Salamula et al. Pastoralism: Research, Policy and Practice (2017) 7:8
DOI 10.1186/s13570-017-0080-6

Pastoralism: Research, Policy and Practice

RESEARCH Open Access

Camel forage variety in the Karamoja sub-region, Uganda

Jenipher Biira Salamula[1*], Anthony Egeru[1,2], Daniel Knox Aleper[3] and Justine Jumba Namaalwa[1]

Abstract

Camels have the potential to increase the resilience of pastoral communities to the impacts of climate variability and change. Despite this potential, there is limited documentation of the camel forage species, their availability and distribution. The study was conducted in Karamoja sub-region in Uganda and involved assessment of vegetation with intent to characterize the range of forage species available for camels in the region. The camel grazing area was stratified based on land cover types, namely woodland, bushland, grassland and farmland using the Amudat and Moroto district vegetation maps. Vegetation plots measuring 20 m × 20 m were mapped out among the land cover types where species identification was undertaken. In addition, a cross-sectional survey involving 52 camel herders was used to document the camel forage species preferences. Shannon and Simpson diversity indices as well as the Jaccard coefficient were used to measure the species richness, relative abundance, diversity and plant community similarities among the land cover types. Results showed high species richness and diversities in the bushland and woodland land cover types. Plant communities in the woodland and bushlands were found to be more similar. A wide range of plant species were reported to be preferred by camels in the study area, that is 63 in Amudat and 50 in Moroto districts. respectively, with *Balanites*, *Euphorbia* and several *Acacia* species taking precedence. Therefore, given the diversity of camel forage species, this study recommends increased adoption of camel rearing in Karamoja sub-region. Further, the camel owners are encouraged to undertake conservation management and deliberate production of preferred forage species such as *Euphorbia tirucalli* that also exhibit ease of propagation and adaptability to the sub-region. This browse could support the milking herd and the camel calves that remain at the homesteads. A toxicological analysis of *E. tirucalli* is however recommended, given irritant latex discharge, prior to taking this recommendation to scale.

Keywords: Camels, Forage, Karamoja, Diversity, Land cover types

Introduction

Camels (*Camelus dromedarius*) as drought-resistant livestock species have become an important facet in the economy, ecology and culture of pastoralists, particularly under current climate variability and environmental change (Hesse and Cotula 2006; Krätli et al. 2013; Megersa et al. 2014b). Prolonged drought spells in many arid and semi-arid areas have heightened the importance of camel rearing among several pastoral groupings in these regions (Evans et al. 1995). Camels, unlike other livestock species, are uniquely adapted to hot and arid environments that are unsuitable for crop production, thus contributing significantly to the food security of pastoral households (Ahmad et al. 2010). This is because they are reliable milk producers during dry seasons when other livestock species such as cattle, sheep and goats have lower milk production levels (Farah 2004). Camels have thus shown enormous potential to enhance the livelihoods and build the resilience of pastoral communities to impacts of climate variability and change. For example, among both the transhumant and semi-transhumant communities such as the Samburu, Rendille, Borana and Somali of eastern Africa, camels have played a pivotal buffering role in safeguarding livelihoods against intermittent drought periods (Belay et al. 2005; Elhadi et al. 2015; Flintan et al. 2011; Tangus et al. 2004). This explains the observed recent transitions to camel rearing in the east African region (Schwartz et al.

* Correspondence: biirajenipher@gmail.com
[1]School of Forestry, Environmental and Geographical Science, Makerere University, Kampala, Uganda
Full list of author information is available at the end of the article

© The Author(s). 2017 **Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

2012) as communities such as the Karrayyuus in Ethiopia and Borana, Samburu and Masaai that were traditionally cattle rearing have adopted camel production (Amante 2014; Kagunyu and Wanjohi 2014; Schwartz et al. 2012).

The extent to which camels have proven to be a buffer has led to camel husbandry in the recent past to thrive as an adaptation strategy in response to ecological and climatic change (Amante 2014). Climate variability and change continuously threaten the productivity of traditional livestock systems in arid and semi-arid environments through their impacts on pasture production, water availability, herd size and productivity, disease risks and thermal stresses (Megersa et al. 2014a; Thornton et al. 2009). The level of variability orchestrated by climate change has had debilitating impacts on livestock herds, and for that reason, the role of camels in enhancing ecological resilience has become more profound, given their exceptional biological and physiological adaptations (Awoke et al. 2015; Kagunyu and Wanjohi 2014).

Based on the role camels play in pastoral livelihoods, their dietary requirements cannot be ignored. The nutritional requirements of camels impact on their meat and milk production and their performance as resilient animals. Camels are, by preference, browsers of a broad spectrum of forage plants including trees, shrubs and hard-thorny, bitter and halophytic (salty) plants that grow naturally in the desert and other semi-arid areas (Dokata 2014). Further, camel diets also include herbs, forbs and grasses (Dorges and Heucke 2003; Iqbal and Khan 2001). More often than not, camels tend to be selective in their diet during the wet season when forage is plentiful (Amin et al. 2011) but become indiscriminate in their forage choices during the dry seasons (Amin et al. 2011; McLeod and Pople 2008) due to forage scarcity. Under natural conditions, camels take the largest percentage of their diet from forage trees than grasses (Abukashawa et al. 2016; Laudadio et al. 2009). These woody plants are mildly affected by seasonal variations, due to their extensive and deep root system and longer life spans (Abel at al. 1997) and are consequently available all year round. They often bear green foliage even in the dry season, and/or highly nutritious flowers and fruits are available (Schwartz et al. 2012).

The camel forage preferences and nutritive value of consumed forages have been studied in different parts of the world. For instance, in northern Ethiopia, *Opuntia sp.*, *Acacia brevispica* and *Becium* species were reported as the most preferred species by both calves and mature camels (Chimsa et al. 2013; Dereje and Udén 2005). According to Schwartz et al. (2012), *Cadaba farinosa*, *Indigofera spinosa*, *Vernonia cinerascens*, *Maerua crassifolia* and *Acacia tortilis* dominated the diet of camels in Isiolo District, Kenya. This was similarly observed in the Jijiga district, eastern Ethiopia (Desalegn and Mohammed (2012). Meanwhile, Kagunyu and Wanjohi (2015) reported that *Euphorbia tirucalli* had emerged as an important drought forage for camels among the Borana of northern Kenya.

Like other livestock, pasture preference in camels depends on the species present in the range, amount of forage available and the nutritional quality of the plant (Shaheen 2009). Additionally, the physical environment, plant environment and animal behaviour all interact to influence selection process during grazing (Iqbal and Khan 2001). Environmental and anthropogenic factors influence the composition and structure of grazing land (Gwali et al. 2010) and thus affect the availability of forage for the livestock species. Moreover, information on forage preference, behavioural activities and availability and quality of forage are important in understanding the camel forage relationship, proper camel husbandry and ensuring sustainable forage as well as landscape management in the semi-arid areas.

Understanding the camel forage array is of utmost importance for the growing sphere of camel herders in Karamoja. A few forage assessments (Egeru et al. 2015b; Gradé 2008) have been done in the sub-region with a broad spectrum for all livestock species. Earlier recommendations by Mukasa-Mugerwa (1981) to undertake research on browse forage for camels, since these were going to become livestock of importance in the region, have never received any further attention. This study therefore focused on identifying camel forage species, their relative abundance and diversity by land cover type in the semi-arid Karamoja sub-region, Uganda.

Study area

The study was conducted in Moroto and Amudat districts of the Karamoja region. Karamoja lies between latitudes 1° 30′ and 4° N, and longitudes 33° 30′ and 35° E in north-eastern Uganda. The region borders Sudan to the north and Kenya to the east (Egeru et al. 2015b). Karamoja experiences a semi-arid type of climate with sporadic uni-modal rainfall patterns experienced between May and August and an intensely hot dry season occurring from November to March (BakamaNume 2010). Rainfall in the sub-region ranges between 350 and 1000 mm per annum, and is variable in space and time (Nalule 2010); this annual total rainfall makes the region characterized as a sub-humid system. The temperatures in the region are high, ranging from a maximum of 28 to 32.5 °C to an average minimum of between 15 and 18 °C (Mubiru 2010). Further, the sub-region has suffered climate variations manifested in extended dry spells, cyclic droughts and erratic rainfall patterns which have affected crop and livestock production. The vegetation is dominated by indigenous tropical grasses, and the overstorey is mostly composed of *Acacia* species (Egeru et al. 2014; Nalule 2010). The livestock population in the region was estimated to be 2,253,960 cattle, 2,025,293 goats, 1,685,500 sheep, 960 donkeys and 32,870 camels according to the 2008 national livestock census (MAAIF and UBOS 2009). Amudat and Moroto districts were purposively selected because they have the highest number of camels in Karamoja sub-region (MAAIF and UBOS 2009).

Methods

The study utilized both bio-physical vegetation assessments and social research approaches. Vegetation assessment was intended to characterize the foraging range for the camels. A multi-stage sampling procedure was used. In the first stage, in each district, one sub-county was selected and further stratified based on the land cover types of bushland, woodland, farmland and grassland. A grid of 1 × 1 km was laid on the district map in order to facilitate systematic sampling within the different strata. At every point of intersection, a cluster of five sampling points was systematically laid out at an interval of 100 m apart distributed in the four cardinal points of the intersection (Figure 1). Sample clusters lying in the preferred vegetation strata were purposively selected based on accessibility.

Three plots were randomly selected from each cluster for assessment. A sampling intensity of 0.01% was adopted as recommended by Malimbwi and Mugasha (2002) and Malimbwi et al. (2005). The number of plots assessed per vegetation strata varied depending on the area size of the strata and relevancy to camel foraging. A total of 46, 10, 6 and 5 plots were assessed in the bushland, woodland, farmland and grassland strata respectively. A Global Positioning System (GPS) was used to capture spatial information for each plot, and in each plot, all the tree and shrub species were enumerated. Information on camel forage preferences was gathered through a cross-sectional survey by way of guided interviews among 52 camel herders selected through a snowball sampling approach.

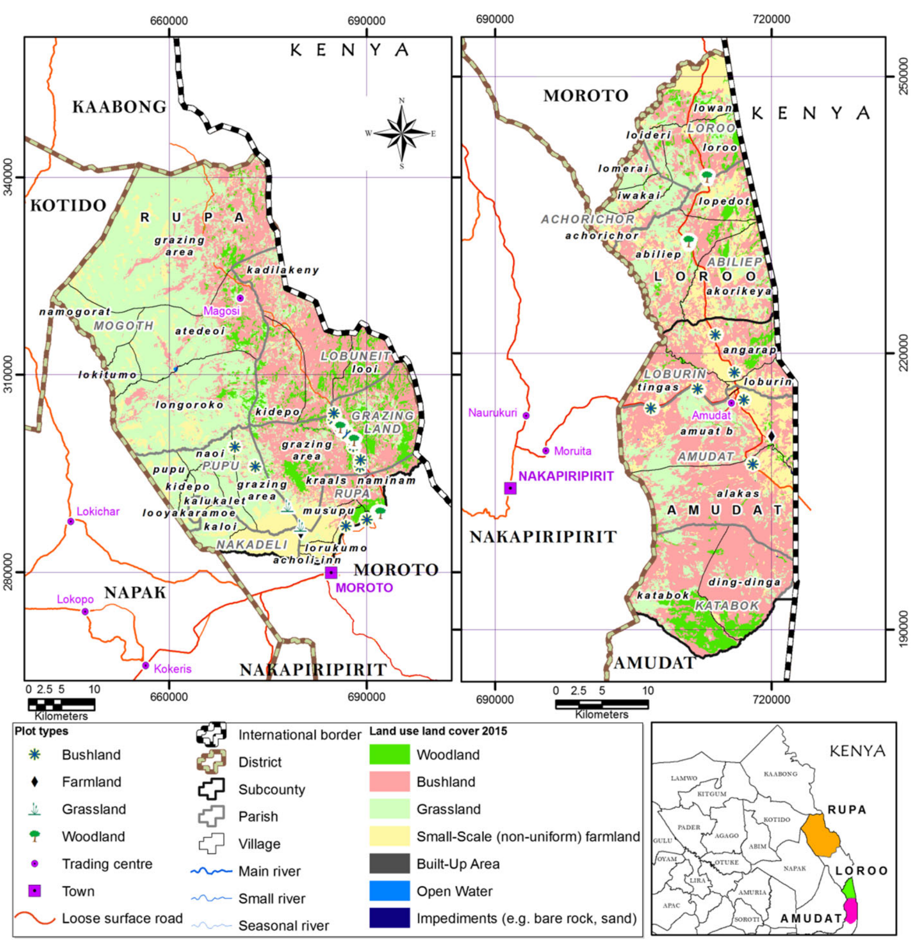

Figure 1 Map showing sampling points in Moroto district (*left*) and Amudat district (*right*)

Data analysis

Descriptive statistics were used to summarize the data on the camel forage preference, relative abundance and species richness. Kindt and Coe (2005) observed that one diversity index does not provide sufficient information to order sites from high to low diversity; consequently, both Shannon and Simpson indices were used to compare the plant diversity across the different land cover types and between districts. The inverse of the Simpson dominance (d_s) was preferred to the Simpson diversity index (D_s) for the analysis given that the latter provides a good estimate of diversity at relatively small sample sizes (Magurran 2004). The formula used was $d_s = 1 - \frac{\sum n_i(n_i-1)}{N(N-1)}$, where, n_i is the abundance of species i and N is the number of all species.

The value of this index ranges between 0 and 1, and the greater the value, the greater the species diversity.

The Shannon index assumes that individuals are randomly sampled from an infinitely large sample community and that all species are represented in the sample (Magurran 2004). The Shannon index was calculated from

$$H' = -\sum p_i \log p_i$$

where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N). The greater the value of the index, the more diverse the community is.

Species compositional similarities among the land cover types and between the two districts were estimated using the Jaccard similarity index. The Jaccard similarity index uses species presence/absence data for two sample sets (in this case, land cover types and the districts) and is calculated as $J = M/(M + N)$, where M is the number of species that occurs in both vegetation types and districts and N is the number of species that occurs in only one of the vegetation types and districts (Asase et al. 2010). Community Analysis Package (CAP-4.1.3) and Species Diversity and Richness (SDR-4.1.2) software were used for diversity analysis. The translation of local species names to scientific names was done with the help of lists generated by Egeru (2014) and Gradé (2008).

Results

Woody species richness in the camel grazing sites

Thirty-eight camel forage species distributed in 20 families were recorded in the study sites. Of these, 28 and 31 camel forage species were recorded in Amudat and Moroto districts respectively. Mimosaceae, Anacardiaceae, Celastraceae and Euphorbiaceae were the most dominant plant families in the study sites (Figure 2). Further, there were differences in species richness across the land cover types. For example, in Amudat, 24 species were recorded in the bushland, 14 in the woodland and 1 species in the farmland. On the other hand, 26, 16, 10 and 3 species were recorded in the bushland, woodland, grassland and farmlands of Moroto district respectively (Figure 3). There was a significant difference in the species richness among the land cover types ($P = 0.011$); however, there was no significant variation ($P = 0.614$) in the species richness between the districts.

The most common species in the two districts included the following: *Acacia brevispica*, *Acacia nilotica*, *Acacia senegal*, *Acacia seyal*, *Acacia tortilis* and *Acacia sieberiana*; *Balanites rotundifolia*, *Opuntia cochenillifera*, *Commiphora africana*, *Dichrostachys cinerea*, *Euphorbia candelabrum*, *Grewia mollis*, *Maytenus undata*, *Rhus natalensis* and *Terminalia brownii*; and *Zanthoxylum chalybeum*, *Rhus vulgaris* and *Lannea* species.

Unique to Amudat district were species such as *Ficus sur*, *Acacia drepanolobium*, *Acalypha fruticosa* and

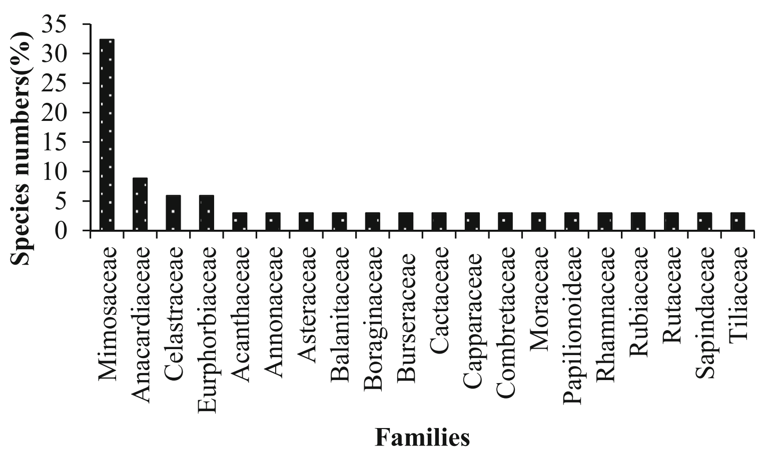

Figure 2 Plant families in the study sites

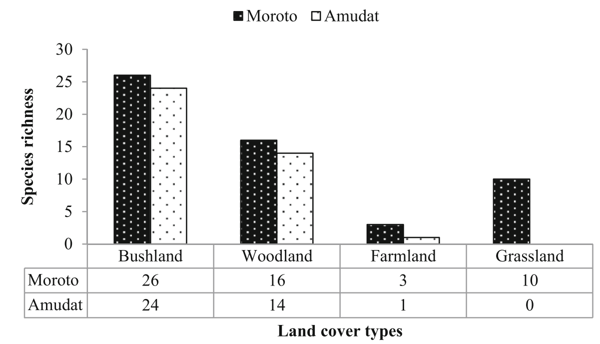

Figure 3 Species richness in the land cover types

Ziziphus abyssinica while *Gymnosporia gracilipes*, *Cadaba farinosa*, *Acacia hockii*, *Annona senegalensis*, *Allophylus africanus*, *Barleria acanthoides* and *Gardenia ternifolia* were unique to Moroto district.

Relative abundance of woody species among the land cover types

The disaggregated results by land cover types that *Grewia mollis*, *Euphorbia candelabrum* and *Acacia brevispica* were the most abundant camel forage species in the bushland, woodland and grasslands of Moroto district respectively (Table 1). Meanwhile, in Amudat district, *Acacia brevispica*, *Grewia mollis*, *Rhus vulgaris* and *Acacia nilotica* were the most abundant camel forage species among the land cover types (Table 2).

Diversity and plant composition similarity in the camel grazing sites

The diversity indices revealed high species diversities in the bushlands and woodlands of both districts, with the least diversity observed in the farmlands (Table 3). Species compositional similarity statistics showed that the plant community in the bushland of Moroto was found to be relatively similar to that in the woodland of Moroto (Jaccard index = 0.466667) (Table 4). The plant community in the woodland of Amudat was found to be similar to that in the bushland and woodland of Moroto (Jaccard index = 0.448276 and 0.428571 respectively). The plant community in the bushland of Amudat was also found to be similar to that in the bushland of Moroto and the woodlands of Amudat and Moroto (Jaccard index = 0.447368, 0.366667 and 0.34375 respectively). The farmland of Amudat was found to have least similarity to all the habitats followed by the farmland of Moroto.

Table 2 Relative abundance of wood species among land cover types of Amudat district

Bushland		Farmland		Woodland	
Species	%	Species	%	Species	%
Acacia brevispica	28.86	*Ficus sur*	100	*Rhus vulgaris*	20.45
Grewia mollis	14.68			*Acacia nilotica*	13.64
Rhus vulgaris	11.94			*Acacia senegal*	11.36
Lannea barteri	9.95			*Grewia mollis*	11.36
Maytenus undata	8.21			*Acacia brevispica*	9.09
Dichrostachys cinerea	5.72			*Maytenus undata*	9.09
Rhus natalensis	3.73			*Terminalia brownii*	6.82
Acacia nilotica	1.99			*Dichrostachys cinerea*	4.55
Balanites rotundifolia	1.74			*Acacia gerrardii*	2.27
Commiphora Africana	1.74			*Acacia seyal*	2.27
Others (*n* = 14)				Others (*n* = 4)	

Camel forage preference

The most common forage species reported by pastoralists as preferred by camels in Moroto included *Balanites*

Table 1 Relative abundance of wood species among land cover types of Moroto district

Bushland		Woodland		Grassland		Farmland	
Species	%	Species	%	Species	%	Species	%
Grewia mollis	20.6	*Euphorbia candelabrum*	26.1	*Acacia nilotica*	30.0	*Acacia tortilis*	55.6
Acacia brevispica	18.7	*Opuntia cochenillifera*	17.6	*Ormocarpum trichocarpum*	18.0	*Acacia seyal*	33.3
Gymnosporia gracilipes	13.0	*Acacia brevispica*	13.6	*Euphorbia candelabrum*	14.0	*Balanites rotundifolia*	11.1
Euphorbia candelabrum	9.6	*Grewia mollis*	10.9	*Gymnosporia gracilipes*	12.0		
Maytenus undata	8.4	*Gymnosporia gracilipes*	10.5	*Cadaba farinosa*	10.0		
Balanites rotundifolia	7.1	*Rhus vulgaris*	6.1	*Acacia tortilis*	6.0		
Rhus vulgaris	6.3	*Maytenus undata*	5.8	*Balanites rotundifolia*	4.0		
Acacia nilotica	4.8	*Acacia seyal*	2.0	*Acacia senegal*	2.0		
Rhus natalensis	1.7	*Rhus natalensis*	1.7	*Barleria acanthoides*	2.0		
Acacia hockii	1.1	Others (*n* = 7)		*Grewia mollis*	2.0		
Others (*n* = 16)							

Table 3 Diversity of wood species among the land cover types

District	Vegetation strata	Shannon index	Simpson dominance index
Amudat	Bushland	2.357	0.85939
	Farmland	0	0
	Woodland	2.366	0.908034
Moroto	Bushland	2.404	0.87686
	Farmland	0.9369	0.63889
	Grassland	1.962	0.84408
	Woodland	2.152	0.85403

aegyptiaca, *Euphorbia tirucalli*, *Barleria acanthoides* and *Grewia mollis* (Table 4). In Amudat, *Cadaba farinosa*, *Rhus kwangoensis*, *Acacia* species and *Balanites aegyptiaca* were reported as most preferred by the camels (Table 5).

Discussion

Richness and diversity of woody camel forage species

The study revealed the existence of a significant variety of browse species in the camel grazing sites. Both Moroto and Amudat districts were rich in browse species with the species richness being more-or-less similar between the districts. In Moroto, the richness in woody species was related to the cultural and spiritual values attributed to these species by pastoralists. Traditional shrines in Moroto prohibit tree cutting since trees are believed to be dwelling places for gods (Aleper and Lotyang 2006). The richness of woody plants in Amudat could on the other hand be attributed to the fact that their elders strongly advise against tree cutting. This district is also inhabited by the Pokot, originally from Kenya, who rear camels. The Pokot attach great value to trees, which they use for fodder, food, medicine, shade and as meeting points for elders (Barrow 1988). The sanctions against tree cutting could be to protect the trees that are used as browse by the camels. It was observed in Amudat that a small portion of land is cleared within the vegetation, when setting up homesteads leaving the rest of the environment intact. The homesteads are also sparsely distributed within the landscape as expected of pastoral groupings and settlement patterns.

The inventory of woody flora also revealed variation in richness and diversity across land cover types. A study by Egeru et al. (2015b) similarly reported a high species richness and diversity in Karamoja sub-region. Higher richness and diversity of browse species were recorded in the bushland and woodland land cover types of both districts in comparison to the other land cover types. The differences could be due to varied micro-site factors, namely micro-climate, soil properties, elevation and nutrients, which could be more favourable for woody species growth in the bushland and woodland land cover types. This could be through an effect on regeneration, germination, seed production and phenological events of these plant species. Spatial and environmental heterogeneity govern species richness-diversity gradients (Egeru et al. 2015a; Stein et al. 2014). Human activities, namely tree clearance by pastoralists in a bid to expand cropping land as well as bush burning in grasslands to allow for nutritious grasses to grow for the benefit of the

Table 4 Perceived camel forage preference in Moroto district

Scientific names[a]	Family[a]	Vernacular name	% preference	Growth form[a]
Balanites aegyptiaca	Balanitaceae	Ekorete	84	Tree
Euphorbia tirucalli	Eurphorbiaceae	Eligoi/Ekilala	64	Tree
Barleria acanthoides	Acanthaceae	Emekui	60	Shrub
Grewia mollis	Tiliaceae	Ekaliye	56	Shrub
Ipomoea kituensis	Convolvulaceae	Eliaro	56	Climber
Acacia spirocarpa	Mimosaceae	Etirir	52	Tree
Rhus kwangoensis	Anacardiaceae	Ekurr	48	Tree
Opuntia cochenillifera	Cactaceae	Edapal	40	Shrub
Cadaba farinosa	Capparaceae	Erereng	40	Shrub
Capparis sp.	Capparidaceae	Echogorom	36	Tree
Acacia mellifera	Mimosaceae	Eregai	36	Tree
Capparis tomentosa	Capparidaceae	Erogorogoete	24	Tree
Capparis fascicularis	Capparidaceae	Ekadelaie	20	Shrub
Acacia nilotica	Mimosaceae	Ekapalimen	20	Tree
Melia azedarach	Meliaceae	Elira	16	Tree
Aspilia mossambicensis	Asteraceae	Ekuyon	16	Shrub

[a]Egeru 2014; Gradé 2008; Katende et al. 1995

Table 5 Perceived camel forage preference in Amudat district

Scientific names[a]	Family[a]	Vernacular names	% preference	Growth form[a]
Cadaba farinosa	Capparaceae	Tugwo	78	Shrub
Rhus kwangoensis	Anacardiaceae	Akurion	59	Tree
		Amongo	44	
Acacia reficiens	Mimosaceae	Panyirit	44	Shrub/tree
Acacia brevispica	Mimosaceae	Kiptari	41	Shrub/tree
Balanites aegyptiaca	Mimosaceae	Akorete/Tuyunwo	33	Tree
		Awapet	30	
Opuntia cochenillifera	Cactaceae	Adapale	26	Shrub
Barleria acanthoides	Acanthaceae	Kelkelyan	26	Shrub
		Pokot	26	
Maerua angolensis	Capparaceae	Sarachan	26	Tree
Acacia tortilis	Mimosaceae	Ses	26	Tree
Grewia bicolor	Tiliaceae	Sitet	26	Shrub/tree
Zanthoxylum chalybeum	Rutaceae	Songowo	26	Shrub/tree
		Mosolen	22	
Grewia tenax	Tiliaceae	Taran	22	Shrub

[a]Katende et al. 1995; Timberlake 1994; Wigrup 2005

grazing animals, could explain the scarcity of woody species in the farmlands and grasslands of Amudat and Moroto districts. Fire is a traditional tool for prevention of bush encroachment and obtaining an early flush of grass growth (McGahey et al. 2008; Turner 1967). According to Egeru et al. (2014), a rapid increase in croplands in the Karamoja sub-region has been observed over the last decade arising from the 'chlorophyll syndrome' - a perception that crop cultivation in the region will assure the Karimojong food security. However, the existence of high diversity and richness of woody species in woodland and bushland land cover types is indicative of how favourable the region is for camel rearing. Camels are predominantly browsers whose forage consists mainly of shrubs, bushes and trees (Iqbal and Khan 2001; Laudadio et al. 2009). Camels are known to prefer the bushland and woodland land cover types because of their shade provision during hot months and their constant rich and varied food supply all year round (Dorges and Heucke 1995, 2003). This implies that camels could have adequate forage even in the face of climate change and variability in Karamoja sub-region, which is often affected by extreme and unpredictable climatic events.

Relative abundance of woody camel forage species

The study revealed a variation in the relative abundance of woody species among the land cover types and across districts. The differences could be attributed to environmental/habitat factors. Variations in habitats are introduced by topography, geology, light intensity, temperature, edaphic factors, humidity and herbivory pressure (Bonkoungou 2001). These environmental gradients with their complex interactions influence the composition, structure, distribution and abundance of woody species (Tadesse et al. 2008). Also, human-induced factors such as selective tree cutting, expansion of farming land and induced fires could explain the difference in the relative abundances among the land cover types. The relative abundance was dominated by species, namely *A. brevispica*, *G. mollis*, *E. candelabrum*, *G. gracilipes* and *R. vulgaris*. These species could perhaps be among those that are least preferred by the locals as construction materials or firewood. However, some of these species such as *A. brevispica* are particularly known for invasive characteristics (Angassa and Oba 2008, 2010); as such, their high relative abundance could be arising from their rapid spread and colonizing effect on the landscapes in Karamoja sub-region. Further, Nalule (2010) has shown that the relative abundance of different tree species in Karamoja sub-region is related to preference by local communities so certain species dominate because they are less frequently harvested by local people. The dominance of these species in all the vegetation types could also be explained by the fact that as camels and other livestock graze, they transfer seeds of these plants from one grazing land cover to another, thus explaining why these species are common and dominant. These species could also be invasive in nature, thus out-competing other species. Studies by Egeru et al. (2014) and Nalule (2010) also reported these species as common in Karamoja sub-region. These species also feature among those that are preferred by camels as browse in southern Ethiopia (Tolera and Abebe 2007). Meanwhile, the limited relative abundance of species, such as *E. tirucalli*, could be a result of an unexpected foraging of the woody species, as this has emerged as dry season forage for camels (Kagunyu and Wanjohi 2015).

Similarity of plant community among land cover types

The plant communities were found to be more similar in the bushlands and woodlands of both Amudat and Moroto districts. These communities could have similar soil conditions, for instance soil texture, saturation, pH and organic matter. Camels are also known to prefer grazing in these two habitat types (Dorges and Heucke 1995, 2003). Thus, it can be argued that camels transfer species between and within the bushland and woodland land cover types as they browse, thereby creating a pool of similar plant species between them. However, the plant communities in the bushland and woodlands were found to be dissimilar to those in the farmlands and grasslands. The differences could be attributed to variations in disturbance levels, microclimate and edaphic factors as well as observed transitions in land use and cover in the region over the last three decades (Egeru et al. 2014). Land clearance for crop production has intensified, especially the production of sorghum, an adaptable staple that occupies 80% of the total cultivated land area in the sub-region. At 1500 kg/ha, sorghum yields are low (Levine 2010). Consequently, households expand land area in order to increase production. This practice has left huge tracts of land open without traditional trees and shrubs but also exposes these lands to rapidly multiplying tree species such as *Acacia oerfota* that quickly form bushlands once cultivated lands are abandoned and their productivity declines.

Camel forage species preference as revealed by pastoralists

A wide range of plant species were reported to be preferred by camels. Camels graze on a broad spectrum of plant species including those that are avoided by other domestic herbivores (El-Keblawy et al. 2009). This is because of their unique anatomical and digestive characteristics (Laudadio et al. 2009). These characteristics come as an adaptation to harsh environments to which camels have been accustomed.The majority of the species reported as preferred by camels were trees and shrubs. Camels' inclination towards these woody plants stems from their anatomical traits such as the mobile and prehensile split upper lips, the long tongue, the stretched neck and extended heads (Amin et al. 2011). These make them preferentially browsers than grazers. The woody plants are also less affected by inter-seasonal variations due to their extensive and deep root system and longer life spans (Abel at al. 1997) and are consequently available all year round. Furthermore, most of the large woody trees are evergreen with high-quality forage throughout the seasons (Schwartz et al. 2012). Their forage preferences and unique traits enable them to efficiently use rangelands that are prone to drought, with a degraded herbaceous layer, and those undergoing bush encroachment (Schwartz et al. 2012). Camels are consequently resilient to drought and can subsequently build the resilience of pastoralists who depend on them.

The species reported as preferred by camels also matched those that were recorded from field assessments as the most abundant in the study sites. Camel herders were in a position to cite preferred camel forage species owing to their accumulated traditional ecological knowledge, especially on livestock forage species and landscape condition, as a result of them having observed their animals feed over time. Two key issues arise from this finding; first, there is correlation between traditional observations of livestock feeding habits and abundant forage species; thus, preference of particular forage-browse species could be related to their availability at the landscape level. Secondly, traditional observations of tree abundance coincide with scientific observations, suggesting that traditional deductions are not mere coincidence. Similar findings have been recorded by a number of researchers among the Borana, Turkana and Rendile in Ethiopia and Kenya (Oba 2012; Oba and Kaitira 2006; Roba and Oba 2008). Further, those forage species observed here to be preferred by camels have also been identified as such in previous studies (Chimsa et al. 2013; Desalegn and Mohammed 2012; Kuria et al. 2012; Rutagwenda et al. 1990; Schwartz et al. 2012).

Conclusion and recommendation

The sub-region presents a high richness, abundance and diversity of woody browse dominated by several *Acacia* species, *Euphorbia sp.*, *Balanites sp.*, *G. mollis*, *and O. cochenillifera* that also featured among the most preferred camel forage as revealed by the community survey. This is indicates availability of a broad spectrum of camel forage. Further, these woody forage species can withstand seasonal and climatic variations rampant in the sub-region, thereby securing camel forage availability all year around, thus making camel production a viable livelihood option in the sub-region.

The study has also revealed that the pastoralists have in-depth knowledge of camels' forage preferences. This diversity and abundance of woody browse coupled with the indigenous knowledge of camel forage preferences should be taken into account as adoption of camel rearing in the region becomes an increasing reality.

Camel owners are encouraged to undertake conservation management and deliberate production of forage species such as *E. tirucalli* that are easy to propagate to secure access to forage particularly for the milking herd and the camel calves that remain at the homesteads. However, given concerns about the irritant latex in this particular species, a toxicological study should be undertaken to determine any likely side effects increased by consumption of this forage on the camels as well as on camel milk and other products.

Future studies should assess camel forage preferences as observed at grazing sites, including consideration of seasonal influences and nutritive value. Further, studies focused on determining the interaction between tree density and ease of browsing, as well as coppicing and regeneration ability of browsed species, need to be undertaken. Finally, to further facilitate in-depth and precise interpretation of differences in species composition between land cover types in camel grazing sites and between regions, bio-physical assessments that explore the effect of site characteristics, namely topography, soil properties and slope among others, on the diversity and density of camel forage species ought to be included in the studies that will be undertaken.

Acknowledgements
Our deepest appreciation and gratitude is extended to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for funding this research. We also thank the people of Karamoja for their hospitality and willingness to avail the information. We are also indebted to our research assistants who helped us in the data collection.

Authors' contributions
JBS identified and recruited the research assistants and collected and analysed the data. All authors read, corrected and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Publisher's Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details
[1]School of Forestry, Environmental and Geographical Science, Makerere University, Kampala, Uganda. [2]Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), Kampala, Uganda. [3]National Agricultural Research Organization, Tororo, Uganda.

Received: 21 September 2016 Accepted: 10 February 2017
Published online: 21 April 2017

References

Abel, N., Baxter, J., Campbell, A., Cleugh, H., Fargher, J., Lambeck, R., Prinsley, R., Prosser, M., Reid, R., Revell, G., Schmidt, C., Stirzaker, R., Thorburn, P. 1997. *Design principles for farm forestry: a guide to assist farmers to decide where to place trees and farms plantations on farms*. Canberra: Rural Industries Research and Development Corporation.

Abukashawa, S., M. Abdelkreim, and M.T. Ibrahim. 2016. Studies on camel's feeding and utilization of camel's milk in Buttana Area, Gaderif State, Sudan. *Advances in Diary Research* 3(3): 1–3. http://dx.doi.org/10.4172/2329-888x.1000141.

Ahmad, S., M. Yaqoob, N. Hashmi, M. Zaman, and M. Tariq. 2010. Economic importance of camel: Unique alternative under crisis. *Pakistan Veterinary Journal* 30(4): 191–197.

Aleper, D.K., and J. Lotyang. 2006. *State of the environment report for Moroto District 2006*.

Amante, D.G. 2014. *Traditional camel management as an adaptation strategy to ecological changes: The case of Karrayyuu Oromo of Ethiopia*. Masters thesis, UiT The Arctic University of Norway, pp. 88.

Amin, A.S., K.A. Abdoun, and A.M. Abdelatif. 2011. Observations on the seasonal browsing and grazing behaviour of camels (Camelus dromedarius) in southern Darfur-Sudan. *Research Opinions in Animal & Veterinary Sciences* 1(4): 213–216.

Angassa, A., and G. Oba. 2008. Effects of management and time on mechanisms of bush encroachment in Southern Ethiopia. *African Journal of Ecology* 46(2): 186–196.

Angassa, A., and G. Oba. 2010. Effects of grazing pressure, age of enclosures and seasonality on bush cover dynamics and vegetation composition in Southern Ethiopia. *Journal of Arid Environments* 74(1): 111–120.

Asase, A., K. Ofori-Frimpong, and P.K. Ekpe. 2010. Impact of cocoa farming on vegetation in an agricultural landscape in Ghana. *African Journal of Ecology* 48(2): 338–346.

Awoke, K., S.M. Ali, and M. Hussein. 2015. Assessment of challenges and opportunities of traditional camel calf management practices in Fafen Zone, Somali Regional State, Ethiopia. *International Journal of Current Science and Technology* 3(6): 20–27.

BakamaNume, B.B. 2010. *A contemporary geography of Uganda*. Dar es Salaam: Mkuki na Nyota Publishers.

Barrow, E. 1988. *Trees and pastoralists: The case of the Pokot and Turkana. Social Forestry Network paper 6b*, 24. London: Overseas Development Institute.

Belay, K., F. Beyene, and W. Manig. 2005. Coping with drought among pastoral and agro-pastoral communities in eastern Ethiopia. *Journal of Rural Development* 28(2): 185–210.

Bonkoungou, E. 2001. *Biodiversity in drylands: Challenges and opportunities for conservation and sustainable land use*. Nairobi: United Nations Development Programme.

Chimsa, M., et al. 2013. Forage preference of camel calves (*Camelus dromedaries*) in eastern Ethiopia. *The Journal Animal Plant Science* 25(5): 1236–1241.

Dereje, M., and P. Udén. 2005. The browsing dromedary camel: I. Behaviour, plant preference and quality of forage selected. *Animal Feed Science and Technology* 121(3): 297–308.

Desalegn, T., and Y. Mohammed. 2012. Preferably browsed forage species by camels (*Camelus dromedarius*) and their mineral contents in Jijiga district, Eastern Ethiopia. Livestock Research for Rural Development 24(3).

Dokata, M.D. 2014. *Factors influencing camel milk production in central division of Isiolo District: A case of three camel milk women self help groups in Isiolo County, Kenya*, MA dissertation. Kenya: University of Nairobi.

Dorges, B., and J. Heucke. 1995. *One humped camel Camelus dromedarius. In the mammals of Australia*, 2nd ed, 718–720. Sydney: Reed.

Dorges, B., and J. Heucke. 2003. *Demonstration of ecologically sustainable management of camels on aboriginal and pastoral land*. Canberra: Final report on project no. 200046 of the National Heritage Trust.

Egeru, A. 2014. *Assessment of forage dynamics under variable climate in Karamoja sub-region of Uganda*. PhD dissertation, University of Nairobi, p 250.

Egeru, A., O. Wasonga, J. Kyagulanyi, G.M. Majaliwa, L. MacOpiyo, and J. Mburu. 2014. Spatio-temporal dynamics of forage and land cover changes in Karamoja sub-region, Uganda. *Pastoralism* 4(1): 1–21.

Egeru, A., B. Barasa, H. Makuma-Massa, and P. Nampala. 2015a. Piosphere syndrome and rangeland degradation in Karamoja sub-region, Uganda. *Resources and Environment* 5(3): 73–89.

Egeru, A., O. Wasonga, L. Macopiyo, J. Mburu, and M.G. Majaliwa. 2015b. Abundance and diversity of native forage species in pastoral Karamoja sub-region, Uganda. *African Study Monographs* 36(4): 261–296. http://doi.org/10.14989/202827.

Elhadi, Y.A., D.M. Nyariki, and O.V. Wasonga. 2015. Role of camel milk in pastoral livelihoods in Kenya: Contribution to household diet and income. *Pastoralism* 5(1): 8.

El-Keblawy, A., T. Ksiksi, and H. El Alqamy. 2009. Camel grazing affects species diversity and community structure in the deserts of the UAE. *Journal of Arid Environments* 73(3): 347–354.

Evans, J.O., Simpkin, S.P. and Atkins, D.J., eds. 1995. *Camel keeping in Kenya. Range Management Handbook of Kenya*, 3 (8). Range Management Division, Ministry of Agriculture, Livestock Development and Marketing.

Farah, Z. 2004. An introduction to the camel. In *Milk and meat from the camel: handbook on products and processing*, 15–22. Zurich: Hochshuleverlag AG ander ETH.

Flintan, F., B. Tache, and A. Eid. 2011. *Rangeland fragmentation in traditional grazing areas and its impact on drought resilience of pastoral communities: Lessons from Borana, Oromia and Harshin, Somali Regional States, Ethiopia*. Oxford, UK: Oxfam.
Gradé, J.T. 2008. *Ethnoveterinary knowledge in pastoral Karamoja, Northern Uganda*, PhD dissertation, 220. Belgium: Ghent University.
Gwali, S., P. Okullo, D. Hafashimana, and D.M. Byabashaija. 2010. Diversity and composition of trees and shrubs in Kasagala forest: A semiarid savannah woodland in Central Uganda. *African Journal of Ecology* 48(1): 111–118.
Hesse, C. and Cotula, L. 2006. *Climate change and pastoralists: Investing in people to respond to adversity. Sustainable Development Opinion, IIED*. Retrieved from: http://pubs.iied.org/pdfs/11059IIED.pdf.
Iqbal, A., and B.B. Khan. 2001. Feeding behaviour of camel. *Pakistan Journal of Agricultural Sciences* 38: 58–63.
Kagunyu, A.W., and J. Wanjohi. 2014. Camel rearing replacing cattle production among the Borana community in Isiolo County of Northern Kenya, as climate variability bites. *Pastoralism* 4(1): 1–5.
Kagunyu, A.F., and J.G. Wanjohi. 2015. The emergency of *Euphorbia tirucalli* as drought feeds for camels in northern Kenya. *Pastoralism* 5(1): 1.
Katende, A.B., A. Birnie, and B. Tengnas. 1995. *Useful trees and shrubs for Uganda: Identification, propagation and management for agricultural and pastoral communities*, 710. Nairobi: Regional Soil Conservation Unit.
Kindt, R., and R. Coe. 2005. *Tree diversity analysis: A manual and software for common statistical methods for ecological and biodiversity studies*. Nairobi: World Agroforestry Centre. http://www.worldagroforestrycentre/treesandmarkets/treediversityanalysis.asp.
Krätli, S., C. Huelsebusch, S. Brooks, and B. Kaufmann. 2013. Pastoralism: A critical asset for food security under global climate change. *Animal Frontiers* 3(1): 42–50.
Kuria, S.G., I.A. Tura, S. Amboga, and H.K. Walaga. 2012. Forage species preferred by camels (*Camelus dromedarius*) and their nutritional composition in North Eastern Kenya. *Livestock Research for Rural Development* 24(8).
Laudadio, V., V. Tufarelli, M. Dario, M. Hammadi, M.M. Seddik, G.M. Lacalandra, and C. Dario. 2009. A survey of chemical and nutritional characteristics of halophytes plants used by camels in Southern Tunisia. *Tropical Animal Health and Production* 41(2): 209–215.
Levine, S. 2010. What to do about Karamoja? Why Pastoralism is not the problem but the solution. In *Karamoja livelihoods support strategy report, Food and Agricultire Organisation /European Civil Protection and Humanitaria Aid Operations*.
MAAIF and UBOS. 2009. *The National Livestock Census Report 2008. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)*. Kampala: Entebbe/Uganda Bureau of Statistics.
Magurran, A.E. 2004. Measuring biological diversity. *African Journal of Aquatic Science* 29(2): 285–286.
Malimbwi, R. and Mugasha, A. 2002. *Reconnaissance timber inventory report for Handeni Hill Forest Reserve in Handeni District, Tanzania for the Tanga Catchment Forest Project, FORCONSULT, Faculty of Forestry and Nature Conservation, Sokoine University of Agriculture, Morogoro, Tanzania.*
Malimbwi, R.E., D.T.K. Shemweta, E. Zahabu, S.P. Kingazi, J.Z. Katani, and D.A. Silayo. 2005. *Inventory for Mvomeroand Morogoro Districts Tanzania*. Morogoro: FOCONSULT.
McGahey, D., J. Davies, and E. Barrow. 2008. Pastoralism as conservation in the Horn of Africa: Effective policies for conservation outcomes in the drylands of Eastern Africa. *Annals of Arid Zones* 46(2): 353–377.
McLeod, S., and A. Pople. 2008. *Modelling management options for management of feral camels in central Australia, DKCRC Research Report 48*. Alice Springs: Desert Knowledge CRC.
Megersa, B., A. Markemann, A. Angassa, J.O. Ogutu, H.-P. Piepho, and A.V. Zárate. 2014a. Livestock diversification: An adaptive strategy to climate and rangeland ecosystem changes in southern Ethiopia. *Human Ecology* 42(4): 509–520.
Megersa, B., A. Markemann, A. Angassa, and A.V. Zárate. 2014b. The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia. *Food Security* 6(1): 15–28.
Mubiru, D. 2010. *Climate change and adaptation options in Karamoja*. Rome: Food and Agriculture Organization.
Mukasa-Mugerwa, E. 1981. *The camel (Camelus dromedarius): A bibliographical review*, 129. Addis Ababa: International Livestock Centre for Africa, Monograph 5.
Nalule, S. 2010. *Social management of rangelands and settlement in Karamoja.* Kampala: Food and Agriculture Organisation.
Oba, G. 2012. Harnessing pastoralists' indigenous knowledge for rangeland management: Three African case studies. *Pastoralism: Research, Policy and Practice* 2(1): 1–25.
Oba, G., and L. Kaitira. 2006. Herder knowledge of landscape assessments in arid rangelands in northern Tanzania. *Journal of Arid Environments* 66(1): 168–186.
Roba, H.G., and G. Oba. 2008. Integration of herder knowledge and ecological methods for land degradation assessment around sedentary settlements in a sub-humid zone in northern Kenya. *The International Journal of Sustainable Development & World Ecology* 15(3): 251–264.
Rutagwenda, T., M. Lechner-Doll, H. Schwartz, W. Schultka, and W. Von Engelhardt. 1990. Dietary preference and degradability of forage on a semiarid thornbush savannah by indigenous ruminants, camels and donkeys. *Animal Feed Science and Technology* 31(3): 179–192.
Schwartz, H.J., Wolfgang, S. and Isaac, L. 2012. *Feeding preferences of one-humped camels (Camelus dromedarius) on a semi-arid thornbush savannah in East Africa - adaptive advantages in view of increasing aridity of the environment, Third International Conference of the Society of Camelid Research(ISOCARD), Muskat, Oman.*
Shaheen, G. 2009. *Seasonal variation in nutritional and anti-nutritional components of native shrubs and trees grown in Hazargangi Chiltan National Park, Karkhasa and Zarghoon*, PhD Dissertation, 2009. Quetta: University of the Bolochistan.
Stein, A., K. Gerstner, and H. Kreft. 2014. Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecology Letters* 17(7): 866–880.
Tadesse, G., T. Bekele, and S. Demissew. 2008. Dryland woody vegetation along an altitudinal gradient on the eastern escarpment of Welo, Ethiopia. *SINET: Ethiopian Journal of Science* 31(1): 43–54.
Tangus, J., E. MO, and M. Mokua. 2004. Influence of enterprise diversification on risk management amongst Samburu pastoralists of Kenya. *Journal of Bussiness Management and Administration* 2(1): 1–6.
Thornton, P., J. Van de Steeg, A. Notenbaert, and M. Herrero. 2009. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems* 101(3): 113–127.
Timberlake, J. 1994. Vernacular names and uses of plants in northern Kenya. *Journal of East African Natural History* 83(1): 31–69.
Tolera, A., and A. Abebe. 2007. Livestock production in pastoral and agro-pastoral production systems of Southern Ethiopia. *Livestock Research for Rural Development* 19(12): 4–7.
Turner, B.J. 1967. Ecological problems of cattle ranching in Combretum savanna woodland in Uganda. *East African Geographical Review* 5(1967): 9–19.
Wigrup, I. 2005. *The role of indigenous knowledge in forest management*. PhD Dissertation, Swedish University of Agricultural Sciences.

Submit your manuscript to a SpringerOpen journal and benefit from:

- Convenient online submission
- Rigorous peer review
- Immediate publication on acceptance
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at ▶ springeropen.com