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Comparison of the Ecological Value of Sacred and Nonsacred Community Forests in Kaboli, Togo

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Abstract

Despite Togo's naturally low forest cover and high rates of deforestation, remnant forest patches play an important role in conserving biodiversity and ensuring the well-being of the country's human population. Many of these remnant forest patches are sacred forests, ecosystems that are increasingly threatened because of changes in belief systems which have accompanied westernization. This study compares the ecological value and level of degradation of two sacred forests with an otherwise similar control forest that does not contain a sacred site based on characteristics including tree cover, vegetation composition, biodiversity, and biomass. The sacred forests had a significantly higher percentage of tree cover, higher biodiversity, and a greater biomass than the forest that did not contain a sacred site. In addition, dominant species within the sacred forests were associated with deciduous dry forest ecosystems while dominant species within the forest not containing a sacred site were introduced plantation species and species associated with savanna ecosystems. These results indicate that sacred forests in Kaboli, Togo, have a higher ecological value and are less degraded than similar community forests that do not contain a sacred site. This important role of sacred sites in forest conservation suggests that feedback loops exist between social and ecological systems, and that both need to be considered together to achieve effective development of forest conservation strategies.

Keywords

sacred forests, sacred groves, biodiversity, dry forests, community-based conservation, West Africa

Introduction

Togo is a country with a naturally low forest cover because of its location in the Dahomey corridor, a break in the West African tropical forest resulting from dry winds originating in the Sahara Desert (Sayer, Harcourt, & Collins, 1992). In recent years, high rates of deforestation have led to the near eradication of certain rare forest types within the country. For example, dry forests in northern and central Togo have nearly disappeared (Kokou, Adjossou, & Kokutse, 2008). The United Nations Food and Agriculture Organization (FAO) reports that in 2015 only 188,000 ha of land, or 3.3% of the country's surface area was forested (Sama, Cozi-Adom, & Ditoatou-Tindandja, 2015). Togo has one of the highest rates of deforestation in the world and lost an average of 5% of its forest cover each year between 1990 and 2015 (FAO, 2015).

Deforestation in Togo is of particular concern considering the important role that forests play in maintaining ecological systems and ensuring the well-being of Togo's human population (Kokou et al., 2008; Kokou & Sokpon, 2006). Ecosystem services provided by forests are necessary for the maintenance of subsistence livelihoods practiced by many throughout the country. For example, residents of Kaboli clearly and consistently describe the role that forests play in increasing rainfall (S. Odohi, personal communication, April 14, 2015). This advantage of forested areas has also been demonstrated within the academic community (Makarieva & Gorshkov, 2007; Sheil & Murdiyarso, 2009), and even

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small forest patches in fragmented areas have the ability to significantly increase rainfall (Bonan, 2008). Forests in Togo also provide windbreaks that protect property and ensure safety during storms. For example, the village development committee of Kaboli has noted that metal roofs are more likely to be pulled from houses during rainstorms in communities lacking protective forest cover. These ecosystem services are increasingly important as unpredictable weather patterns linked to climate change increase the risk of drought, irregular rainfall, and windstorms, causing increased safety and food security concerns (Giannini, Saravanan, & Chang, 2003).

In addition to the provision of ecosystem services, community forests also play a direct role in subsistence activities and social and cultural life. Activities including hunting, gathering firewood, and the collection of medicinal plants and other nontimber forest products are regularly carried out in forests throughout Togo (Kokou, Adjossou, & Hamberger, 2005; Kokou et al., 2008). These activities rely heavily on the maintenance of biodiversity; many species used as sources of food or medicine are found exclusively in forest ecosystems. In addition, these forests are often valued by community members for their cultural and religious significance; sacred forests provide a space in which people can pray, carry out ceremonies, and connect with their ancestors (Kokou et al., 2008; Kokou & Sokpon, 2006).

Much of the remaining forest area in Togo is located inside sacred forests, or forests which have been maintained because of a religious or spiritual significance (Kokou et al., 2008; Kokou, Caballé, Akpagana, & Batawila, 1999). These sacred forests protect rare forest types, contain high levels of biodiversity, and harbor threatened species found nowhere else in the country (Kokou et al., 2008). Unfortunately, changes in belief systems resulting from the introduction of proselytizing religions (Christianity and Islam) have caused reduced respect for sacred forests, resulting in further degradation of these important habitats (Kokou et al., 2005, 2008; Kokou & Kokutse, 2007; Kokou & Sokpon, 2006). Research to understand the role that sacred forests play in biodiversity conservation, and effective strategies for ensuring their preservation are therefore becoming increasingly important.

While many studies have demonstrated the importance of sacred forests for biodiversity preservation (Bhagwat, Kushalappa, Williams, & Brown, 2005; Bosart, Opuni-Frimpong, Kuudar, & Nkrumah, 2006; Campbell, 2004; Kokou et al., 1999, 2008; Mgumia & Oba, 2003; Sanou, Devineau, & Fournier, 2013), others have pointed out limitations of the role that they are able to play in conservation (Decher, 1997). For example, while these ecosystems are often significantly less disturbed than the surrounding landscape, their small size and a lack of landscape connectivity can limit their value (Kokou et al., 2008). More case studies specifically comparing the ecological value of sacred forests with that of surrounding landscapes are therefore needed.

This study compares the ecological value and level of degradation of two sacred forests with an otherwise similar community forest that does not contain a sacred site. The level of forest degradation and ecological value are assessed based on the percentage tree cover within historic forest boundaries as identified by forest owners, the ecological role of dominant species, and measurements of biodiversity and biomass. We hypothesized that sacred forests would have a higher percentage tree cover within their historical boundaries, and that species associated with dry and semideciduous forests would be more dominant while introduced species would be less dominant within sacred forests than within community forests not containing sacred sites. In addition, we expected measurements of both biodiversity and biomass to be higher in sacred forests than in community forests not containing sacred sites.

Methods

Study Site

This study was carried out in three community forests surrounding the town of Kaboli, Togo, in West Africa. The town of Kaboli has a population of approximately 21,600 people (Togo Data Portal, 2010) and functions as a regional center where people from surrounding villages can visit the market or health center and attend school. The landscape can be categorized as Guinean savanna with interspersed patches of dry forest. Annual rainfall is between 1,200 and 1,500 mm which falls during the rainy season between May and October. The temperature ranges from 25 °C to 40 °C and the soil within this region is generally tropical ferruginous (Kokou et al., 2008).

The town of Kaboli is divided into nine different neighborhoods, each of which includes one or more large extended family groups. Each of these extended family groups has a distinct history and leadership structure. Land within and surrounding the town is divided between each of these family groups and includes residential areas, farmland, plantations, and community forests.

We examined three community forests. These include the Legu Forest which belongs to the Atafa family group, the Sabi Forest which belongs to the Sabi family group, and the Kala Forest which belongs to the Kala family group (Figure 1, Figure 2). These forests are located within 25 kilometers of Kaboli and have an area between 157 and 509 ha. In addition, they have similar histories and management structures. All the three were used 200 to 300 years ago by early residents as village sites because the dense forest allowed them to defend themselves from raids carried out by the neighboring Dahomey Empire,

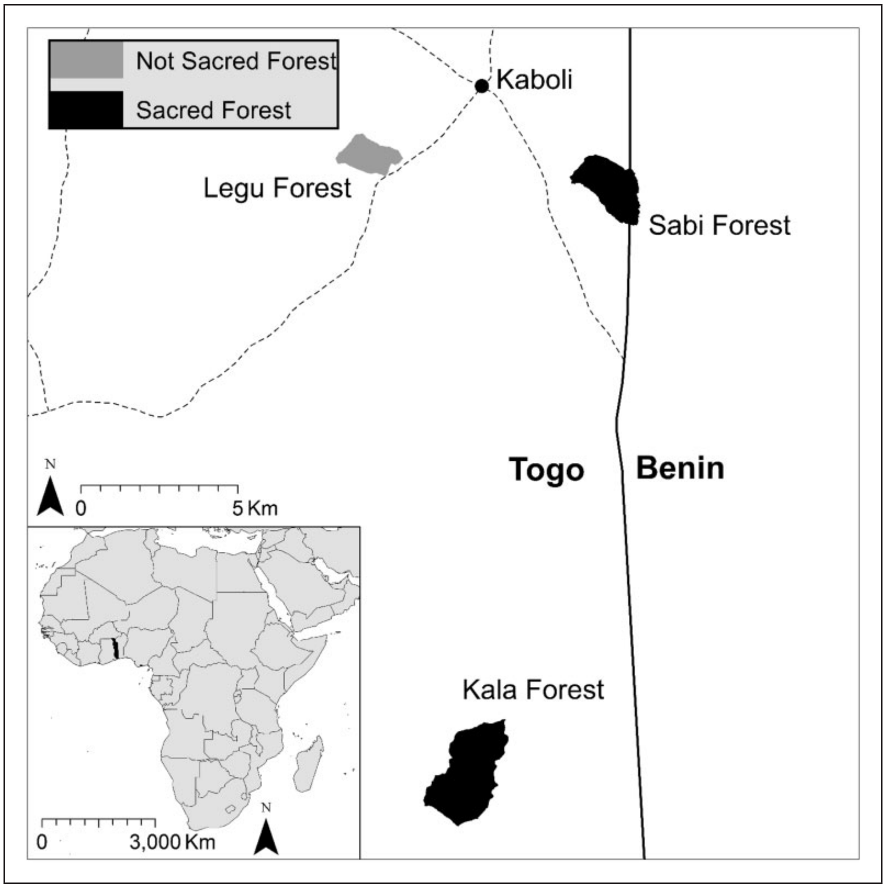

Figure 1. Map of the Legu, Sabi, and Kala community forests. Dotted lines represent major roads, and solid lines represent the Togo–Benin border. Inset in bottom left corner shows the location of Togo (in black) in Africa.

which was an important player in the trans-Atlantic slave trade (Manning, 1982). While there are several other community forests near the town belonging to other family groups, we chose to include these three forests in the study because we felt that the historical and management similarities between them would minimize the number of factors contributing to the ecological patterns observed, and therefore allow us to more accurately observe the effects of the presence of sacred sites within the forests. The Atafa, Sabi, and Kala family groups who own the community forests today are the descendants of the people who once inhabited these three forests. The chiefs, elders' councils, and land use committees of each of these three family groups make decisions regarding forest use and management.

The Sabi and Kala community forests function as sacred forests while the Legu Forest does not. We determined this based on conversations that occurred during focus group interviews with members of the Atafa, Sabi, and Kala family groups, which were conducted as part of a concurrent study. Permission was obtained from the chief of the Canton, the chief of each participating family, and the president of the Village Development Committee before data collection began. Three to six focus groups were carried out with the members of each family group and participants were separated by age (elders and younger adults) and gender during interviews to ensure that differences in status did not prevent certain groups from voicing their opinions (Kokou et al., 2008; Ormsby, 2011). Each focus group included between 3 and 15 participants. We chose participants who were active and well respected within the community, and who were knowledgeable about their family's forests. In many cases, family chiefs assisted in recruiting participants, who were often members of their family's women's group, young people's group, or elders' group. Interviews were conducted in either French or the local language, Kaboli. When interviews were conducted in Kaboli, a translator was used.

Family members were asked whether their community forests were used as sites for the practice of traditional religion. Members of Sabi and Kala explained that shrines to local gods exist within their forests in the places where their ancestors had previously lived. Members of the Atafa family reported that no shrines exist within their forest and that it has never been used as a religious site, although they did identify a nearby sacred site that falls outside the boundaries of the Legu forest.

Each of the *forests* considered in this study are part of a land use matrix which includes agricultural land, plantations, residential areas, and other forests. Because land use has changed over time, there are now areas of land falling within traditional forest boundaries which are deforested. While this deforestation is often the result of human activity, it is also important to note that in some cases the land may naturally be a savanna ecosystem. In addition, in some cases the *forests* considered in this study are bordered by other forests. Therefore, historical forest boundaries do not indicate the current boundaries of areas with tree cover. However, community members belonging to all three family groups refer to the land falling within the historical forest boundaries as a *forest*. In this article, the names "Legu Forest," "Sabi Forest," and "Kala Forest" will be used to refer to the historic forest boundaries which are still recognized by community members today despite changes that have occurred within all the three forests. These boundaries simply represent an area of land belonging to a certain group of people and used for certain purposes.

The term *sacred site* will be used to refer to specific shrines or other spiritually relevant landmarks existing within sacred forests. In most cases, the specific locations of these sites were not shared with us.

Tree Cover

We defined *tree cover* within the boundaries of each community forest based on the United Nations FAO's definition of *forest land*. According to the definition used by the FAO, forested land must have at least 10% crown cover by trees. Therefore, we considered survey plots to be *forested* when they had a crown cover greater than 10% and *nonforested* when they had a crown cover less than 10%. Other aspects of the FAO's definition of forest land were not considered in our determination of tree cover. For example, the FAO definition requires that land considered to be forest must not be used for agricultural or urban purposes, and defines land that does not currently meet the thresholds but has the potential to meet them in the future as forest land (Forest Resources Assessment, 2010). As these characteristics cannot be determined based on satellite images, they are not considered here.

We mapped historic boundaries of each of the three community forests (Legu, Sabi, and Kala) using a GPS unit. Chiefs and elders helped to identify community members who were knowledgeable about the forests and would be able to identify forest boundaries. In all cases, the historic boundaries of the forests were larger than the currently forested areas. We chose to map historic forest boundaries in order to be able to compare the percentage of tree cover within the boundaries of each locally recognized community forest. In doing this, we assume that land falling within historical forests was entirely forested at the time when their boundaries were first delimited. As we are using the FAO's definition of *forest land*, which considers any land with greater than 10% tree cover to be forested, we believe that this is a fairly reasonable assumption despite the potential historic presence of savanna ecosystems within forest boundaries.

A community forests polygon layer was created based on the GPS forest boundary data. We obtained satellite images from the year 2014 from Google Earth for each forest. We then geo-referenced these images based on control points created in Google Earth. All maps were projected to WGS 1984 UTM Zone 31.

We used maximum likelihood classification in ArcGIS to categorize land as either forested or nonforested. The model used for classification was created based on 36 randomly placed training polygons with a radius of 20 m within the boundaries of the three community forests considered, and the satellite images acquired from Google Earth. We combined the Google Earth images using the "Mosaic to New Raster" tool with a mosaic colormap setting of "MATCH" in order to create a single image that could be used to accurately compare forest cover between the three sites.

A naive estimate ($\mu_{f,naïve}$) of forest cover indicating the proportion of pixels within historic forest boundaries classified as forest was calculated based on the maximum likelihood raster maps produced. We tested the accuracy of the classification using 37 randomly placed validation points (Magdon, Fischer, Fuchs, & Kleinn, 2014; McRoberts & Walters, 2012). First, we determined the bias of the model based on the following equation:

$$\widehat{\text{Bias}}(\mu_{f,naive}) = \frac{n_{01} - n_{10}}{n} \quad (1)$$

where n_{01} represents validation points where pixels that were actually nonforest were incorrectly classified as forest by the model, n_{10} represents validation points where pixels that were actually forest were incorrectly classified as nonforest by the model, and n represents the total number of validation points used.

This measurement of bias was then subtracted from the naive estimate of tree cover in order to create a corrected estimate, $\hat{\mu}_f$, of the proportion of forest cover within historic forest boundaries:

$$\hat{\mu}_f = \frac{1}{N}\sum_{i=1}^{N}\hat{y}_i - \frac{n_{01} - n_{10}}{n} \quad (2)$$

and the variance of this model was calculated as

$$\hat{\text{Var}}(\hat{\mu}_f) = \frac{1}{(n-1)}\left[(1 - OA) - \hat{\text{Bias}}(\hat{\mu}_{f,naive})^2\right] \quad (3)$$

where OA represents overall accuracy, or the proportion of validation points that were correctly classified.

Based on this measurement of variance, 95% confidence intervals of forest cover were created for each of the three forests considered:

$$CI(\hat{\mu}_f) = t_{1-\frac{\alpha}{2}}\left(\sqrt{\hat{Var}(\hat{\mu}_f)}\right) \quad (4)$$

where t represents the $1-\frac{\alpha}{2}$ percentile of the students distribution. We then used these confidence intervals to determine whether or not the percentage tree cover within sacred forests (Sabi and Kala) was significantly greater than the percentage tree cover within the Legu Forest which did not contain a sacred site (Magdon et al., 2014; McRoberts & Walters, 2012).

Vegetation Characteristics

We chose random survey points so that 1% of each forest would be surveyed. In the case of the Sabi Forest, a portion of the forest fell on the other side of Togo's border with Benin and had been the subject of a long land use conflict between Sabi and Biguna, a town on the other side of the border. As permission could not be obtained from residents of Biguna to carry out research on this portion of land, it was excluded from the survey. A total of 13 survey points was used in the Legu Forest, 19 in the Sabi Forest, and 41 in the Kala Forest.

Each plot was a circle with a radius of 20 m. All trees with a diameter at breast height (DBH; diameter of the tree 1.3 m from the ground) of more than 10 cm falling within the circle were included in sampling. Sampling began in the North and continued clockwise around the circle. We identified sampled trees to species when possible and otherwise to the most specific achievable taxonomic rank. Unidentified species at each survey point were given a unique identifier so that they could be included in biodiversity and biomass calculations. We measured the DBH of all trees. If a tree had multiple trunks, we included all trunks with a DBH greater than 10 cm. We also included vines meeting the size specifications described in this survey as they contribute to measurements of biodiversity and biomass, and represent an important component of these forest ecosystems. Like trees, vines were measured 1.3 m from their base. We also estimated tree height using a basic handmade protractor and pendulum clinometer. A smaller circle with 4 m diameter was drawn at the center of the larger circle. Trees and vines with a DBH between 5 and 10 cm were identified and measured within this circle. We carried out forest surveys during the 2016 rainy season between May and August.

We used the data collected during forest surveys to compare the biomass of the three forests. We estimated the biomass of each individual tree based on DBH, height, and wood density using the pantropical allometric equation proposed in Chave et al.'s (2014) article, where AGB_{est} represents estimated above ground biomass (AGB, Mg/ha), ρ represents wood density (g/cm^3), D represents DBH (cm), and H represents the total height of the tree (m):

$$AGB_{est} = 0.0673(\rho D^2 H)^{0.976} \quad (5)$$

We acquired wood density values for individual species or groups of species from the Global Wood Density Database (Zanne et al., 2009). In cases in which the wood density was not available for a particular species, we used an average of the wood density for the genus. When the wood density was not available at the genus level or the individual was unidentified, we used a site average of density (Dayamba, Djoudi, Zida, Sawadogo, & Verchot, 2016). We chose this model over other general tropical models (Brown, 1997; Chave et al., 2005) because it was developed using comparatively large datasets, included data points from African forests, and included larger trees with a DBH up to 212 cm (Chave et al., 2014).

In addition, data collected during forest surveys was used to compare the biodiversity of vegetation communities within sacred forests with those within the forest that did not contain sacred sites. Species richness, Shannon's diversity index, and the Berger–Parker index were used to measure biodiversity. We chose these three measures in order to address the effects of both rare and abundant species on biodiversity. Species richness is more effective in measuring changes in biodiversity when rare species are more affected while the Berger–Parker index is more effective in measuring biodiversity when abundant species are more affected. It has been suggested that Shannon's diversity index can be effective when the roles of both rare and abundant species are relevant (Morris et al., 2014). The Berger–Parker index is a measurement of the proportion of a community made up of the most abundant member of that community (Berger & Parker, 1970). The Shannon index can be represented by the following equation, where f_i represents the proportion of total individuals belonging to a particular species i (Condit et al., 1996):

$$H' = f_i \ln \sum (f_i) \quad (6)$$

Following the calculation of AGB and biodiversity, statistics were used to determine whether the AGB, species richness, Shannon diversity index, and Berger–Parker diversity index were significantly different between the Legu Forest which did not contain a sacred site and the Sabi and Kala Forests which were sacred forests. First, we used the Shapiro–Wilks test to test for normality of data. As several data sets were found to violate the normality assumption, we used the nonparametric Kruskal–Wallis test rather than an analysis of variance to test whether significant differences in AGB and biodiversity existed between the Legu Forest and the Sabi and Kala Forests. A Mann–Whitney test with a Bonferroni correction was used as a post-hoc test to determine which differences were significant and which were not. As our hypothesis was that sacred forests would have a higher biomass and biodiversity than forests without a sacred site, we compared the biomass and biodiversity of the Legu Forest with that of the Sabi and Kala Forests, but did not compare the biomass and biodiversity of the Sabi and Kala Forests with each other.

Results

Tree Cover

The two sacred forests considered in this study were found to have a significantly higher percentage tree cover within their historical boundaries than the community forest that did not contain a sacred site. The overall areas of the Legu, Sabi, and Kala Forests were 158, 275, and 509 ha, respectively. The Sabi and Kala Forests, which were both sacred forests, had corrected tree cover estimates of $88 \pm 6\%$ and $98 \pm 6\%$, respectively, while the Legu Forest, which did not contain a sacred site, had a corrected tree cover estimate of only $62 \pm 6\%$. (see Table 1 and Figure 3).

Vegetation Characteristics

The three most common species observed within both the Kala and Sabi forests were *Anogeissus leiocarpus* (making up 13.16% and 17.55% of individuals in each forest, respectively), *Cola millenii* (making up 12.67% and 6.64% of individuals in each forest, respectively), and *Pouteria alnifolia* (making up 8.33% and 16.22% of individuals in each forest, respectively). All three of these species are associated with deciduous dry forests (Hutchinson, Dalziel, Keay, & Hepper, 1972; Kupicha, 1983; Kokou et al., 2008). *C. millenii* is especially common in secondary forests while *P. alnifolia* is a common understory species in deciduous forest, lowland rainforest, and riverine forest (Hutchinson et al., 1972; Kupicha, 1983).

Table 1. Total Area and Percentage Land Cover by Forests and Fields of Community Forests.

Forest	Total area (ha)	Size relative to largest forest	Percentage forest cover	Percentage field cover
Legu Forest	158	31%	62 ± 6	38 ± 6
Sabi Forest	275	54%	88 ± 6	12 ± 6
Kala Forest	509	100%	98 ± 6	2 ± 6

The three most common species found within the boundaries of the Legu Forest were *Anacardium occidentale* (making up 24.76% of individuals), *Tectona grandis* (making up 19.42% of individuals), and *Parinari curatellifolia* (making up 8.25% of individuals). *A. occidentale* and *T. grandis* are both plantation species. The nuts of *A. occidentale* (cashews) are sold as a cash crop while *T. grandis* is harvested for lumber. *P. curatellifolia* is associated with savannas (Hutchinson et al., 1972).

Based on three different measurements, biodiversity was generally found to be higher in the Sabi and Kala Forests than in the Legu Forest. The average species richness of survey plots was 5.46 for the Legu Forest, 8.79 for the Sabi Forest, and 14.51 for the Kala Forest (see Table 2). The species richness of the Kala Forest was found to be significantly higher than that of the Legu Forest ($p = 1.206 \times 10^{-5}$) while no significant difference was found between the species richness of the Sabi Forest and the Legu Forest ($p = .1055$). The mean Shannon diversity index was 1.13 for the Legu Forest, 1.67 for the Sabi Forest, and 2.22 for the Kala Forest (see Table 2). Mean Shannon diversity index values of both the Sabi Forest ($p = .02477$) and the Kala Forest ($p = 7.067 \times 10^{-6}$) were found to be significantly higher than those of the Legu Forest. Finally, the mean Berger–Parker diversity index was 0.59 for the Legu Forest, 0.38 for the Sabi Forest, and 0.30 for the Kala Forest (see Table 2). Mean Berger–Parker diversity index values of both the Sabi Forest ($p = .00448$) and the Kala Forest ($p = 4.738 \times 10^{-5}$) were significantly lower than those of the Legu Forest, indicating that the most common species made up a greater proportion of total individuals in the Legu Forest than in the Sabi or Kala Forests.

AGB was also found to be significantly higher in the Sabi ($p = .0003704$) and Kala ($p = 3.427 \times 10^{-6}$) Forests than in the Legu Forest. The mean AGB of plots within the Legu Forest was 22 Mg/ha, the mean AGB of plots within the Sabi Forest was 104 Mg/ha, and the mean AGB of plots within the Kala Forest was 131 Mg/ha (see Table 2). This indicates that community forests with sacred sites in them stored more biomass than the community forest that did not contain a sacred site.

Discussion

These results indicate that community forests containing sacred sites (the Sabi and Kala Forests) in the town of

Figure 2. Photographs of the Legu, Sabi, and Kala community forests. Top left: Remnants of a "yaa" from the time of the slave trade, located in the Legu Forest. These ditches, filled with spikes and hidden with brush, were used to trap kidnappers. Top right: Patch of regenerating secondary forest in the Sabi Forest. Bottom left: Technician collecting data in the Kala Forest. Bottom right: A woman clearing brush in the Legu Forest. Photos taken by Lauren Lynch.

Kaboli were less degraded and had a higher ecological value than a similar community forest (the Legu Forest) that did not contain a sacred site. The Sabi and Kala Forests had significantly higher percentages of tree cover within their historical boundaries than the Legu Forest. In addition, the most frequently encountered species within the Sabi and Kala Forests were species associated with deciduous dry forests while the most frequently encountered species in the Legu Forest were introduced plantation species and species associated with savanna habitat. While the species richness in the Sabi Forest was not significantly higher than the Legu Forest, the Kala Forest did have significantly higher species richness. With respect to two other measures of biodiversity, the Shannon and Berger–Parker diversity indices, both the Sabi and Kala Forests were significantly higher than the Legu Forest. Average AGB was more than four times higher in both the Sabi and Kala Forests than in the Legu Forest.

While a variety of vegetation characteristics indicate lower levels of degradation in the Sabi and Kala Forests, it is important to note that animal communities were not considered in this study and that healthy flora does not necessarily indicate healthy fauna (Redford, 1992). Further research investigating the characteristics of taxa such as birds and mammals would be valuable and allow for a more complete understanding of sacred forest ecosystems in Kaboli.

These results align with those of previous studies which have suggested that sacred forests in West Africa act as important refuges for biodiversity (Bosart et al., 2006; Campbell, 2004, 2005; Decher, 1997; Kokou et al., 2008; Kokou & Kokutse, 2007). Kokou et al. (2008) explain that sacred forests in Togo are generally composed of typical forest affinity species, host high levels of biodiversity, and provide habitat for numerous species found nowhere else in the country. The Kala and Sabi Forests are especially valuable for biodiversity conservation because of their large sizes. While the average size of sacred forests in Togo is 0.74 ha (Kokou et al., 2008), tree cover within the Sabi and Kala Forests covers areas of 242 and 499 ha, respectively. This advantage is particularly relevant for biodiversity conservation considering that dispersal limitations and lack of genetic diversity within small forest patches is one of the main limitations of the conservation value of sacred forests in the region (Decher, 1997).

Table 2. Vegetation Characteristics of Community Forests.

Forest	Species richness	Shannon index	Berger–Parker index	Above ground biomass (Mg/ha)
Legu Forest	5.46	1.13	0.59	22
Sabi Forest	8.79	1.67	0.38	104
Kala Forest	14.51	2.22	0.30	131

The biomass of the Sabi and Kala Forests is relatively high compared with the results of other studies in the region (Baccini, Laporte, Goetz, Sun, & Dong, 2008; Carreiras, Vasconcelos, & Lucas, 2012; Dayamba et al., 2016), suggesting that in addition to conserving biodiversity, sacred forests in Kaboli provide important local carbon sinks. Baccini et al. (2008) report that closed deciduous forests across tropical Africa have an average AGB of 85 Mg/ha. Based on this measurement, the Sabi and Kala Forests, with an average AGB of 104 and 131 Mg/ha, fall well above average in terms of carbon storage. The Legu Forest, with a mean AGB of

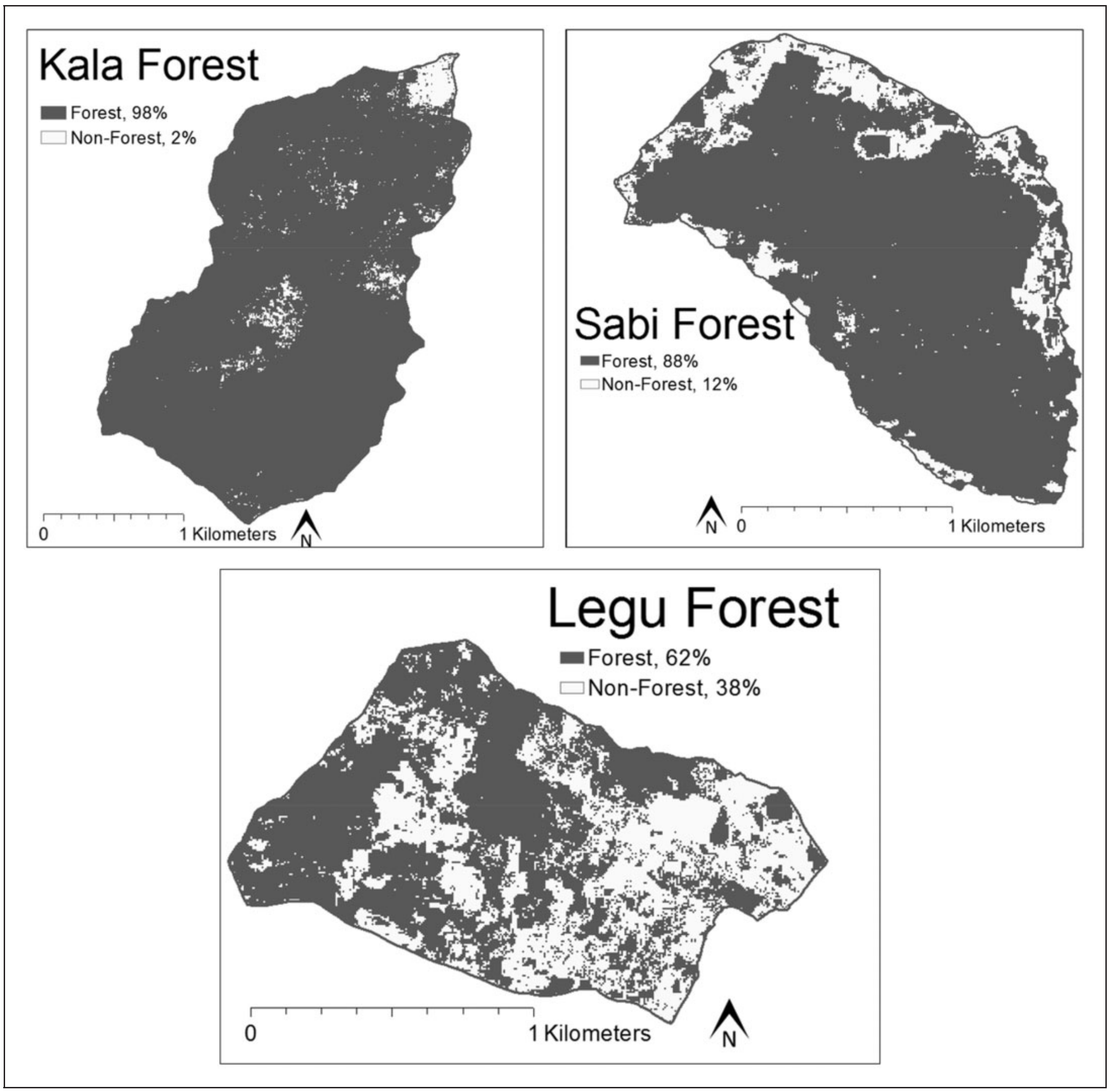

Figure 3. Land cover maps of each of the three forests considered in this study. The Sabi and Kala Forests are sacred forests while the Legu Forest does not contain a sacred site.

22 Mg/ha, was more similar to biomass measurements reported for more open deciduous woodland ecosystems (Baccini et al., 2008; Carreiras et al., 2012).

The results of this study indicate that the Kala and Sabi Forests may have particular conservation value compared with other sacred forests in the region. Considering this, it is important to note that the ecological characteristics of the sacred forests considered in this study are likely to differ from those of other sacred forests in Togo. However, the Legu Forest was chosen as a control site because of its similarities with the Kala and Sabi Forests; it is also much larger than the majority of community forests in Togo. Therefore, we do not believe that the large size of the forests detracts from our ability to consider the differences between sacred forests and those not containing a sacred site.

Authors have suggested that the strength of the sacred forest system comes from its relevance to the beliefs, traditions, and lifestyles of local communities (Kokou et al., 2008). Even today, many people living near sacred forests respect the gods and ancestors living within them and fear the consequences of upsetting them (Barre, Grant, & Draper, 2009; Campbell, 2004, 2005; Gottlieb, 2008; Kokou et al., 2005). Residents of the Sabi family in Kaboli explain that their forest is protected by several different gods, and that these gods can cause problems for people who fail to follow community-imposed regulations regarding the sustainable use of natural resources within them. For example, somebody who has harvested a tree within the forest without permission could become lost in the forest and unable to escape unless aided by a member of the Sabi family.

Despite this protection, sacred forests across Togo have suffered high levels of deforestation and degradation. For example, of nine sacred forests mapped in southern Togo in 1998, seven had decreased in size when revisited in 2006. Of those seven, three lost over half of their area (Kokou & Kokutse, 2007). The Sabi and Kala Forests are not exceptions to this rule. While they remain significantly more intact than the Legu Forest, both have experienced deforestation and degradation. Members of the Sabi family group explain that conservation of their forest has become increasingly difficult in recent years, saying that lack of respect for the forest has caused several of the gods who previously protected it to move elsewhere.

Implications for Conservation

The results of this study contribute to a large body of research which suggests that sacred forests can contribute significantly to the conservation of biodiversity (Bhagwat et al., 2005; Bosart et al., 2006; Campbell, 2004; Decher, 1997; Kokou et al., 1999, 2008; Mgumia & Oba, 2003; Parthasarathy and Karthihayan, 1997; Sanou et al., 2013). While in many cases, ecological conservation is not the primary intended function of these forests, they nevertheless play an important role in the conservation of ecological systems (Lebbie and Guries, 2008). It is therefore important that natural resource managers consider the interactions between social and ecological systems when developing strategies for forest conservation in West Africa.

Residents of Kaboli and academic researchers have both indicated that changes to religious systems resulting from westernization and the introduction of proselytizing religions present a significant threat to forest ecosystems in West Africa (Campbell, 2004, 2005; Kokou et al., 2005, 2008; Kokou & Kokutse, 2007; Kokou & Sokpon, 2006). Considering this, the role of local religious systems should not be discounted by those interested in encouraging the preservation of remnant forest patches in Togo. Recognition by scientists and natural resource managers of the social and cultural factors contributing to forest conservation, and respect for indigenous knowledge systems by the scientific community are a prerequisite for effective forest conservation.

Authors' Note

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Data Availability Statement

The data sets generated during the current study are available from the corresponding author on reasonable request.

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