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Temporal changes in woody-plant use and the *ekwar* indigenous tree management system along the Turkwel River, Kenya

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Summary

Indigenous systems of management for regulating extraction of non-timber forest products (NTFP) have not been well documented in arid zone grazing lands. Conservation projects have therefore lacked information on customary rights to trees, while they have enforced systems of tree resource management that often conflicted with the indigenous system. This study focused on the indigenous tree tenure system of the Turkana pastoralists called *ekwar* (plural *ngikwarin*). The indigenous tree management system in 15.4 km^2 of the Turkwel River floodplain woodlands near Lodwar, Kenya was investigated. The study began in 1990 after impoundment of the Turkwel Gorge Dam. In 1990 and 1998, Turkana pastoralists were interviewed about the ekwar. In individual ngikwarin woody cover, wood volume and woody-plant density were measured, and wood extraction assessed in terms of stems and twigs removed by the pastoralists and the urban population of Lodwar. Intensity of charcoal burning was assessed in terms of the density of earthen kilns, and livestock impact in terms of browsing frequency on woody plants. Potential *Acacia tortilis* litter production was estimated and an ekwar quality index developed to describe woodland productivity conditions. Tree produce was shared with and leased to friends and relatives. Woody cover showed no significant changes, while woody-plant density and volume declined, over the 8-year period. The Turkana usually do not cut live trees, but use dead trees and dry tree-parts for making charcoal. Increased kiln density and increased extraction of tree-parts were considered to be indicative of increased pressure on the riverine woodlands. Livestock browsing did not seem to contribute to woodland degradation. However, decline in woody-plant density and volume might have contributed to the reduction of litter production of *A. tortilis*. Trends in woodlands in the floodplain might be associated with damming of the Turkwel River and local anthropogenic pressures. Also, the ekwar system of tree tenure seemed to be threatened by the official forestry policy that it be ignored. Incorporating the ekwar system into the forestry conservation policy may achieve sustainable use and improve conservation of the Turkwel River floodplain woodlands.

Keywords: *ekwar* silvo-pastoral system, extraction of non-timber forest products, floodplain, Kenya, tree tenure, Turkana pastoralists, Turkwel River, woodland conservation

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Introduction

Indigenous tree tenure and customary rules that control harvesting of tree produce are scarcely mentioned in the conservation literature on arid zones. Conservation projects have tended to lack information on customary rights to trees while they have enforced systems of tree-resource management promoted by forestry plantation policies that often conflicted with the indigenous system of woodland exploitation for browse, fruits and fuelwood. In contrast to conventional land tenure, pastoralists in sub-Sahara in general and those of north-western Kenya in particular distinguish tree tenure as systems of rights to tree produce that are claimed by individuals (Barrow 1996). Trees can be owned or leased to friends and relatives (Neef & Heidhues 1994). Owners have the right to exclude other non-owners, while they themselves retain inheritance rights (Fortmann 1985). Tree tenure rights are means for regulating extraction of non-timber forest products (NTFPs) including; browse, fruits, medicine, fuelwood, charcoal, and building materials (Gakou *et al.* 1994), and might be used to understand effects of NTFP extraction on woodlands in the arid zones.

Turkana pastoralists in the arid zone of Kenya have an indigenous system of tree management that is directly linked to ownership of the pod-bearing *Acacia tortilis* (Forssk.) Hayne, other fruit-bearing tree species and sorghum gardens. The system of tree ownership within strips of the riverine woodland is known as *ekwar* (plural *ngikwarin*) (Barrow 1990, 1991). Ngikwarin provides browse for livestock during the dry season and food for human use all year. Browse is available in the form of leaf litter, flowers and pods (hereafter referred to as total litter). The pastoralists strictly regulate pod and flower utilization in order to feed sheep and goats (Haro & Oba 1993). Other uses of ngikwarin are as sources of fuelwood, medicinal plants, building materials and grazing (Morgan 1981).

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In the past, the silvo-pastoral system of ekwar may have contributed to the conservation of the woodlands of the Turkwel River floodplain (Barrow 1987), but recent changes in land-use patterns after the construction of the Turkwel Gorge Dam and establishment of irrigation schemes in the upstream and settlements in the downstream may have caused woodland degradation (Ecosystems Ltd 1983; Adams 1989; Oba 1991). The main concern of the Turkana pastoralists is that land-use changes in and around urban centres may be contributing to the loss of *Acacia tortilis*, a keystone species, and other woody plants through increased exploitation along the Turkwel River. Effects of wood extraction on the ekwar system have not been investigated, and ekwar productivity conditions after dam impoundment have not been monitored before. Furthermore, even though the ekwar system is widely used throughout Turkana, especially along the dry watercourses and rivers (Barrow 1987), impact assessments of woodland exploitation near areas of greater human pressure are needed. Two previous surveys in 1986 and 1991 have shown heavy use near settlements, but trends in NTFP extraction were not understood (Oba 1991; G. Oba, unpublished data). Moreover, a monitoring system after dam impoundment is needed to understand trends in riverine woodland changes. The information is critical for future conservation of the riverine woodlands along the lower Turkwel River.

In 1990 and 1998, we surveyed 15.4 km^2 of the Turkwel River floodplain near the town of Lodwar (3° 07′ N, 35° 35′ E) and assessed effects of NTFP extraction on the riverine woodlands. The objectives of the present study were to (1) map the ngikwarin in the study area, (2) identify tree ownership rights, (3) assess human and livestock utilization of woody plants, (4) estimate potential production of *Acacia tortilis* litter, and (5) develop an ekwar quality index (EQI) to assess conditions of woodland productivity.

Methods

Study area

The Turkwel River has its source in Mount Elgon and the Cherengani and forms a floodplain of about 800 km^2 in the downstream section. The lower sections of the river have mean channel width of 455 m and mean bank height of 1.4 m (Oba 1991). Channel width is related to flooding regimes and floodplain geomorphology. River meanders and abandoned channels create highly complex riverine woodland mosaics (Hughes 1988; Oba 1991; J. Stave, unpublished data).

In the downstream section, the river flows through a semi-desert country where evapotranspiration exceeds 2000 mm $year^{-1}$ (Pratt & Gwynne 1977). The rainfall from outside the region of Turkana contributed a greater volume of river water before the Turkwel Gorge Dam was impounded in 1990. Pre-dam channel flow in the downstream was semi-perennial and occurred during April–May and July–August. During the flow period the groundwater was recharged, rising to 40–80 cm below surface and falling to 1.5–3.0 m when dry (Vleeshouwer & Mbuvi 1974). Even though the immediate effect of the dam will be to absorb seasonal floods and change the spate flood regimes (Adams 1989), water balance and recharge in the floodplain downstream takes a longer time to show effects. Annual floods prior to dam impoundment supported luxuriant woodlands that were sustained by groundwater (also called groundwater woodlands), in contrast to the adjoining dry areas where woody-plant growth relies on rainfall in the immediate vicinity. The riverine woodlands were dominated by *Acacia tortilis, Hyphaene compressa* H. Wendl, *Salvadora persica* L., *Cordia sinensis* Lam., *Cadaba rotundifolia* Forssk., *Grewia tenax* (Forssk.) Fiori, *A. elatior* Brenan, *A. nubica* Benth., *Boscia coriacea* Pax, and *Ziziphus mauritiana* Lam. among a total of 26 woody species. The woodlands in the study area were subject to intensive NTFP exploitation pressure by the urban population of Lodwar (Oba 1991). The livestock of the pastoralists grazed in the riverine woodlands during the dry season and in the adjoining dry areas during the wet season (Oba 1996).

Ekwar resource survey

An aerial photograph (black and white) of the study area taken in 1961 (scale 1:20 000) together with ground checking was used to map vegetation patches in the study area (Stave 1999). With the help of knowledgeable Turkana elders, a total of 23 ngikwarin were identified and mapped, and their ownership and use were discussed (Fig. 1). The Turkana used landscape features such as footpaths, floodplain terraces, vegetation patches, and prominent trees to identify ngikwarin perimeters on the ground. Since the ekwar constitutes an informal system of tree tenure, we identified ngikwarin by families. The ekwar map was overlaid on the vegetation map and ArcView GIS Version 3.1 was used to determine areas of individual ngikwarin.

Assessments of NTFP extraction

During the 1990 and 1998 surveys, a series of 50–100 m line intercepts (Kent & Coker 1992) were randomly located in order to estimate woody cover in each ekwar. We also assigned 3–9 plots of 225–500 m^2 per ekwar and counted woody plants in them. We measured tree heights, but because traditional techniques for measuring stem diameters such as diameter at breast height are inappropriate for the branching tree growth forms of the dry tropics, we measured stem diameters at 50–100 cm above ground level. In the case of *Acacia tortilis* we also counted primary stems, secondary stems (i.e., branches descending from the primary stems) and dry twigs ($<$5 cm at the point of removal) for each tree, as well as the number of extracted stems and twigs. We assessed livestock impact by inspecting woody plants for traces of browsing. Goats had access to tree browse from ground level up to 1.5 m height, while camels reached a height of 2.5 m

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(Oba & Post 1999). The proportion of woody plants of each species in the sample that showed evidence of browsing was used to indicate utilization as a frequency (%). Dead and fallen live trees were used for making charcoal using earthen kilns. During the 1990 survey, old and active kilns were counted in each ekwar; while in 1998 we randomly assigned a total of 82 sample plots, each measuring 2500 m^2. The difference in sampling regime between the surveys was not expected to influence data quality.

Potential litter production and ekwar quality index

The ngikwarin in the study area comprised variable amounts of vegetation resources like firewood, building materials and fodder. The Turkana pastoralists on questioning suggested that ekwar conditions could be assessed in terms of total wood volume and *Acacia tortilis* litter production. The Turkana distinguished between different varieties of *A. tortilis*. The most widespread in the floodplain are those with flat crowns and highly-branched stems, reaching a height of 10 m: these are called *edungoit*. The edungoit trees produce pods in quantities throughout the year. The second variety is called *ekoroputh*: these trees often reach >20 m in height and are restricted to the leeveland of the river. The ekoroputh variety produces pods only between December and January, but both varieties produce leaf litter continuously (Haro & Oba 1993). Since the edungoit and the ekoroputh contribute massive volumes of wood for charcoal and firewood, as well as substantial amounts of browse for livestock, the *A. tortilis* is considered the most valuable woody-plant species in ngikwarin.

Wood volume was calculated for all woody species, according to Dawkins (1961):

$$v = \tfrac{1}{2}gh \quad (1)$$

where v = total above-ground volume (m^3), g = girth basal area (m^2), and h = height (m).

Potential *Acacia tortilis* litter production in individual ngikwarin was estimated using an equation developed by Haro & Oba (1993) for the Turkwel River woodlands. The equation combined the two *A. tortilis* varieties and was based on morphometric measurements and total litter yields of 40 trees between 4 and >10 m in height;

$$Y = 11.921 + 4.568 \log HT \quad (2)$$

where Y = potential *A. tortilis* litter production (kg $tree^{-1}$ yr^{-1}) and HT = tree height (m).

Data from Equation 1 and Equation 2 were used to calculate an ekwar quality index (EQI) in order to assess the spatial and temporal variability of woodland productivity conditions;

$$EQI = (v_i - \bar{v}) + (p_i - \bar{p}) \quad (3)$$

where v_i = proportion (%) of total wood volume located in ekwar i, $\bar{v}$ = mean proportion (%) of wood volume per ekwar, p_i = proportion (%) of potential *Acacia tortilis* litter production in ekwar i, and $\bar{p}$ = mean proportion (%) of potential *A. tortilis* litter production per ekwar.

The resulting values reflected potential productivity, the degree of human and livestock utilization, and environmental impacts. An EQI >3 was used to indicate high quality, −3< EQI <3 moderate quality, and an EQI <−3 was used to indicate low quality.

Statistical analysis

Variations in woody cover, woody-plant density, wood volume, and kiln density among ngikwarin and over time were each analysed by two-way ANOVA. With the exception of woody cover, the data were ln (x + 1) transformed in order to improve the normality and homogeneity of the variance. Between-year variation of NTFP extractions was assessed by Mann-Whitney U-test, whereas changes in livestock browsing and potential *Acacia tortilis* litter production were evaluated by t-tests ($p < 0.05$). The relationships between changes in kiln density and changes in woody cover, woody-plant density, and wood volume were tested by Pearson's correlation. All statistical procedures were based on the use of SYSTAT Inc. (1992).

Results

The silvo-pastoral system of ekwar

Ekwar size varied from 2.9 to 156.8 ha with a mean of 37.4 (± SE 7.6) ha (Table 1, Fig. 1). About 48% of the ngikwarin were shared among families, whereas individual families owned 43%, and 9% were communal, being jointly used by all families in the area. The extraction of NTFPs in the communal ngikwarin was regulated by rules established by the area elders. By comparison, tree tenure rights in the family ngikwarin were distinguished from the rights to use tree produce. The Turkana shared tree produce with friends and relatives. Tenants had rights to trees as long as they lived

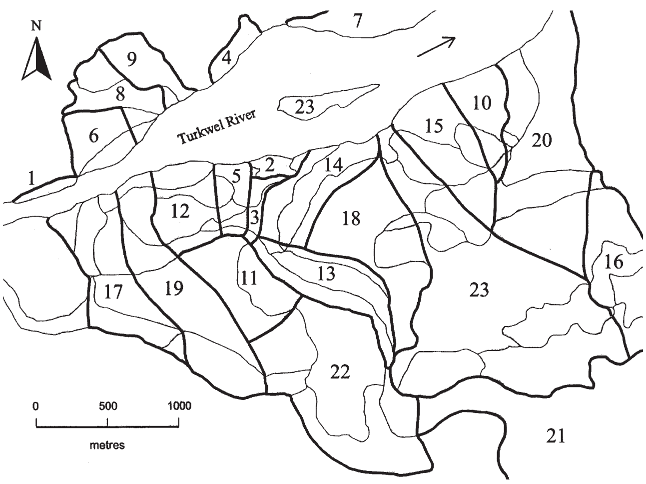

Figure 1 Location of study area. Immediately east of Lodwar, Kenya. Spatial distribution of ngikwarin (bold lines) in 15.4 km^2 of the lower Turkwel River floodplain woodlands. Ekwar numbers match those provided in Table 1.

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Table 1 Weighted mean total woody cover (%), woody-plant density (trees ha^{-1}) and standing wood volume (m^3 ha^{-1}) of ngikwarin (locations in Fig. 1) in the study area during the 1990 and 1998 surveys. – = no data.

Ngikwarin (Ekwar family)	*Area (ha)*	*Cover*		*Density*		*Wood volume*	
		1990	*1998*	*1990*	*1998*	*1990*	*1998*
1. Ngatoto Loche	2.9	–	76	520	533	463	307
2. Egalan Towot	5.1	56	80	210	178	205	451
3. Esokon Lokwala	5.7	–	66	380	311	1100	490
4. Eluk Ewoi	6.2	100	96	320	111	926	542
5. Loyokoro Egalan	12.0	100	73	380	356	711	366
6. Ekenu Imutwa	15.5	41	57	707	338	976	390
7. Communal	16.4	82	93	3790	1378	603	406
8. Amor Ewoton	17.9	37	35	660	187	149	53
9. Akuri Amathe	18.4	62	47	2380	969	313	507
10. Ngitome Nakolojey	22.0	92	99	683	1259	460	443
11. Edapal Lodeya	24.3	47	13	793	128	722	59
12. Kawar Loyokoro	24.8	66	76	312	218	449	696
13. Nanguru Arapon	29.8	39	29	360	187	306	161
14. Ekai Mukoo	31.0	74	59	348	183	1718	602
15. Lotilem Amoni	31.1	60	92	828	1170	540	572
16. Emani Korr	32.3	35	35	454	277	147	206
17. Ngoli Ekenu	52.6	52	48	233	170	642	244
18. Etura Arapon	52.6	49	19	240	258	167	125
19. Abok Koriang	55.0	69	52	137	122	471	240
20. Awet Ekori (Communal)	69.7	67	66	2156	600	657	334
21. Ngitome Ekhal	79.9	33	1	137	15	368	1
22. Ngibuwo Lomartoi	99.7	41	38	332	183	164	281
23. Abong Lomartoi	156.8	37	30	709	357	247	260

in the area, but when they migrated, management of tree produce reverted to the owners. In contrast to tenants, absence of ekwar families would not terminate their customary user rights. In their absence, as general rule, caretakers were appointed to protect tree tenure rights. Under the traditional lease system, rights to tree litter did not include processing dry trees and tree parts for charcoal because it was considered the right of the ekwar family, with the exception of the communal ngikwarin where members had equal rights. If tree litter was in short supply, users were allocated tree branches for pods and flowers to feed goat kids and lambs. Those with user rights carefully regulated extraction of fruits, pods and flowers by shaking tree branches with help of hooked long poles, while outsiders were prevented because of concern that they might damage tree branches.

According to the Turkana elders interviewed, the proper functioning of ekwar was undermined after the Forestry Department became involved. The Forestry Department employed guards who often threatened individuals (including ekwar owners) with arrests if they harvested woody plants without permits. In the study area, the Forestry Department issued permits for extraction of NTFP by non-pastoralists, thus disregarding the rights of ekwar owners. Whereas the Forestry Department treated the ekwar as an open-access resource, the owners considered it as semi-private.

NTFP extraction

Mean woody cover, density and volume varied among ngikwarin (Table 1). Year and ekwar significantly explained variations in woody-plant density and wood volume between ngikwarin, but interactions between year and ekwar were not significant (Table 2). Woody cover varied significantly among ngikwarin, but not between years (Table 2). Woody cover was 55 ± 4% in 1990 and 51 ± 3% in 1998. By comparison

Table 2 Results of two-way ANOVA of spatial and temporal effects of ngikwarin on the three different vegetation attributes. NS = not significant ($p > 0.05$).

Dependent variable	*Source*	*df*	*SS*	*F*	*p*
Woody cover	Ekwar	22	61 406	3.4	< 0.001
	Year	1	590	0.7	NS
	Ekwar × year	20	8 360	0.5	NS
	Error	168	137 662		
Woody-plant density	Ekwar	22	138	2.6	< 0.001
	Year	1	42	17.4	< 0.001
	Ekwar × year	22	40	0.8	NS
	Error	221	531		
Wood volume	Ekwar	22	194	2.3	< 0.001
	Year	1	38	9.9	0.002
	Ekwar × year	22	57	0.7	
	Error	220	844		

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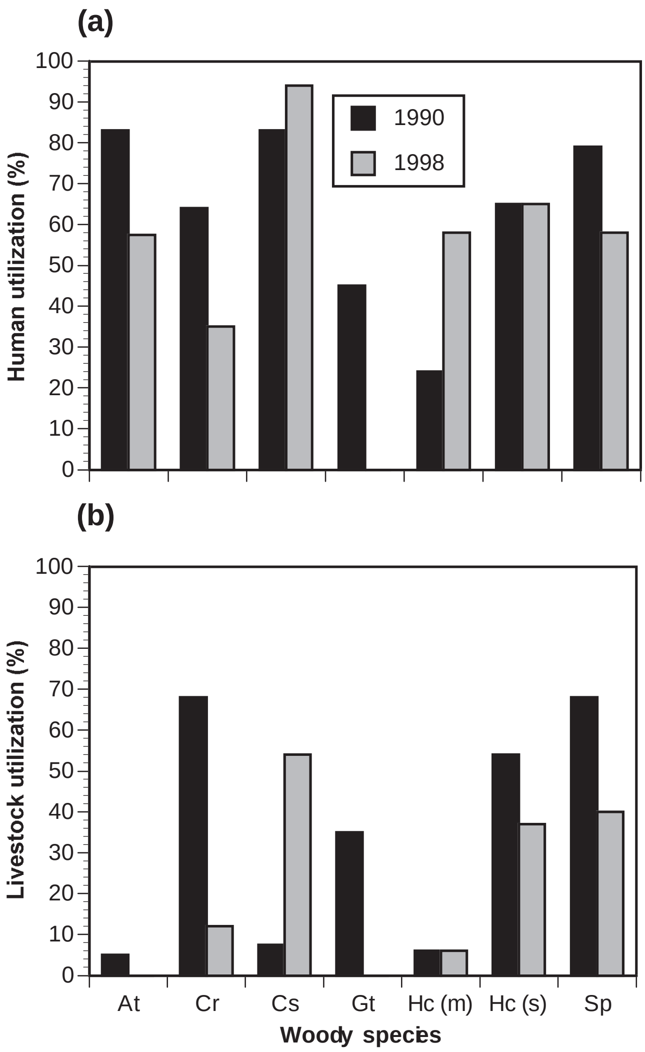

Figure 2 Utilization frequencies of dominant woody species extracted by (*a*) people and (*b*) livestock in the lower Turkwel River woodlands for the periods of 1990 and 1998. At = *Acacia tortilis*, Cr = *Cadaba rotundifolia*, Cs = *Cordia sinensis*, Gt = *Grewia tenax*, Hc (m) = *Hyphaene compressa* (mature), Hc (s) = *Hyphaene compressa* (saplings), and Sp = *Salvadora persica*.

mean wood volume showed a significant decline (Table 2) between 1990 ($552 \pm 58\,m^3\,ha^{-1}$) and 1998 ($299 \pm 29\,m^3\,ha^{-1}$). Woody-plant density was reduced by 62% between 1990 (922 ± 109 trees ha^{-1}) and 1998 (352 ± 34 trees ha^{-1}).

Several woody species were extracted as NTFPs (Table 3). Among individual species, the percentage of woody plants used for extracting NTFPs was less during 1998 than in 1990, the exceptions being *Cordia sinensis* and *Hyphaene compressa* (Fig. 2*a*). On average, the extraction intensity was greatest for *C. sinensis*, *Acacia tortilis*, *H. compressa*, and *Salvadora persica*. Total live primary stems per tree in *A. tortilis* showed highly significant difference between 1990 and 1998, while the number of extracted live primary stems did not (Table 4). Total live and dead secondary stems, and live and dead secondary stem extractions, also showed significant difference between years. Dry twigs that were extracted increased significantly in 1998 compared to 1990, but this was also the case for number of available dry twigs (Table 4).

Livestock-browsing pressure in the riverine woodland showed no significant differences ($t = 1.239$, $p = 0.222$) between 1990 ($38 \pm 29\%$) and 1998 ($28 \pm 22\%$), even though variations in browse-plant utilization frequencies were found among individual woody species. *Cadaba rotundifolia*, *Hyphaene compressa* (saplings) and *Salvadora persica* received greater utilization frequencies during 1990 than 1998 (Fig. 2*b*).

At ekwar level, NTFP extraction frequencies did not show significant variations ($t = 0.737$, $p = 0.465$) between 1990 ($78 \pm 19\%$) and 1998 ($73 \pm 25\%$) (Fig. 3*a*). By comparison livestock browsing frequency did not show significant variations among ngikwarin and between years (Fig. 3*b*). Moreover, there was no significant variation in spatial patterns of kilns ($F = 1.2$, $df = 22$, $p = 0.299$), while significant differences in kiln density occurred between surveys ($F = 25.7$, $df = 1$, $p < 0.001$) (Fig. 3*c*). Means ($\pm$ SE) for 1990 and 1998 were 3.0 ± 0.7 kilns ha^{-1} and 20.4 ± 2.2 kilns ha^{-1}, respectively. Greater kiln density was recorded in the communal ngikwarin (Table 1, Fig. 3*c*), while kilns were absent in some semi-private ngikwarin. Generally, the relationships between changes in kiln density and changes

Table 3 Woody plant species used as NTFPs (+ = used, − = not used) in the lower Turkwel River floodplain.

Species	*Building*	*Fuel*	*Food*	*Fodder*	*Medicine*	*Utensils*	*Shade*	*Religious*
Acacia elatior	+	+	+	+	+	+	+	+
A. nubica	+	+	−	−	+	−	−	−
A. tortilis	+	+	+	+	+	+	+	+
Boscia coriacea	+	+	+	+	+	+	−	−
Cadaba rotundifolia	+	−	−	−	−	−	−	−
Cordia sinensis	+	+	+	+	−	+	+	−
Grewia tenax	+	−	+	+	−	−	−	−
Hyphaene compressa	+	−	+	−	−	+	+	−
Salvadora persica	+	+	+	+	+	−	+	−
Ziziphus mauritiana	+	+	+	+	−	+	+	−

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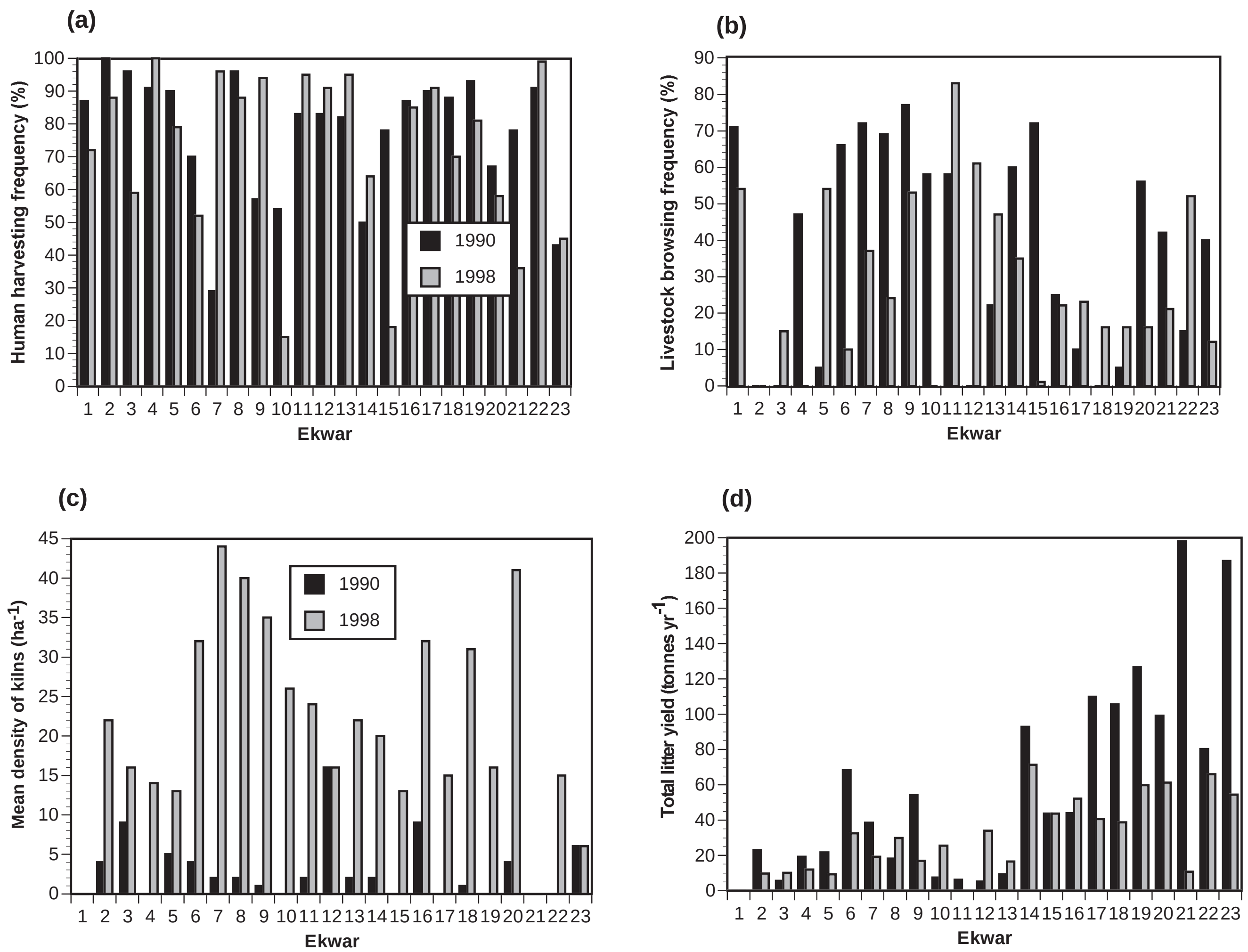

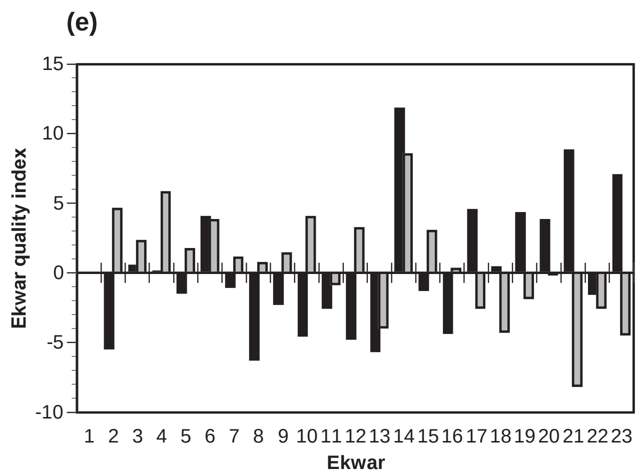

Figure 3 (*a*) Human harvesting frequency (%), (*b*) livestock browsing frequency (%), (*c*) mean density of kilns (ha^{-1}), (*d*) total litter yield (tonnes yr^{-1}), and (*e*) ekwar quality index (EQI) during 1990 and 1998 in the ngikwarin of: Ngatoto Loche (1), Egalan Towot (2), Esokon Lokwala (3), Eluk Ewoi (4), Loyokoro Egalan (5), Ekenu Imutwa (6), communal (7), Amor Ewoton (8), Akuri Amathe (9), Ngitome Nakolojey (10), Edapal Lodeya (11), Kawar Loyokor (12), Nanguru Arapon (13), Ekai Mukoo (14), Lotilem Amoni (15), Emani Korr (16), Ngoli Ekenu (17), Etura Arapon (18), Abok Koriang (19), Awet Ekori (20), Ngitome Ekhal (21), Ngibuwo Lomartoi (22), and Abong Lomartoi (23). List of the ngikwarin are given in Table 1.

in woody cover, wood volume and tree density were not significant ($r < 0.3$, $p > 0.1$ for all correlations).

Potential litter production and ekwar quality index

Potential *Acacia tortilis* litter production of ngikwarin varied greatly between the years ($t = 2.374$, $p = 0.025$), with a mean of 62 ± 14 tonnes ekwar^{-1} yr^{-1} during 1990 and 31 ± 6 tonnes ekwar^{-1} yr^{-1} in 1998 (Fig. 3*d*). Mean litter production in ngikwarin declined by 49%. Patterns of EQI were highly dynamic (Fig. 3*e*) showing that 33% of ngikwarin were high quality, 10% moderate quality and 57% low quality in 1990.

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Table 4 Mean (± SE) number of stems and twigs, and number of extracted stems and twigs, per tree of *Acacia tortilis* in the Turkwel riverine woodland in 1990 ($n = 556$) and 1998 ($n = 247$). Between-year differences have been evaluated by Mann-Whitney U-test. NS = not significant ($p > 0.05$).

	Extraction of NTFPs			
NTFP	*1990*	*1998*	*U*	*p*
Live primary stems	1.74 ± 0.04	1.34 ± 0.08	53 334	< 0.001
Live primary stems utilized	0.01 ± 0.01	0.01 ± 0.01	68 635	NS
Dead primary stems	0.11 ± 0.02	0.13 ± 0.03	67 646	NS
Dead primary stems utilized	0.09 ± 0.01	0.10 ± 0.03	68 542	NS
Live secondary stems	4.49 ± 0.13	2.80 ± 0.10	43 082	< 0.001
Live secondary stems utilized	0.02 ± 0.01	0.08 ± 0.03	67 025	0.025
Dry secondary stems	0.38 ± 0.04	0.20 ± 0.04	62 706	0.006
Dry secondary stems utilized	0.35 ± 0.03	0.14 ± 0.03	59 484	< 0.001
Dry twigs	6.53 ± 0.24	18.86 ± 0.60	16 020	< 0.001
Dry twigs utilized	3.54 ± 0.17	6.40 ± 0.43	49 266	< 0.001

In 1998, 24% ngikwarin were high quality, 33% moderate and 43% low quality. The ngikwarin, in which mass tree mortality occurred earlier, including those of Edapal Lodeya, Nanguru Arapon and Ngibuwo Lomartoi, had low EQI scores (Table 1, Figs. 1, 3*e*). In other ngikwarin, decline in EQI followed loss of mature *A. tortilis* due to riverbank erosion by floodwater (for example, Ngatoto Loche and Egalan Towot) and disturbance by wind throw (for example, Ekai Mukoo) and drought (for example, Etura Arapon) (Table 1, Figs. 1, 3*e*).

Discussion

The silvo-pastoral system of ekwar

The silvo-pastoral system of ekwar has traditionally been used to control exploitation of riverine woodlands. According to the Turkana pastoralists interviewed, they had owned the ekwar for long time, and Barrow (1987) reported that ownership time varied from a minimum of 12 years to a maximum of 57 years. In the present study, new ngikwarin were established on old river bars and in abandoned river channels. The sites were used for sorghum gardens until trees colonized them and management was turned into tree conservation for livestock browse and extraction of NTFP (personal communication with Turkana elders).

In the study area, there were two parallel anthropogenic processes contributing to trends of the riverine woodlands. First, increased population pressure by sedentary pastoralists has led to sub-division of ngikwarin among families (i.e., 48% of ngikwarin were shared). Moreover, the riverine woodland in the study area was being threatened by the increased harvesting and gathering of NTFPs by the urban population, the needs of which conflicted with those of the pastoralists. The population of Lodwar estimated at 20 000 people (1990 estimates) was growing at annual rate of 7.5%, producing growing demands for NTFPs (Oba 1991). Second, competition for resources as well as ignorance of the ngikwarin by the Forestry Department weakened the ekwar system (Barrow 1990). The Forestry Department, which has the jurisdiction over regulation of forest use, did not differentiate between the urban and pastoralist users when issuing permits for extraction of NTFPs. By doing so, they undermined the pastoralists' tenure rights.

The conflict between state-controlled and traditional tree tenure in arid zones of sub-Saharan Africa is a well-known problem (Wiersum & dit Deprez 1995). Generally, state-controlled tree tenure rarely responds to local management systems (Laban 1995; IUCN 1997). The state has legal rights to forest lands and decides on management systems, which it imposes on natural forest management where an indigenous tree tenure system has previously been stronger. Whereas the state control over forest utilization has a single goal of conservation of natural forests in general (Wiersum & dit Deprez 1995), traditional tree tenure was influenced by multiple rights to tree produce within a community's jurisdictions (IUCN 1997). Thus, in the traditional system, as opposed to state forestry system, woodlands were part of wider natural resources to which local communities had rights either by residence or birth (Laban 1995). In the present study, it was shown that tree produce may be leased to neighbours and friends, but property rights to trees would not be violated. In the traditional system, therefore, the community who enjoyed access to tree produce were custodians of the customary laws that protected the rights of individuals. Undermining the traditional systems of tree tenure not only failed to conserve forestry resources but also resulted in greater degradation (Van den Breemer & Venema 1995).

Thus, there should be a rethinking, if sustainable management of the riverine woodlands is to be achieved. In our study area, active participation of the Turkana pastoralists in riverine woodland conservation should imply that the Forestry Department builds on ekwar systems instead of forcing on them professional forestry management. The greatest challenge is to establish indigenous management on empirical foundation that would be attractive to policy makers (Van den Breemer & Venema 1995). In the current study, we mapped and identified traditional tree tenure of ekwar, which provides a sound scientific basis for planning

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conservation of the riverine woodlands along the lower Turkwel River.

NTFP extraction

Trends in the lower Turkwel River woodlands might have been influenced by ecological and climatic factors. During the eight-year period, the impact on the Turkwel River woodlands was a reflection of general trends throughout the floodplain as well as localized human pressure. Pre-dam surveys in 1983 and 1986 of the upstream and downstream floodplain woodlands, respectively, showed that the population of woody plants utilized was variable, with greater exploitation near irrigation schemes (Ecosystems Ltd 1983) and settlements (Oba 1991). In the downstream sections, during the 1986 surveys, 7% of the riverine woody plants showed evidence of harvesting. In 1991 surveys of selected woodland transects mean woody-plant exploitation had increased from 5 ± 3% (1986) to 17 ± 7% (1991). Similarly, there was a slight decline in woody-plant density, while woody cover was unchanged (G. Oba, unpublished data). In the study area, the decline in woody-plant density might have been due to exploitation, natural mortality and riverbank erosion. By contrast, sustained woody cover may be explained by crown expansion of the flat-topped *Acacia tortilis* between the surveys (Stave 1999).

Decline in wood volume suggested loss of mature trees. However, our data on NTFP extraction was inconclusive regarding the direct causes of woodland degradation. The response varied from species to species. Regeneration in *Hyphaene compressa* was promoted by harvesting (J. Stave, unpublished data). Indeed, ekwar owners allowed urban residents to harvest *H. compressa* saplings without hindrance. By contrast, *Acacia tortilis* may be sensitive to extraction. Thus, the decline in harvest of dry secondary stems of *A. tortilis* between 1990 and 1998 might show the implied threat, forcing the pastoralists to shift utilization to the dry twigs. However, this trend may also be attributed to the slight decline in number of available dry secondary stems and the substantial increase in number of dry twigs. Together with the decrease in live stems per tree, we suspect that the changes might be reflecting gradual drying up of the woodlands.

In terms of processing charcoal, however, twigs were less valued but used because they were more abundant than the dry primary and secondary stems. The Turkana are aware that extraction of live tree parts might pose a threat to ekwar system and so far are avoiding cutting live trees. The exceptions are the residents of Lodwar who needed live tree posts (for example, mature *H. compressa*) for constructing semi-permanent houses. The urban residents of Lodwar exploited an estimated 921 tonnes yr^{-1} of air-dried palm wood (Oba 1991).

In contrast to human exploitation, browsing by livestock based on utilization frequency data did not seem to have increased compared to the earlier surveys (Oba 1991). Livestock browsing might have promoted tree regeneration (Reid & Ellis 1995) and browse production (Oba 1998). In the downstream Turkwel River area livestock utilized 56% mature woody plants compared to 54% of saplings (G. Oba, unpublished data). In the current study, variations in livestock utilization frequency between 1990 and 1998 were probably related to yearly browse production variability, rather than browsing intensity. In the study area, sheep and goat density within <10 km of the riverine woodland during 1990 averaged about 70 animals km^2 (Turkana District Drought Monitoring Unit data). According to the interviews with the Turkana, population of sheep and goats had not changed significantly between 1990 and 1998. However, because livestock generally used the riverine woodlands during the dry season, if the surveys were conducted during the wet season they underestimated the browsing pressure. This was probably the case in 1998 (Stave 1999).

Further, processing and trading in charcoal is not a traditional method of woodland utilization by the Turkana pastoralists. According to the Turkana informants, charcoal exploitation was promoted by poverty and increased demands in urban areas. The sedentary pastoralists traded in charcoal and fuelwood, but the link between increased charcoal burning and decline in woody-plant density and wood volume is conjectural. Generally, charcoal processing did not initiate wood degradation; rather it involved harvesting of tree parts that did not constitute browse for livestock (Oba 1990). Although increased kiln density implied widespread exploitation of dead wood, some ekwar owners avoided harvesting, while others did not. According to the Turkana elders interviewed, the difference may be a reflection of economic status, with poor families extracting more than the wealthy.

Potential litter production and the ekwar quality index

The annual floods promoted woodland regeneration, and hence created distinct woodland patches (Hughes 1988, 1990; Oba 1991; J. Stave, unpublished data). Therefore, decline in woody-plant density and volume, which caused a decline in potential *Acacia tortilis* litter production, might have also been linked to changes in frequency of river floods and woodland disturbances. According to the Turkana pastoralists, flood frequency influenced *A. tortilis* seedpod production and tree survival (G. Oba, unpublished data). The effects of loss of ground water recharge by floodwater can be observed along dead river channels where there has been mass tree mortality (Oba 1991). The lower EQI is attributed to greater mortality of woody plants along dead channels. Thus, EQI may be used effectively in extension programs to inform pastoralists about the status of ngikwarin. By identifying reasons for the decline in EQI, the pastoralists may be helped to improve woodland conservation. The Turkana elders interviewed were aware of changes in ngikwarin conditions, but were unable to reduce NTFP extraction because they

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lacked legal powers to regulate use of the woodlands in the study area.

Conclusions

Ngikwarin constitute a system of land use and management of tree browse with broad implications for conservation of riverine woodland in Turkana. The ekwar system might have formerly helped conserve the Turkwel riverine woodlands, but the anthropogenic pressure and possible long-term impact of the dam might in future undermine any such functions. Another threat to the riverine woodland is a forestry policy that ignores indigenous tree tenure. Incorporating the silvo-pastoral system of ekwar into the policy of the Forestry Department may ensure sustainable exploitation of the woodlands in the lower Turkwel River floodplain. The Forestry Department should (1) give official recognition of the silvo-pastoral tree tenure system of ekwar, (2) use mapping to document ngikwarin ownership throughout the Turkwel River floodplain, registering owners as co-managers and beneficiaries of the forest produce, and (3) support the pastoralists to control exploitation of NTFPs by outsiders.

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