Understory species diversity, regeneration and recruitment potential of sacred groves in south west Nigeria

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Abstract
Global species extinction rates due to forest conversions are increasing. Ecologists, conservationists and governments have adopted various conservation methods. Sacred grove is one conservation option that has gained attention in recent time. We assessed understory species diversity, regeneration and recruitment potentials of four sacred groves in southwestern Nigeria. Overstory tree species were inventoried in eight 800 m² temporary sample plots, systematically laid along two transects of 1000 m each. Understory tree species were assessed in 100 m² plots for saplings and 25 m² plots for seedlings in all sample plots. Shannon–Wiener diversity index (1.8–3.46 (overstory); 2.65–3.55 (understory)), number of species (32–58 (overstory); 39–78 (understory)) and tree density (309–417 individuals/ha (overstory); 775–1445 individuals/ha (understory)) were comparable and/or higher at the understories than the overstories. Dbh distribution curves showed highest stand density at the lowest class (10–20 cm) and decreased with increasing dbh, indicating good regeneration status and healthy ecosystem. Regeneration was considered good and fair, because in most cases, number of seedlings > saplings > overstory trees or number of seedlings > saplings ≤ overstory trees. The good regeneration status was further confirmed by the good species recruitment in the understory. However, the high influx of people into sacred groves for festivals and rituals, which results in trampling and burning of seedlings, is a threat to the diversity, regeneration and recruitment potentials of the groves. High regeneration and recruitment status maintained in all the sacred groves in this study were achieved using taboos, cultural and traditional methods. These methods could be incorporated in managing forest reserves in Southwestern Nigeria.

Keywords Biodiversity conservation · Ecological indicators · Ecosystem services · Natural regeneration

Introduction
Biodiversity is essential for the wellbeing of the ecosystem but the escalating extinction crisis shows that the diversity of nature can no longer support the current pressure that humanity exerts on the forest (Shushma et al. 2015). High density and diversity of species in rainforests have attracted incessant disturbances of the ecosystem through high harvesting pressure (both legal and illegal) (Onyekwelu et al. 2008) and other anthropogenic activities. Species extinction rate is increasing, reaching up to 1000 or more times higher than the natural rate because of habitat destruction, land conversion for agriculture and development, climate change, pollution and the spread of invasive species (Shushma et al. 2015). Consequently, ecologists, conservationists and governments have recommended and adopted various conventional and traditional conservation methods. One of the methods that have gained attention in the recent past is the use of traditional practices in protecting and managing biodiversity, among which the sacred grove system is prominent (Daye and Healey 2015). In Nigeria and elsewhere, sacred groves have been observed to play important role in biodiversity conservation (Bhagwat and Rutte 2006; Khan et al. 2008; Kokou et al. 2008; Onyekwelu and Olusola 2014). Many studies have assessed the population, structure and biodiversity conservation potentials of the overstory layers of sacred groves in Nigeria (Onyekwelu and Olusola 2014; Salami and Akinyele 2018; Ikyaagba et al. 2019). However, studies on understory tree species diversity in sacred groves...
are rare while no known study has assessed the regeneration and recruitment potentials of sacred groves in Nigeria.

The forest understory is an integral component of the forest ecosystem, thus it demands as much attention as the overstory. Ecologically, understory tree species play a fundamental role in diversity, structure, and functioning of forest ecosystems (Svenning 2000). They support a large fraction of total community floristic diversity and provide habitats and food for many kinds of animals (Tchouto et al. 2006). The forest understory plays a central role in the dynamics of forest ecosystems by influencing long-term successional patterns and contributing to forest nutrient cycling (Chastain et al. 2006). It has been suggested that the forest understory may show different patterns of species diversity than the overstory due to different responses to light level, nutrient availability, and temperature (Svenning 2000) and could be as species-rich as the forest overstory (Tchouto et al. 2006) or even richer.

Sacred groves have been noted to harbour many commercially important and highly valuable tree species, they are religio-culturally and socio-economically important to their communities, hence their sustainability is key to their host communities (Onyekwelu and Olusola 2014; Adeyanju 2020). But today, sacred groves are confronted with anthropogenic infringement. Therefore, the task of finding suitable strategies to enhance regeneration and species recruitment in sacred groves becomes inevitable. Regeneration is a biological process that involves asexual and sexual reproduction, seed dispersal and establishment of seedlings (Barnes et al. 1997); successful regeneration and vigorous height growth lead to recruitment. In silviculture, recruitment is a process by which trees move from one size class to another (Helms 1998) or by which young trees overgrow certain threshold values of height or diameter (Lexerod and Eid 2005). Greene et al. (1999) listed the factors that could influence the density and composition of seedlings in forest ecosystems to include: site conditions, seed rain and seed banks, light conditions, competition, intra- and inter-species relations.

Regeneration of forest trees is essential for conservation and maintenance of biodiversity in forest ecosystems as well as for forest management. The knowledge of plant regeneration status helps in developing management options and setting priorities. Limited tree regeneration is a major threat to forest sustainability. The satisfactory natural regeneration behaviour of the forests depends on population structure characterized by the production and germination of seed, establishment of seedlings and saplings in the forest (Khumbongmayum et al. 2006). Complete absence of tree seedlings and saplings in a forest indicates poor regeneration, while presence of sufficient number of seedlings indicate successful regeneration (Saxena and Singh 1984). In Nigeria, sacred groves serve as source of food, income, energy, medicine and shelter (Oyelowo et al. 2014). They are also known to harbour economic tree species that are threatened by extinction in our primary and secondary forests (Onyekwelu and Olusola 2014). Despite the biodiversity conservation merits of sacred groves and their importance in sustaining and maintaining biodiversity, studies on tree species regeneration status in Nigerian sacred groves are scanty. Also, no known study has evaluated the regeneration status and recruitment potentials of the sacred groves of this region. Therefore, an attempt was made in this study to fill this knowledge gap. Consequently, this study was aimed at evaluating the understory tree species diversity in the studied sacred groves. Seedlings regeneration status and recruitment potentials of sacred groves in Southwestern Nigeria were also assessed.

**Methodology**

The study was carried out in southwestern region of Nigeria made up of six federal States of Lagos, Ogun, Oyo, Osun, Ekiti and Ondo (Fig. 1). The region lies between longitude 2° 31’ and 6° 00’ East and Latitude 6° 21’ and 8° 37’ N with land area of 77,818 km² (Agboola 1979). A high percentage of the region lies within the tropical rainforest zone of Nigeria. Annual rainfall ranges between 1400 and 4000 mm while mean temperature varies between 21 and 34 °C. Rainy season occurs between the months of April and November while dry season lasts from December to March. Soils are predominantly ferruginous tropical, typical of the variety found in intensively weathered areas of basement complex formations in the rainforest zone of southwestern Nigeria (Onyekwelu et al. 2008).

Osun-Osogbo sacred grove is located outside Osogbo town in Osun State, Nigeria, it is dedicated to the Osun goddess. It is dotted with 40 sanctuaries and shrines, two palaces and several sculptures and artworks in honour of the Osun goddess. The sacred grove, which is a Nigerian national monument and a UNESCO World Heritage site since 2005, covers an area of 75 ha. Igbo-Olodumare sacred grove is located in Igbo-Olodumare town in Okeigbo/Ile-Oluji local government area of Ondo state, Nigeria. It covers an area of 7 ha and is known for its spiritual significance. The sacred grove harbours many mysterious and wonderful enclaves. Idenre Hills is one of the most awesome natural landscapes in Ondo State, Nigeria. It consists of high plains with spectacular valleys interspersed with inselbergs of about 3000 ft above sea level. Idenre Hills sacred grove covers an area of 48 ha and its physical attributes include Owa’s Palace, Shrines, Old Court, Belfry, Agboogun footprint, burial mounds for kings, etc. Ogun-Onire sacred grove is located in Ire-Ekiti community in Ekiti State, Nigeria. It covers an area of about 10 ha. The sacred grove is dedicated to Ogun, the Yoruba god of iron. In Yoruba mythology, Ogun is referred to as the leader of the deities because it is believed that he

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led other deities in Yoruba land to the earth. All the sacred groves are protected using taboos and strict restrictions.

**Method of data collection**

Out of the sacred groves in southwestern Nigeria, four (Osun-Osogbo, Igbo-Olodumare, Idanre Hills and Ogun-Onire) were purposefully selected based on prominence/significance, accessibility and permission to conduct inventory. The selected groves covered three (Ekiti, Ondo and Osun) of the six southwestern states. Two line transects of 1000 m each in length, separated by a distance of at least 1000 m were laid approximately at the middle of each sacred grove. Temporary sample plots of 40 m x 20 m were laid on alternate sides along each transect at every 250 m interval, giving a total of 4 plots per transect, 8 per sacred grove and 32 for the study. Within each sample plot, all trees with Dbh ≥ 10 cm were identified and their Dbh and total heights measured. For tree sapling enumeration, a 10 m x 10 m sub-plot was laid at the middle of each plot. All saplings (Dbh > 1.0 cm but < 10 cm) were identified and their dbh measured. A 5 m x 5 m quadrant was laid within each sub-plot for seedlings (Dbh < 1.0 cm) enumeration. Frequencies of identified seedling species were recorded. The scientific names of all trees and their authorities were confirmed using the Flora of West Tropical Africa by Hutchinson and Dalziel (1954).

**Data computation and analysis**

The following biodiversity indices were computed:

(i) Species area curve for each of the sacred groves was obtained by plotting the cumulative number of the species encountered within the sample plots against the cumulative area of the plots following the method of Scheiner (2003). Other biodiversity indices were calculated using the following formulae:

(ii) Relative frequency (RF)

\[
RF = \frac{\text{Frequency of a species}}{\text{Sum frequencies of all species}} \times 100.
\]

(iii) Species relative density (RD)

\[
RD = \frac{n_i}{N} \times 100,
\]

where RD (%) is the species relative density; \(n_i\) is the number of individuals of species i; \(N\) is the total number of all tree species in the entire community.

(iv) Species relative dominance (RDo (%))

![Fig. 1 Map of southwestern Nigeria showing the locations of the selected sacred groves](image-url)
\[ RD_o = \frac{\sum Ba_i \times 100}{\sum Ba_n} , \]

where \( Ba_i \) is the basal area of individual tree belonging to species \( i \); \( Ba_n \) is the stand basal area.

(v) Importance value index (IVI):

\[ IVI = RF + RD + RD_o . \]

(vi) Sorensen’s species similarity index

\[ SI = \left(\frac{2C}{a + b}\right) \times 100 , \]

where \( C \) is the number of species common to sites \( a \) and \( b \); \( a, b \) is the number of species at sites \( a \) and \( b \).

(vii) Species diversity index was calculated using the Shannon–Wiener diversity index

\[ H' = -\sum_{i=1}^{S} p_i \ln(p_i) , \]

where \( H' \) is the Shannon–Wiener diversity index; \( P_i \) is the proportion of \( S \) made up of the \( i \)th species, \( \ln \) is the natural logarithm

(viii) Shannon’s maximum diversity index

\[ H_{\text{max}} = \ln(S) , \]

where \( H_{\text{max}} \) is the Shannon’s maximum diversity; \( S \) is the total number of species in the community.

(ix) Species evenness

\[ E_H = \frac{H'}{H_{\text{Max}}} = \frac{\sum_{i=1}^{S} p_i \ln(p_i)}{\ln(S)} , \]

(x) Margalef’s index

\[ D = \frac{S - 1}{\ln(N)} , \]

where \( S \) is the number of species; \( N \) is the number of individuals.

The five most dominant tree species in each sacred grove were selected for regeneration assessment. Regeneration status was determined based on population sizes of seedlings, saplings, (Bhuyan et al. 2003; Khumbongmayum et al. 2006) and overstory trees. Regeneration was categorized as: (i) good regeneration: seedlings > saplings > overstory trees; (ii) fair regeneration: seedlings > or ≤ saplings ≤ adults; (iii) poor regeneration: the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults); (iv) if a species is present only at adult stage it is considered as not regenerating (Khumbongmayum et al. 2006); and (v) species is considered as ‘new’ (recruitment) if the species has no adults and saplings but only seedlings. In this study, a species was considered unique to a sacred grove if found only in that sacred grove. Also, a species was considered endemic if it is only found in a sacred grove and never been reported in any forest site in southwestern Nigeria based on the information at our disposal.

**Results**

Generally, the number of tree species increased with increase in area coverage, though the rate of increase varied among the sacred groves (the rate was highest and lowest at Ogun-Onire and Igbo-Olodumare groves, respectively) (Fig. 2). Compared to other sacred groves, Igbo-Olodumare grove had the highest number of species at 800 m² and the lowest from area of 4000 m² upwards, which was attributed to the observed marginal increase in the number of species with increase in area covered in this sacred grove. Thus, for Igbo-Olodumare, most of the tree species were encountered within a small area, there was indication that further increasing the sampled area will not lead to commensurate increase in the number of species in this sacred grove (Fig. 2). The reverse is the case for Ogun-Onire and Osun-Osogbo groves.

The overstories and understories of the studied sacred groves were dominated by few tree species. Results of species relative dominance revealed that seven tree species occupied between 66.06 and 85.69% of the overstories and 60.81% and 92.56% of the undertories of the sacred groves (Tables 1, 2, 3, 4). As few as 2–3 tree species could occupy over 50% of the sacred groves. *Hidergardia barterii* alone occupied 65.09% of the overstory of Igbo-Olodumare (Table 2), making it the species with the highest relative dominance in this study. At the understory layer, *Napoleona imperialis* was the most dominant species, occupying 33.65% of the understory of Iddanre Hills grove (Table 1). No single species was dominant in all the four sacred groves (both overstories and understories). *Ceiba pentandra* and *Funtumia elastica* were dominant in the overstories of three of the four sacred groves. In most cases, the dominant tree species in the overstory layer were not the dominant species in the understory of specific sacred grove, the only exception being *Sterculia tragacantha* and *Cola hispida* which were dominant in the overstory and understory of Igbo-Olodumare and Osun-Osogbo sacred groves, respectively (Tables 2, 4). The dominant tree species (*Cassia siamea, Hidergardia barterii, Celtis zenkerii* and *Cola hispida* in Iddanre Hill, Igbo-Olodumare, Ogun-Onire and Osun-Osogbo sacred groves, respectively) were also the species with the highest IVI in their respective sacred groves (Tables 1, 2, 3, 4).

Number of tree families in the overstory and understory layers of the various sacred groves varied from 19 to 29...
and 15–25, respectively (Table 5). The understory of the sacred groves had higher species richness (39–78) than the overstory layer (32–62), a situation that was observed across all sacred grove (Table 5). Similarly, tree density at the understory layer (775–1445 ha⁻¹) was much higher (by between 85.5 and 367.6%) than the density at the overstory.
layers (309–417 ha⁻¹) of the sacred groves (Table 5). Shannon–Wiener diversity index ranged from 1.8 to 3.46 at the overstory layer of the sacred groves and 2.65–3.55 at the understory (sapling) layer.

Species similarity between pairs of sacred groves varied from 57.69 to 82.35% in the overstory and 24.66–75.47% in the understory (Table 6). Species similarity between pairs of groves was higher in the overstory than the understory. In the Overstory, species similarity was highest between Idanre Hills and Osun-Osogbo (82.35%) sacred groves and lowest between Igbo-Olodumare and Osun-Osogbo (57.69%) sacred groves. In the understory layer,
the highest similarity index was between Ogun-Onire and Osun-Osogbo (75.47%) groves while the lowest value was between Igbo-Olodumare and Ogun-Onire (24.66%) groves.

In all the sacred groves, tree dbh distribution followed inverse-J shape (Fig. 3). Majority of the trees in the four sacred groves fell within 10–20 cm dbh class, followed by 20–30 cm class; only few trees had dbh above 100 cm (Fig. 3). The highest stand density across the four groves was recorded in the lowest dbh class of 10–20 cm, making this class the highest contributor of stand density to total density for each grove. Stand density consistently decreased with increase in dbh (Fig. 3).

Species regeneration status was studied using the 5 dominant species in each sacred grove. Except Dialum guinensis and Funtumia elastica, whose regeneration was poor because they were not found at seedling stage, other species in Osun-Osogbo recorded higher number of seedlings followed by saplings and overstory trees (Fig. 4), indicating that the species had good regeneration status. In Igbo-Olodumare grove, three of the five dominant tree species had good to fair regeneration while Funtumia elastica and Ceiba pentandra displayed poor regeneration status (Fig. 5). The regeneration of Ceiba pentandra, Alstonia boonei and Cassia siamensis at Idanre Hills were considered poor due to the absence of seedlings of the species and the lower density of saplings compared to overstory trees (Fig. 6). The other two species had good regeneration (Fig. 6). Figure 7 presented a picture of poor regeneration status at Ogun-Onire sacred grove. Out of five dominant species, three species were not represented at seedling stage and had lower density of saplings compared to overstory trees. The regenerations of Trilepsion madagascariensis and Pterygota macrocarpa were fair. Figure 8 revealed that Ogun-Onire sacred grove had the highest recruitment potential, followed by Osun-Osogbo. Both Igbo-Olodomare and Idanre Hills groves displayed

Table 6 Species Similarity

| Sorensen similarity index | Overstory (%) | Understory (%) |
|---------------------------|--------------|----------------|
| Idanre Hill and Igbo Olodumare | 66.67 | 31.03 |
| Idanre Hill and Ogun-Onire | 79.31 | 65.45 |
| Idanre Hill and Osun-Osogbo | 82.35 | 50.00 |
| Igbo-Olodumare and Ogun-Onire | 72.73 | 24.66 |
| Igbo-Olodumare and Osun-Osogbo | 57.69 | 40.00 |
| Ogun-Onire and Osun-Osogbo | 80.00 | 75.47 |

Fig. 3 Tree diameter distribution in the selected sacred groves
low recruitment potential. Tree species that occurred at only one site were regarded as unique to that site and denoted with “+”. Tree species common to at least two sacred groves were denoted with “o”. Results on Table 7 revealed that among the four sacred groves, Ogun-Onire grove had the highest number of unique species (24), which was followed by Osun-Osogbo grove with a total of 14 unique species. Both Igbo-Olodumare and Idanre Hills sacred groves had 9 unique species each. Tree species endemic in the sacred groves are presented on Table 8. For example, Hildegardia barterii, Piptadeniastrum africanum and Irvigia smithii were the tree species found only in Igbo-Olodumare. Angylocarlyx oligophyllus was found only in Osun-Osogbo. Anopyxis klaineana, Tetrapleura tetraptera, Draceana arborea, Lovoa trichilioides, Lannea welwitschii and Drypetes gossweileri were tree species found only in Ogun-Onire sacred grove.

Discussion

The understory, which accounts for a major component of plant diversity, contributes to the structural complexity of forests and is important in the dynamics and functioning of the forest ecosystem (Royo and Carson 2005; Su et al. 2019). Where the understory is species poor, the sustainability of the forest is threatened, since there may not be enough seedlings to replace the overstory trees when they die or are removed. The absence of or poor seedling or sapling population may imply lack of or poor regeneration or temporal cessation in recruitment. Except at Igbo-Olodumare sacred grove, the Shannon–Wiener diversity indices of the understories of the other sacred groves in this study (Osun-Osogbo, Idanre Hills and Ogun-Onire) were generally similar to those of their respective overstories. This implies that species diversity in the understories and overstories of
The three groves are similar. The diversity indices of our sacred groves are higher than or similar to those reported for some primary forests, degraded forests and sacred groves in Nigeria (Lawal and Adekunle 2013; Onyekwelu and Olu­sola 2014). The higher diversity index at the understory of Igbo-Olodumare grove than its overstory is an indication of higher species diversity at its understory. Johnston (2019) reported a significantly higher Shannon diversity index in the understory of hardwood forests in northern Michigan and Wisconsin, USA compared to the overstory.

The future community structure and regeneration status of a species could be predicted from the relative proportion of understory species in the total populations of various species in the forest (Khumbongmayum et al. 2006). The higher number of species at the understory layers (39–78) compared to the overstory layers (32–62) of our sacred groves is an indication of the contribution of the understory to biodiversity conservation and a confirmation that the understory of sacred groves could be more species rich than the overstory layer. Our results imply that tree regeneration in the four sacred groves is healthy, which is similar to the view expressed by Khumbongmayum et al. (2006). The sacred groves in our study had higher number of understory species compared to what was reported by Onyekwelu and Olu­sola (2014). Similarly, Khumbongmayum et al. (2006) reported higher understory species (seedlings and sapling) than overstory trees in four sacred groves in Manipur, India. Higher number of understory species was also reported by Johnston (2019) for hardwood forests of northern Michigan and Wisconsin, USA. Another indication of good regeneration in our sacred groves is the much higher tree density in the understory layer than the overstory layer, which is in consonance with some published results (Khumbongmayum et al. 2006; Onyekwelu and Olu­sola 2014; Johnston 2019).

In most cases, the number of seedlings was higher than number of saplings and overstory species in our sacred groves. Ballabha et al. (2013) opined that regeneration is considered good if the number of seedlings > number

Fig. 5 Regeneration status of five (5) most dominant species in Igbo-Olodumare sacred grove
saplings > number of overstory trees; fair if the number of seedlings > number saplings ≤ number of overstory trees; which were the situations in our groves. The differences in the densities of seedlings, saplings and overstory trees among the four sacred groves in this study may be due to the interactive influences of an array of biotic and abiotic factors, especially anthropogenic factors and natural phenomena. Studies have shown that anthropogenic activities are increasing in sacred groves in Nigeria (Onyekwel and Olusola 2014; Adeyanju 2020).

Currently, the Nigerian forest ecosystems are facing many challenges. Illegal logging, urbanization and clearance of forests for agriculture have negatively impacted on the extent of the forests and the population of valuable tree species (Onyekwel et al. 2008). Some Nigerian forest reserves have undergone various degrees of degradation from both illegal and legal loggers, which has led to reduction in species richness (Aruofor 2001; Onyekwel et al. 2008; Olayinka et al. 2018). Recent studies (Onyekwel and Olusola 2014; Adeyanju 2020) have revealed that sacred groves are gradually being encroached upon. Species regeneration is usually negatively affected by forest degradation. Therefore, forestry professionals are confronted with the task of finding the best approach to enhance regeneration of valuable tree species.

Tree species regeneration depends on the maturity and diameter structure of their population (Bhuyan et al. 2003). Characteristics of the forest floor, micro-environmental conditions under the forest canopy and anthropogenic activities influence tree regeneration. Tree diameter distribution is an indication of how well the forest is regenerating and is making use of site resources (Rao et al. 1990). The tree dbh distribution curves of the sacred groves in this study followed the inverse-J shape typical of natural tropical rainforests (Onyekwel et al. 2008) and some sacred groves (Khumbongmayum et al. 2006; Onyekwel and Olusola 2014; Sarkar and Devi 2014). Inverse-J dbh distribution is an indication of good regeneration status and healthy forest ecosystem (Sarkar and Devi 2014). It suggests an evolving or
expanding population, climax or stable type of population in forest ecosystem, indicating that the forest harbours a growing population (Mishra et al. 2005; Sahu et al. 2012). We share similar opinion with Khumbongmayum et al. (2006) that the presence of established seedlings of dominant species is an indication of their excellent recruitment which also suggests that the prevailing environmental conditions of the study site are favourable for their establishment stage. The high recruitment recorded in the sacred groves may be attributed to dispersal by birds and other animals that bring new seeds or fruits to the sacred groves. In addition, the high recruitment could be attributed to dispersal by worshipers, visitors and tourists to the groves.

Conservation and maintenance of biodiversity in natural forest ecosystem can only be guaranteed through regeneration. Our observation is that the overall tree regeneration status in our sacred groves is satisfactory showing “good” and “fair” regeneration, though few tree species fell under “poor” and “No” regenerating categories. Successful regeneration of a tree species depends on its ability to produce large number of seedlings and the ability of seedlings and saplings to survive and grow, situations that were evident in our sacred groves. The good species regeneration recorded in the sacred groves could be attributed to high level of access of the restrictions imposed by their managements (chief priests, community leaders, etc.). For instance, nobody dared enter Ogun-Onire grove without the permission of the chief priest as the grove is believed to be sacred and the habitation of the gods. Also, there are taboos and myths that are feared by the people, which prevents their entrance into the groves. With these restrictions, anthropogenic activities that could destroy seedlings are reduced, thereby enhancing regeneration and recruitment potentials. However, some of these appear to be changing or could change given some recent developments in sacred grove management in Nigeria. Activities (rituals, initiations, festivals, and other ceremonies) in Nigerian sacred groves have increased in recent times, which has led to an alarming high influx of people into the sacred groves. It

Fig. 7 Regeneration status of five (5) most dominant species in Ogun-Onire sacred grove
is estimated that between 130,000 and 150,000 people visit Osun-Osogbo grove for annual festival celebration (Aleshinloye and Maruyama 2015; Adeyanju 2020). Due to this high influx of people, seedlings and saplings are sometimes trampled upon and their survival is affected. Oftentimes, ritual rites and sacrifices may involve ground clearing and ground fires by priests and devotees. Since individual species in young stages are more vulnerable to any kind of environmental stress and anthropogenic disturbance, sapling and seedling densities in the sacred groves are adversely affected, thereby negatively influencing species regeneration and recruitment. In addition, lot of seeds in the soil seed bank could be destroyed through trampling by visitors as well as during ground clearing or burning, which could affect their germination and result in limited or no regeneration.

Sacred groves could serve as reservoir for preserving unique and endangered tree species. In this study, some tree species were discovered to exist only in one sacred grove. For instance, *Hildegardia barteri* was endemic to Igbo-Olodumare, *Lovoa trichilioides* was unique to Ogun-Onire sacred grove. No known study has reported the presence of any of these species in any forest reserves in Southwestern Nigeria. Also, some tree species that are not found in protected forests in Nigeria (e.g. Akure forest reserve, Queen’s plot, Omo forest reserve) (Lawal and Adekunle 2013; Salami and Akinyele 2018; Omomoh et al. 2019) were encountered in some of the sacred groves. The presence of these unique tree species directly or indirectly contributes to the welfare and stability of the local environment. The prevalence of the unique species clearly indicates the potential of sacred groves for conservation of important tree species. Onyekwelu and Olusola (2014) reported that about 32% of the species encountered in Osun-Osogbo and Igbo-Olodumare sacred groves are among the tree species classified as endangered in Nigeria (FORMECU 1998).

**Conclusion and recommendation**

We conclude that sacred groves promote tree species conservation and harbour high regeneration. Most of the sacred groves housed some unique and important tree species, implying that they can serve as reservoir for unique and endangered tree species. The understory layer had higher species richness and diversity than the overstory layer. Shannon–Wiener diversity index was relatively higher at the understory (sapling) layer than the overstory layer. The higher species richness at the understory layers (39–78) than the overstory layers (32–62) is an indication of the contribution of the understory to biodiversity conservation and a confirmation that the understory of sacred groves could be more species rich than the overstory. The overall tree regeneration status in the studied sacred groves was satisfactory showing “good” and “fair” regeneration. The inverse-J dbh distribution in the sacred groves, which is an indication of good regeneration status, suggest an evolving or expanding population, climax or stable type of population in forest ecosystem, indicating that the forest
Table 7 Unique tree species in the study area

| S/N | Name of species          | Osun-Osogbo | Igbo-Olo-dumare | Idanre Hills | Ogun-Oonire |
|-----|--------------------------|-------------|-----------------|--------------|-------------|
| 1   | Afzelia africana         | −           | −               | −            | +           |
| 2   | Albizia ferruginea       | o           | o               | o            | o           |
| 3   | Albizia lebbeck          | o           | −               | −            | o           |
| 4   | Albizia zygia            | o           | −               | o            | o           |
| 5   | Alchornea laxiflora      | −           | −               | −            | +           |
| 6   | Alchornea cordifolia     | −           | −               | +            | −           |
| 7   | Alstonia boonei          | −           | −               | o            | o           |
| 8   | Amphimann pterocarpoides | −           | +               | −            | −           |
| 9   | Angylocalyx oligophyllus | +           | −               | −            | −           |
| 10  | Anopyxis klaineana       | −           | −               | −            | +           |
| 11  | Anthocleista djalonensis | −           | −               | +            | −           |
| 12  | Anthonotha macrophylla   | −           | −               | −            | +           |
| 13  | Antiaris africana        | o           | −               | o            | o           |
| 14  | Baphia nitida            | o           | −               | o            | −           |
| 15  | Berlinia grandiflora     | −           | −               | o            | o           |
| 16  | Blighia sapida           | o           | o               | o            | o           |
| 17  | Bombas buonopozense      | −           | −               | −            | +           |
| 18  | Brachystegia eurycoma    | +           | −               | −            | −           |
| 19  | Brachystegia kennedyi    | −           | −               | −            | +           |
| 20  | Brachystegia nigerica    | o           | o               | −            | −           |
| 21  | Canarium schweinfurthii  | −           | −               | −            | +           |
| 22  | Cassia siamen            | −           | −               | +            | −           |
| 23  | Ceiba pentandra          | o           | o               | o            | o           |
| 24  | Celtis mildbraedii       | o           | o               | −            | o           |
| 25  | Celtis philippensis      | −           | −               | −            | +           |
| 26  | Celtis zonerrii          | o           | o               | −            | o           |
| 27  | Chrysophyllum albidan   | −           | −               | o            | o           |
| 28  | Cleistopholis patens     | −           | +               | −            | −           |
| 29  | Cola acuminata           | −           | −               | −            | +           |
| 30  | Cola gigantea            | −           | −               | o            | o           |
| 31  | Cola hispida             | o           | o               | o            | o           |
| 32  | Cola millenii            | o           | o               | −            | o           |
| 33  | Cordia millenii          | −           | +               | −            | −           |
| 34  | Dialium guineense        | o           | −               | o            | −           |
| 35  | Diospyros dendo          | −           | o               | o            | o           |
| 36  | Diospyros mobutensis     | o           | −               | −            | o           |
| 37  | Discoglyprema caloneura  | +           | −               | −            | −           |
| 38  | Distemonanthus benthamianus | o       | −               | o            | −           |
| 39  | Dracaena arborea         | −           | −               | −            | +           |
| 40  | Dracaena marginata       | o           | −               | o            | −           |
| 41  | Drypetes gosweieri       | −           | −               | −            | +           |
| 42  | Drypetes oblongifolia    | +           | −               | −            | −           |
| 43  | Entandrophragma angolense | −           | −               | −            | +           |
| 44  | Entandrophragma cylindricum | −           | −               | +            | −           |
| 45  | Ficus sycomorus          | −           | +               | −            | −           |
| 46  | Ficus exasperate         | −           | o               | o            | o           |
| 47  | Ficus mucoso             | o           | −               | o            | o           |
| 48  | Funtumia elastica        | o           | o               | o            | o           |
| 49  | Gliricidia sepium        | +           | −               | −            | −           |
| 50  | Gmelina arborea          | +           | −               | −            | −           |
| S/N | Name of species          | Osun-Osogbo | Igbo-Olo-dumare | Idanre Hills | Ogun-Oonire |
|-----|--------------------------|-------------|-----------------|-------------|------------|
| 51  | Hanoa cleniana           | +           | −               | −           | −          |
| 52  | Hildegardia barteri      | −           | +               | −           | −          |
| 53  | Holarrhena floribunda    | −           | −               | +           | −          |
| 54  | Hunteria Umbellata       | −           | −               | −           | +          |
| 55  | Irvingia smithii         | −           | +               | −           | −          |
| 56  | Ixora guinensis          | +           | −               | −           | −          |
| 57  | Khaya grandifoliola      | −           | o               | o           | o          |
| 58  | Lannea welwitschii (Hiern) | −   | −               | −           | +          |
| 59  | Lecaniodiscus cupanioides| o           | o               | −           | o          |
| 60  | Lovoa trichilioides      | −           | −               | +           | −          |
| 61  | Malachanta alnifolia     | −           | −               | −           | +          |
| 62  | Mallotus oppositifolius  | −           | −               | −           | +          |
| 63  | Manilkara obovata        | o           | −               | o           | −          |
| 64  | Mansonia altissima       | −           | +               | −           | −          |
| 65  | Margaritaria discoidea   | o           | o               | o           | o          |
| 66  | Massularia acuminata     | +           | −               | −           | −          |
| 67  | Melachanta alnifolia     | +           | −               | −           | −          |
| 68  | Milicia excels           | −           | o               | o           | o          |
| 69  | Milletia thonningii      | o           | −               | o           | o          |
| 70  | Monodora myristica       | o           | −               | o           | −          |
| 71  | Monodora tenuifolia      | −           | −               | −           | +          |
| 72  | Morinda lucida           | −           | −               | +           | −          |
| 73  | Morus mesozygia          | −           | −               | o           | o          |
| 74  | Myrianthus arboreus      | −           | −               | −           | +          |
| 75  | Napoleonaea imperialis   | +           | −               | −           | −          |
| 76  | Newbouldia laevis        | o           | −               | o           | −          |
| 77  | Piptadeniastrum africanum| −           | +               | −           | −          |
| 78  | Pterocarpus mildbraedii  | −           | −               | +           | −          |
| 79  | Pterygota macrocarpa      | −           | o               | o           | o          |
| 80  | Pycnanthus angolensis     | −           | −               | −           | +          |
| 81  | Rauvolfia vomitoria       | −           | −               | +           | −          |
| 82  | Ricinodendron heudelotii | o           | o               | −           | o          |
| 83  | Rothmannia longiflora    | o           | o               | −           | −          |
| 84  | Rothmannia whitfieldii   | +           | −               | −           | −          |
| 85  | Spathodea campanulata    | o           | −               | −           | o          |
| 86  | Spondias mombin          | −           | o               | o           | −          |
| 87  | Spondias pinnata         | o           | −               | o           | o          |
| 88  | Sterculia oblonga        | o           | o               | o           | o          |
| 89  | Sterculia rhinopetala    | −           | −               | −           | +          |
| 90  | Sterculia tragacantha    | −           | o               | o           | −          |
| 91  | Strombosia fascae        | +           | −               | −           | −          |
| 92  | Strombosia postulata     | −           | −               | −           | +          |
| 93  | Tabernaemontana coronaria| +           | −               | −           | −          |
| 94  | Terminalia superba       | −           | −               | o           | o          |
| 95  | Tetrapleura tetraptera   | −           | −               | −           | +          |
| 96  | Trema orientalis         | −           | −               | +           | −          |
| 97  | Trichilia monadelpha     | o           | −               | o           | −          |
| 98  | Trichilia welwitschii    | o           | o               | o           | o          |
| 99  | Trilepisium madagascariense | o   | −               | −           | o          |
|100  | Triplochiton scleroxylon | o           | −               | −           | o          |
contains a growing population. The high regeneration and recruitment status in the sacred groves were achieved using taboos, cultural and traditional methods. These methods could be incorporated in managing forest reserves in Southwestern Nigeria. Also, conservative efforts should be made to avert the extinction of endemic species in the sacred groves.

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Table 7 (continued)

| S/N | Name of species     | Osun-Osogbo | Igbo-Olodu-mare | Idanre Hills | Ogun-Oonire |
|-----|---------------------|-------------|-----------------|--------------|-------------|
| 101 | *Voacanga africana* | –           | –               | –            | +           |
| 102 | *Zanthoxylum zanthozaloides* | – | +               | –            | –           |

+ a unique species, 0 species common to sites, – species not found in the site

Table 8 Tree species endemic in the sacred groves in comparison with protected forest in Southwestern Nigeria

| Name of species                          | Sacred Groves | Protected forests                        |
|------------------------------------------|---------------|----------------------------------------|
|                                          | Osun Osogbo   | Igbo-Olodu-mare | Idanre Hills | Ogun-Oonire | Akure Queen’s Plot (Lawal and Adegunle 2013) | Omo Biosphere Reserve (Salami and Akinyele 2018) | Oluwa forest reserve (Oneyekwu et al. 2008) |
| *Angylocalyx oligophyllus*               | +             | –               | –           | –          | –                 | –                 | –                                  |
| *Anopysis klaineana*                     | –             | –               | –           | +          | –                 | –                 | –                                  |
| *Dracaena arborea*                       | –             | –               | –           | +          | –                 | –                 | –                                  |
| *Drypetes gossweileri*                    | –             | –               | –           | +          | –                 | –                 | –                                  |
| *Hildegardia barteri*                     | –             | –               | +           | –          | –                 | –                 | +                                  |
| *Irvingia smithii*                        | –             | +               | –           | –          | –                 | –                 | +                                  |
| *Lannea welwitschia*                      | –             | –               | –           | +          | –                 | –                 | –                                  |
| *Lovoa trichiliioides*                    | –             | –               | –           | +          | –                 | –                 | +                                  |
| *Piptadeniastrum africanum*               | –             | +               | –           | –          | –                 | –                 | +                                  |
| *Tetrapleura tetraptera*                  | –             | –               | –           | +          | –                 | –                 | +                                  |
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