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Multiple use patterns of medicinal trees in an urban forest in Nairobi, Kenya

Takuya Furukawa[a,*], Samuel K. Kiboi[b], Patrick B. Chalo Mutiso[b], Kazue Fujiwara[c]

[a] Forestry and Forest Products Research Institute, 1 Matsunosato, Tsukuba, Ibaraki 305-8687, Japan
[b] School of Biological Sciences, University of Nairobi, P.O. BOX 30197-00100, Nairobi, Kenya
[c] Graduate School of Nanobioscience, Yokohama City University, Seto 22-2, Kanazawa, Yokohama 236-0027, Japan

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ABSTRACT

Medicinal plants support the healthcare needs of the most vulnerable human populations, including the rapidly increasing urban poor in developing countries. However, little is known about the role of urban forests in supplying traditional herbal remedies compared to those in rural areas. Different parts of medicinal species could be used to supply different forest products, and multiple uses may exacerbate impacts to the species. We focused on the debarking and cutting of woody species harvested for medicine and fuelwood in an urban forest in Nairobi, Kenya. Since informal harvest was common, we surveyed the signs of harvest (i.e., stem debarking and cutting) in the forest rather than conducting household interviews. The survey covered a total of 14,993 stems of 93 species, of which 9169 were standing and 5824 were cut. Among those standing, 172 stems of nine species were debarked. The barks of most of the nine species were known to be used as traditional medicine in the region. Debarking was concentrated on *Warburgia ugandensis* and *Elaeodendron buchananii*, which were also affected by cutting, and we analyzed them in detail. Debarking occurred primarily on larger stems of *W. ugandensis* and *E. buchananii*, and cutting more frequently involved smaller *W. ugandensis* stems. Debarking and cutting of *E. buchananii* was concentrated near the low-income housings adjacent to the forest. Patrolling nearly failed to protect either species from debarking and cutting. We discussed management options of the urban forest including reformed patrolling strategy and planting of useful species in degraded areas, and demonstrated how our approach could aid the management of informal and multiple uses of urban forest products.

1. Introduction

Forests provide essential ecosystem services in the form of plant stocks that can be used to meet the basic needs for food, medicine, materials and fuel (Belcher et al., 2005; Ticktin, 2004). Formal and informal harvests of such non-timber forest products (NTFPs) play key roles in supporting the livelihoods of the poorest community members in developing countries (Angelsen et al., 2014; Ticktin, 2004). Among the NTFP products, a surprising number of medicinal plant species are used to treat various symptoms (Estomba et al., 2006; Moshi et al., 2010; Vandebroek et al., 2004). Seeking traditional remedies continues to be a popular custom especially in developing countries because of its low cost, the low availability of modern medicine, and its cultural and religious preferences (Botha et al., 2004; Shackleton, 2009; Shanley and Luz, 2003). As a consequence, medicinal plants continue to support the healthcare needs of the most vulnerable human population including the rapidly increasing urban poor in developing countries (Gopal et al., 2015; Njoroge and Kibunga, 2007; Petersen et al., 2012).

Even though domestication and cultivation of useful medicinal plants have increased, the majority of plant materials are still harvested from the wild (Angelsen et al., 2014; Schippmann et al., 2002). The collection of medicinal plants for subsistence and trade is a prominent practice in rural communities in developing countries (Bista and Webb, 2006; Estomba et al., 2006). The flow of medicinal plant materials from rural areas to city centers sustains a large portion of the ever-increasing urban demand (Jusu and Sanchez, 2013; Williams et al., 2000), and studies highlight the great distances some plant materials can be transported before reaching the city (Botha et al., 2004; Jusu and Sanchez, 2014;

Abbreviations: AICc, Akaike Information Criterion for small sample sizes; DBH, diameter at breast height; GLMM, generalized linear mixed model; IOV, importance of variables; NTFP, non-timber forest product.

* Corresponding author.
E-mail addresses: tfurukawa@affrc.go.jp, tkyfurukawa@gmail.com (T. Furukawa), samuel.kiboi@uonbi.ac.ke (S.K. Kiboi), mutiso_chalo@uonbi.ac.ke (P.B.C. Mutiso), kazue@ynu.ac.jp (K. Fujiwara).

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Williams et al., 2000). In comparison, relatively little is known about the harvest and trade of medicinal plant materials within and near the city. In Suriname, urban vendors of traditional medicine, who also practice field collection, preferred visiting forests closer to the city for harvest (van Andel and Havinga, 2008), and designated commonages near the city are important sources of medicinal plants in South Africa (Davenport et al., 2012). One of the most comprehensive illustrations of informal harvest and trade of wild medicinal plants within cities is given by Petersen et al. (2012), where the authors found that more than half of the flora traded in the city of Cape Town, South Africa, is harvested within its boundary. In other regions, however, the extent of informal harvest of medicinal plant materials from urban forests remains largely unknown (Kuchelmeister, 2000).

Patterns and preferences of resource extraction are the reflection of demand and availability of the resource, and such information is useful for forest management (Furukawa et al., 2011a). Harvest of medicinal plant materials is selective in nature, targeting particular parts of specific species (Kokwaro, 2009). In Africa, tree bark is one of the most popular plant parts collected for medicinal use (Jusu and Sanchez, 2013; Williams et al., 2000), and harvest tends to be concentrated on known medicinal species with particular bark quality or size class (Cunningham and Mbenkum, 1993; Gaoue and Ticktin, 2007; Guedje et al., 2007). The ecological impacts of bark harvest can be detrimental to some non-resistant species (Chungu et al., 2007). Effects may also depend on management practices, harvest intensity, and climatic conditions (Delvaux et al., 2010; Gaoue and Ticktin, 2010). Medicinal trees can be subjected to multiple modes of harvests when different plant parts are used for different purposes including non-medicinal NTFP uses (Gaoue and Ticktin, 2007; Ticktin et al., 2012). Fuelwood collection predominates subsistence NTFP use in terms of quantity and frequency (Angelsen et al., 2014), and severe forest degradation as a result of intensive harvests (Furukawa et al., 2011b) can diminish the availability of medicinal species (Shanley and Luz, 2003). Furthermore, fuelwood collectors often harvest a wide range of species including those used for medicine (Furukawa et al., 2011a; Pote et al., 2006; Tabuti et al., 2003). This type of multiple use can impose a higher pressure on the local population of medicinal species than medicinal use alone (Gaoue et al., 2013; Gaoue and Ticktin, 2007; Ticktin et al., 2012). How each mode of harvest affects tree species could vary depending upon resource use patterns.

The pattern of NTFP harvest is also influenced by access to and conservation of forest resources (Albers and Robinson, 2013). Other than the rules regarding use of forest resources (Ghimire et al., 2005), travel cost is another underlying factor determining spatial harvest patterns; longer distances to the resource require more time and energy for collection (Albers and Robinson, 2013). Concentrated collection near settlements is commonly reported for fuelwood harvests (Furukawa et al., 2011a; Pote et al., 2006; Tabuti et al., 2003). However, the collection of other lighter NTFPs including medicinal plants might be less constrained by distance (Estomba et al., 2006; Perge, 2011). When NTFP harvest is conducted informally, enforcement activities might also influence the behavior of harvesters (Furukawa et al., 2011a; Petersen et al., 2012). Patrolling is widely used to control informal resource extraction, but empirical data are still sparse to inform spatial enforcement strategies (Albers and Robinson, 2013).

In this study, we investigated the patterns of two modes of NTFP harvest (i.e., stem debarking and cutting) that might affect the viability of medicinal tree species in an urban forest in Nairobi, Kenya. Since informal resource use was common in the study area (Furukawa et al., 2011a), we surveyed the signs of harvest (i.e., bark scars and stumps) left inside the forest rather than conducting interviews that could be biased towards friendly and cooperative resource use groups. This allowed us to sample a large number of potential resources subjected to both formal and informal NTFP harvests throughout the forest. We first examined whether bark harvest of medicinal tree species was commonly practiced in the urban forest and which species were most frequently targeted. Secondly, we analyzed the patterns of debarking and cutting of frequently used medicinal tree species and examined how multiple resource use affected each species. Patterns of resource harvest were investigated for size preference and spatial patterns in relation to distance from housings, representing travel cost, and from ranger stations, a proxy for patrol frequency. Based on the findings, we discussed management options of the urban forest, and demonstrated how our approach could aid the management of informal and multiple uses of urban forest products.

2. Materials and methods

2.1. Study site

The study site was located in Ngong Road Forest Reserve (1°19′S, 36°45′E), Nairobi, Kenya, managed by the Kenya Forest Service and its predecessor, the Forest Department, since 1932. The reserve harbors one of the largest green areas (approximately 1100 ha) in the rapidly growing city (Mundia and Aniya, 2006). The semi-deciduous indigenous forest (*Brachylanena-Croton* forest) is a now-rare remnant of the lower Afromontane forest of East Africa (Fujiwara et al., 2014; Lind et al., 1974). Selective logging occurred in the past, but relatively undisturbed sites still contain a diverse mix of indigenous broadleaf trees forming a closed canopy of more than 20 m in height (Hayashi et al., 2006; Kigomo et al., 1990), whereas an invasive alien shrub *Lantana camara* L. (Verbenaceae) has spread in heavily disturbed areas (Furukawa et al., 2011b).

An earlier study conducted by the authors revealed that the forest has been intensively and informally used by the urban poor for fuelwood and less frequently for a luxury carving wood (Furukawa et al., 2011a). Most of the fuelwood collectors entered the forest from the adjacent Kibera slum, which is one of the largest informal settlements in Africa with an estimated population of approximately 300,000, with most living below the national poverty line (da Cruz et al., 2006). An electric fence installed in 2003 was not fully functioning at the time of our survey because of frequent blackouts and poaching of wires. No people resided in the reserve on a regular basis. Forest rangers conducted daily patrols from four forest stations located inside the reserve (Fig. 1). According to the forest rangers, people from adjacent communities, including the Kibera slum, were allowed to harvest medicinal plant materials, including bark, on a permission basis, but informal harvests were also reported.

2.2. Data collection

The survey focused on the largest contiguous section of the reserve (about 600 ha) consisting of approximately 500 ha of indigenous forest, 80 ha of plantations (mostly *Eucalyptus* spp.), and small patches of grassland (Fig. 1). The area was divided into 87 grid cells (i.e., sampling units) of 250 m × 250 m (543.75 ha total; Fig. 1). In August and September 2009, we walked near the center of each grid cell and recorded the species name and diameter (≥3 cm) of each woody/semi-woody stem (both main and lateral) encountered during the survey. The survey covered both standing stems and stumps that were obviously cut by the people, and the diameters were measured at breast height and at the cut end, respectively. The presence/absence of scars on the bark of standing stems was also recorded. To record a large number of stems throughout the reserve, sampling was adjusted by time rather than by unit area. Minimum sampling effort was set to 45 min and 30 min per sam-