured, multilayered montane forest was the main source of most traditionally useful species. Therefore, this vegetation belt is most important for Kilimanjaro not only from an ecological, but also from a cultural perspective. However, since the montane forest was included into the National Park in 2005, most of the traditional uses are not permitted anymore. Since also the so-called half-mile forest strip, a kind of buffer zone between natural forest and cultivation, managed formerly by the local communities, was incorporated into the National Park, conflicts of interest are inevitable. As we showed, not only natural, but also managed habitats maintain a high diversity of useful wild plants species at Kilimanjaro and could at least partly fill this gap. In any case, given the high proportions of useful species we conclude that preserving the biodiversity of Kilimanjaro ecosystems is indispensable for maintaining the diversity of useful plant species for the local people who rely on it for food and sustainable access to medicinal, fuel, construction and forage material.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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