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Research Article

Conventional and Indigenous Biodiversity Conservation Approach: A Comparative Study of Jachie Sacred Grove and Nkrabea Forest Reserve

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Conventional managed forests and sacred groves are seldom assessed to determine their effectiveness in biodiversity conservation strategies. This study investigated tree and insect diversity in Jachie sacred grove (JSG) and Nkrabea forest reserve (NFR) in Ashanti region, Ghana. The study area constituted eight plots of 50 × 50 m along two 300 m long transects. Insects were sampled in eight pitfall traps, diagonally between the transects. Out of 150 individuals, 13 species in NFR and 15 species from JSG were registered. *Celtis mildbraedii* was the most dominant species in NFR = 43.18% and JSG = 23.58%. Mean DBH showed a significant relationship with basal area in NFR and JSG. Tree diversity and richness were higher in JSG ($H' = 1.43–2.3 \pm 0.10$; $D = 1.8–3.69 \pm 0.30$) compared to NFR ($H' = 0.86–1.56 \pm 0.09$; $D = 1.1–2.3 \pm 0.57$). However, insect diversity was higher in NFR ($H' = 1.34 \pm 0.10$) than in JSG ($H' = 0.5 \pm 0.005$). *Camponotus furvus* and *Pachycondyla tarsata* were most abundant in JSG and NFR, respectively. These findings will help conservationists work closely with traditional authorities in protecting sacred groves as key biodiversity hotspots.

1. Introduction

Forest resources play a key role in protecting the environment and are of tremendous importance to the sustainable development of every society [1]. Ghana is recognized as one of the most advanced tropical African countries in terms of established forest policy, legislation, forest inventory, and management planning. Additionally, there are a National Forest Standard and principles, criteria, and indicators for judging the quality of forest management and usage [2]. The forest reserve system established is one of the most extensive in sub-Saharan Africa covering 11 percent of the country [3]. Ghana's long and distinguished tradition of formal forest management stretching back to 1909 is manifested by the existence of 283 forest reserves under the Ministry of Lands and Natural Resources. It has been reported that nearly all the forest reserves in Ghana have close links with sacred groves and/or sociocultural ties with the local communities' zone [4, 5]. There are an estimated 2000–3200 sacred groves, about 80% of which are in the southern zone of Ghana [4, 5]. The introduced forest management systems have been the exclusive function of state authorities and agencies, mostly excluding the indigenes who are in close proximity with these resources [6]. This deficiency in protection strategy normally results in stand-offs between state authorities and forest fringe communities [7]. Other factors such as the increasing rate of deforestation, illegal logging, population pressures, and unsustainable agricultural practices have caused the once rich evergreen and lush forests of Ghana to dwindle significantly [8].

Estimates are that 80–90% of original high canopy forest in the country which was mainly state forest estates has been eliminated and nearly all areas not set aside as forest reserve are gone. Only about 1% of forests cover in Ghana remains outside gazetted reserves, and sacred forest groves account for most of this. Even though one of the main aims of formally protected areas is biodiversity conservation, only 25% of these forest reserves are designated for biodiversity protection. Recently, some innovations in biodiversity conservation have been introduced through the establishment of Globally Significant Biodiversity Areas (GSBAs), Important Bird Areas (IBAs), and Community Resource Management Areas (CREMA).

However, data on the biodiversity intactness index in both our conventional forest reserves and local sacred forests grove are scanty and the effect of these conservation methods on genetic resources present in protected areas has not been assessed. Moreover, the effectiveness of both conventional and local biodiversity conservation strategies is seldom assessed, and comparative assessment of effectiveness of the two conservation strategies, despite being complex and subjective, has been rarely attempted in Ghana. In this study, we compare the contribution of traditional sacred grove and the conventional state managed forest reserve conservation strategies, in harnessing biodiversity status.

2. Methods

Two sites were selected for the study, Jachie sacred grove (JSG) in Bosomtwe district and Nkrabea forest reserve (NFR) in the Adansi south district of Ashanti region (Figure 1). Jachie is predominantly a farming community. About 11.5 hectares of natural forest has been reserved through taboos and other cultural practices and beliefs for religious sanctions, thus making it a sacred grove. Nkrabea forest reserve derives its name from a hill in the southeastern corner of the reserve. The entire reserve comprises 63 compartments covering an area of 8,086 ha managed for sustainable timber production under a forty-year felling cycle. Compartment 43 of Nkrabea forest reserve was purposefully selected for the study because it is designated for biodiversity conservation recently from being under recovery from previous logging. The total area of the compartment is 214.4 ha.

Both study sites fall under the high forest zone of Ghana. Jachie is located at 1°31′W and 6°33′N, about 15 kilometres southeast of Kumasi, while Nkrabea forest reserve lies between latitude 5°25′ and 6°05′ north and longitude 1°30′ and 2°00′ west, in the Adansi south district of the Ashanti region of Ghana (Figure 1). The vegetation is typical of semideciduous forest type [9], with two well-defined bimodal rainfall seasons (major season, which occurs from March to July, and the minor season, from September to November). Temperature appears to be uniformly high throughout the year, with a mean of 24°C. The highest mean temperature occurs just before the major wet season in February while the mean minimum occurs during the minor wet season. Soil type in Jachie sacred grove originates from a wide range of highly weathered granite, known as the Tarkwaian and Birimian rock formation, while Nkrabea forest reserve soils are moderately deep, yellowish brown clay loam. The reserve landscape is typically undulating, with an altitude between 121.5 m and 152.44 m above MSL.

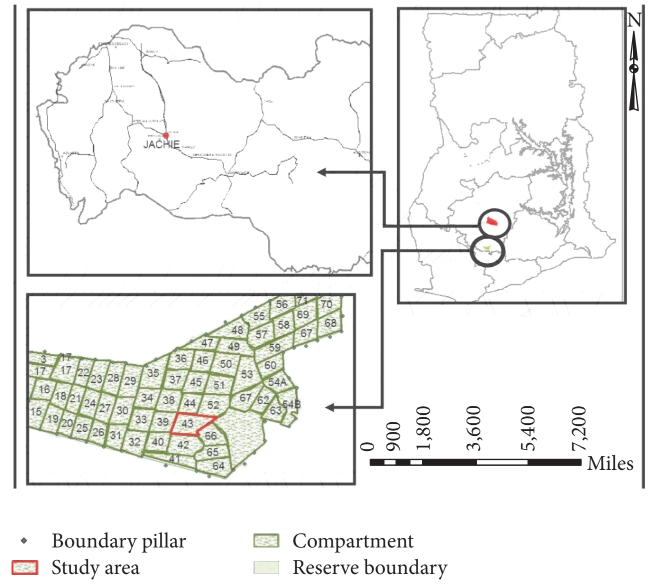

Figure 1: Map of Ghana showing the locations of Jachie community and compartment 43 of Nkrabea forest reserve.

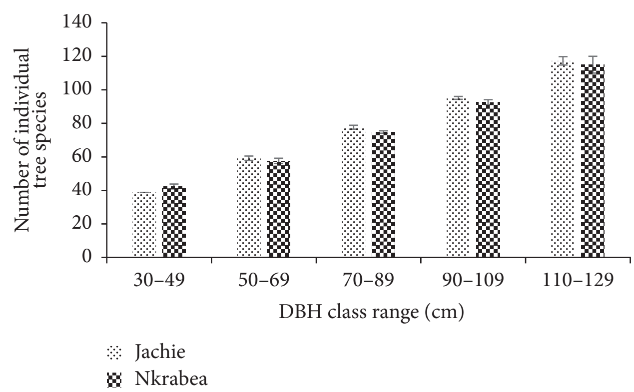

Figure 2: Variations in diameter at breast height among trees in Nkrabea forest reserve and Jachie sacred grove.

2.1. Sampling Procedure for Woody Species. Four plots of size 50 × 50 m were each laid on two transect lines of length 300 m. The plots were laid in the middle of the sacred grove and compartment 43 of the Nkrabea forest reserve. Plots of size 50 × 50 m were laid on two transect lines of length 300 m each and separated from each other by 300 m every 75 m along each transect, as shown in Figure 2, giving a total of four plots per transect and eight in total for each study site giving a total of sixteen for the study. Within each plot, all living trees with diameter at breast height (DBH) ≥30 cm will be identified and their DBH measured.

Eight pitfall traps were laid diagonally from one end of the main sample plot to the other at 50 m intervals to trap the insects found on the forest floor. After 24 hours, the insects trapped in the pitfall were collected and the traps remounted for the next 24 hours, bringing the total sampling replicates to two days. The insects collected were preserved in 70% alcohol solution and sent to the Forest Research Institute of

Ghana (FORIG) entomology department for identification. The indigenous practices that protect Jachie sacred grove were investigated through interview with members of the Jachie traditional council in charge of the grove.

2.2. Statistical Analysis. Basal area of tree species was calculated using the following equation:

$$\mathrm{BA} = \frac{\pi \times (\mathrm{DBH})^2}{40000}, \quad (1)$$

where BA is the basal Area in $\mathrm{m}^2\,\mathrm{ha}^{-1}$ and DBH is the diameter at breast height of the tree in centimetres. Linear regression was used to determine tree diameter relationship with basal area. Shannon-Wiener's diversity indices were employed to compute the current status of diversity and richness of plant and arthropod species. Shannon-Wiener's index was expressed as [10]

$$H' = \sum_{i=1}^{s} P_{i \ln P_i}, \quad (2)$$

where H' is Shannon's diversity index, s is the total number of species in the habitat, p_i is the proportion of individuals or the abundance of the ith species expressed as a proportion of the total cover, and ln is a natural logarithm. Species evenness distribution in the two sites was evaluated using Pielou evenness index (J) expressed as

$$J = \frac{H'}{\ln S}, \quad (3)$$

where H' is the diversity index, S is the species number, and ln is natural logarithm of total number of species in the population. We finally applied Margalef's index (D) [11] to deduce species richness, using the equation as follows:

$$D = \frac{(S-1)}{\ln N}, \quad (4)$$

where S is the number of species in the population, ln is a natural logarithm, and N is the number of sites. A paired t-test was used to test for significant differences in diversity indices between the forest reserve and the sacred grove, using GenStat statistical software version 12.

3. Results

A total of 150 individuals were recorded in Nkrabea forest reserve (44) and Jachie sacred grove (106) (Table 1). Out of this number, 13 species from nine families from Nkrabea forest reserve (hereafter referred to as NFR) and 15 species, from 11 families in Jachie sacred groves (hereafter referred to as JSG), were identified. Of this number, 12 species belonging to 10 families were recorded in NFR, while 22 species from 13 families were registered in JSG. *Celtis mildbraedii* (Ulmaceae) was the most dominant species in the two sites (NFR = 43.18% RA and JSG = 23.58% RA) (Table 1), while eight species in NFR (e.g., *Antrocaryon micraster*, 2.27% RA) and three species in JSG (e.g., *Cedrela odorata*, 0.94% RA) were the least recorded. Seven species (e.g., *Alstonia boonei*, *Celtis mildbraedii*, *Ceiba petandra*, and *Entandrophragma angolensis*) occurred in the two sites. Average diameter at breast height (DBH) did not substantially vary between the two sites (t-test = 0.016, F = 1.14, p = 0.9) and ranged between 30 cm and 117 cm (Figure 2). The highest DBH was registered in Jachie sacred grove (117 cm), while that of NFR was 115 cm. Trees in JSG showed a high regeneration capacity, and this is reflected in the estimated 41 species of diameters < 50 cm. Although NFR is composed of mature trees, with ≤ 70–89 cm DBH, only 19 trees were found within this range (Figure 2). There was a significant relationship between tree diameter and basal area in NFR ($r^2 = 0.969$, $U = 0$, $z = -8.076$, $p < 0.0001$, Mann–Whitney U test) and JSG ($r^2 = 0.964$, $U = 0$, $z = -12.58$, $p < 0.0001$) (Figures 3 and 4).

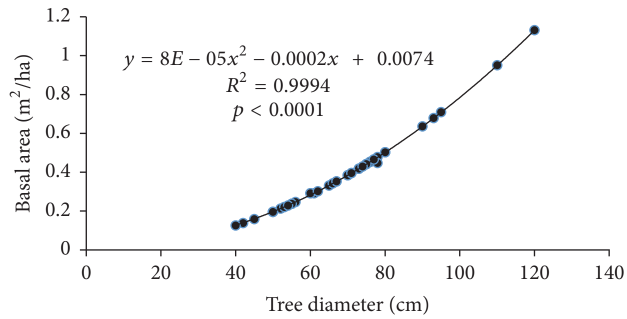

Figure 3: Relationship between tree diameter and basal area in Nkrabea forest reserve. Notice that the basal area increased with the increase in tree diameter.

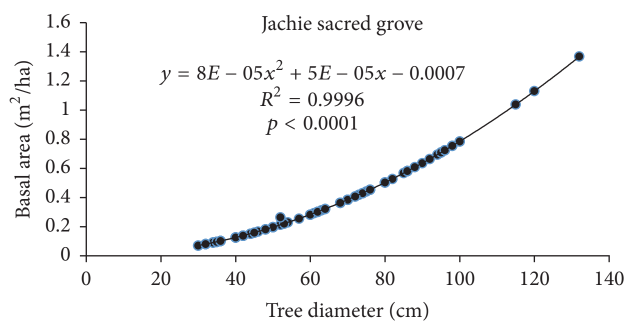

Figure 4: Relationship between tree diameter and basal area in Jachie sacred grove. Notice that the basal area increased with the increase in tree diameter.

Species diversity did not differ significantly in each site: NFR (*one-way ANOVA test*, F = 0.03, $p > 0.05$) and JSG (F = 0.38, p = 0.9) (Figure 5). However, overall comparison of the two sites showed significant variations (t-test = −4.6, p = 0.002). Diversity in NFR was in the range H' = 0.86–1.56 ± 0.09, while that of JSG was H' = 1.43–2.3 ± 0.10. Species richness followed similar pattern-like diversity and substantially differed between the two sites (t-test = −4.1, p = 0.004) and was in the range 1.1–2.3 ± 0.57 in NFR and 1.8–3.69 ± 0.30 in JSG (Figure 6). Monte-Carlo permutation test (99999 iterations) further confirmed

Table 1: A checklist of plant species and their relative abundance in Nkrabea forest reserve.

Family	Species	Total	% relative dominance
	Nkrabea forest reserve		
Anacardiaceae	*Antrocaryon micraster*	1	2.27
Apocynaceae	*Alstonia boonei*	1	2.27
Combretaceae	*Terminalia superba*	2	4.54
Fabaceae	*Berlinia occidentalis*	1	2.27
Malvaceae	*Ceiba petandra*	2	4.54
	Nesogordonia papaverifera	1	2.27
	Sterculia oblonga	1	2.27
	Triplochiton scleroxylon	7	15.9
Mimosaceae	*Piptadeniastrum africanum*	1	2.27
Meliaceae	*Entandrophragma angolense*	1	2.27
	Entandrophragma utile	1	2.27
Myristicaceae	*Pycnanthus angolensis*	2	4.54
Ulmaceae	*Celtis mildbraedii*	19	43.18
	Jachie sacred grove		
Fabaceae	*Albizia adianthifolia*	3	2.83
	Albizia ferruginea	2	1.89
	Albizia zygia	2	1.89
	Alstonia boonei	6	5.66
Moraceae	*Antiaris toxicaria*	4	3.77
	Blighia sapida	6	5.66
Meliaceae	*Cedrela odorata*	1	0.94
	Entandrophragma angolense	2	1.89
Malvaceae	*Ceiba petandra*	7	6.6
	Cola nitida	1	0.94
	Sterculia rhinopetala	10	9.43
	Sterculia tragacantha	3	2.83
	Bombax buonopozense	1	0.94
	Triplochiton scleroxylon	7	6.6
Ulmaceae	*Celtis mildbraedii*	25	23.58
	Celtis zenkeri	9	8.49
Sterculiaceae	*Cola gigantean*	7	6.6
Anacardiaceae	*Lannea welwitschii*	2	1.89
Myristicaceae	*Pycnanthus angolensis*	5	4.72
Euphorbiaceae	*Ricinodendron heudelotii*	1	0.94
Olacaceae	*Strombosia glaucescens*	1	0.94
Combretaceae	*Terminalia superba*	2	1.89
Total		*150*	

significant variations in diversity ($p < 0.01$) and richness ($p < 0.01$). In spite of the varied diversity and richness, overall species evenness distribution pattern appeared to be similar in NFR and JSG ($F = 2.55$, $t = 1.15$, $p = 0.14$) (Figure 7). Both the distribution of tree species in a sample population (evenness index) and site occupancy of tree species (basal area) were found to be similar at both study sites. However, mean diameters of trees recorded at both sites were significantly different ($p = 0.025$) with Nkrabea forest reserve recording the highest mean diameter of 68.48 cm and Jachie sacred grove 61.90 cm for this study.

4. Arthropod Population and Diversity

Arthropod abundance in Jachie sacred grove was higher ($n = 84$) than in Nkrabea forest reserve ($n = 57$) (Table 2). Species from the families Formicidae and Gryllidae, respectively, dominated in the two sites. *Camponotus furvus* (85.71%) and *Pachycondyla tarsata* (47.37%) were the most abundant species in JSG and NFR, respectively, while *Diasemopsis apifasciata* (1.75%) and *Auplopus* sp. (1.75%) constituted the least individual taxa registered and were only found in NFR. Mean arthropod diversity significantly differed (t-test = 8.04,

Table 2: Summary of arthropod species and their relative abundance, registered at the study sites.

Family	Order	Species	Common name	Abundance	% rel. dominance
		Nkrabea forest reserve			
Gryllidae	Orthoptera	*Nemobius sylvestris*	Wood cricket	12	21.05
Gryllidae	Orthoptera	*Gryllus* sp.	Ground cricket	4	7.01
Formicidae	Hymenoptera	*Camponotus consobrinus*	Sugar ant	8	14.04
Formicidae	Hymenoptera	*Pachycondyla tarsata*	Black ant	27	47.37
Pompilidae	Hymenoptera	*Auplopus* sp.	Spider wasp	1	1.75
Gnaphosidae	Araneae	*Gnaphosidae* sp.	Ground spider	2	3.51
Thomisidae	Araneae	*Thomisidae* sp.	Crab spider	2	3.51
Diopsidae	Diptera	*Diasemopsis apifasciata*	Stalked eye fly	1	1.75
Total		7		57	
		Jachie sacred grove			
Gryllidae	Orthoptera	*Gryllus* sp.	Ground cricket	6	12.53
Formicidae	Hymenoptera	*Camponotus consobrinus*	Sugar ant	6	12.53
Formicidae	Hymenoptera	*Camponotus furvus*	Carpenter ant	72	85.71
Total		3		84	

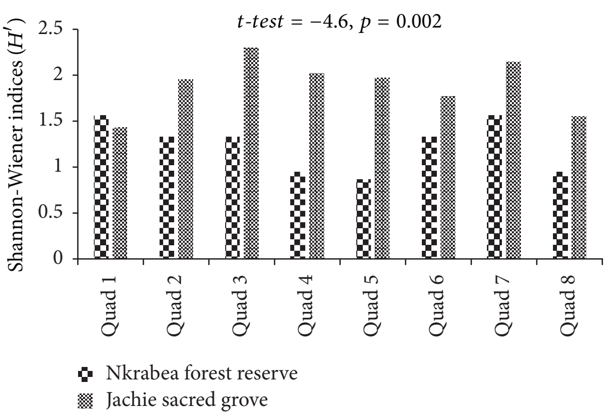

Figure 5: Comparison of variations in tree diversity in Nkrabea forest Reserve and Jackie sacred grove.

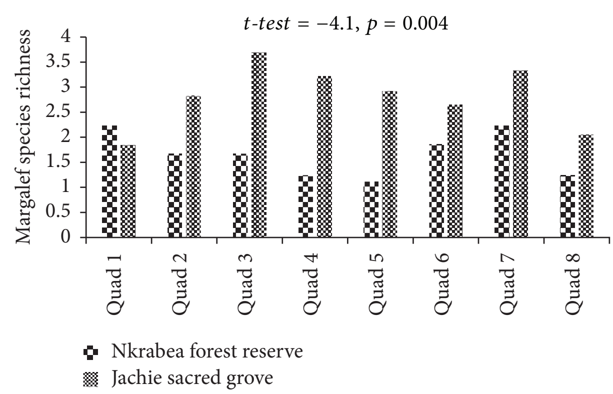

Figure 6: Variations in tree richness in Nkrabea forest reserve and Jackie sacred grove.

$p < 0.01$) in NFR ($H' = 1.34 \pm 0.10$) compared to JSG ($H' = 0.5 \pm 0.005$) (Table 3). Species evenness distribution also followed similar pattern-like diversity and varied significantly (t-test = −6.29, $p = 0.021$) in the two sites. Although species richness in NFR was high ($D = 6.5 \pm 4.5$), it did not differ significantly (t-test = 2.33, $p = 0.14$) from JSG ($D = 3.0 \pm 00$) (Table 3).

5. Discussion

Conservation of forest biodiversity has received much attention in recent times, compared with any time in human history, because of the rate of loss [12]. Various conservation methods have been used to protect forest biodiversity loss and encourage natural regeneration (e.g., [13]). In this study, we observed greater woody species diversity and richness in a Jachie sacred grove (a traditional forest conservation approach) than the government managed Nkrabea forest reserve, in spite of the relatively small hectares it occupied. This was largely due to the high restrictions of human access by the chief fetish priest locally known as *okomfuɔ* from exploiting the forest resources and causing disturbance in the process. While sacred groves were not created for biodiversity conservation [14], their complex sociospiritual or sociocultural associations with deities and spirits of dead ancestors have contributed to the protection of some ecosystems [15]. This makes communities hold so much respect and fear for the sacred grove, because of their apparent spiritual link to the ancestors, who are custodians of the land. Traditional respect for the environment and access restrictions to sacred sites had often led to well-conserved areas with high biological diversity within otherwise degraded environments [16].

Low wood species diversity and richness in the Nkrabea state managed forest reserve were probably due to illegal timber exploitation, coupled with intermittent bushfire occurrence, farming activities, and charcoal production. Logging has been found to impact tree diversity, due to low regeneration dynamics [17]. Indigenes use of taboo days as a protection technique of biological resources in sacred groves

Table 3: Summary of arthropod diversity and evenness distribution, in Jachie sacred grove and Nkrabea forest reserve.

Indices	Jachie sacred grove	Nkrabea forest reserve	t-test	p value
Diversity (H')	0.5 ± 0.005	1.34 ± 0.10	8.44	0.014*
Species richness (D)	3.0 ± 0.14	6.5 ± 4.5	2.33	0.145
Species evenness (E)	0.45 ± 0.10	0.73 ± 0.04	−6.29	0.021*

*Significant at p value = 0.05; ± values represent standard error of the mean.

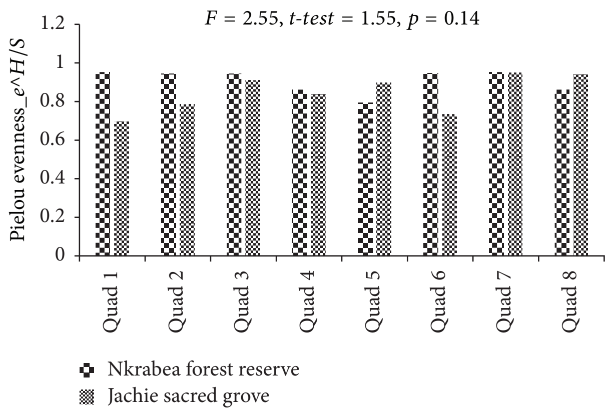

Figure 7: Variations in tree richness in Nkrabea forest reserve and Jackie sacred grove.

is widely reported across Ghana [18–21]. For instance, studies in other parts of Ghana and elsewhere have found species richness to be higher in sacred groves than in state forest reserves [22, 23]. In most traditional settings in Ghana, trees useful to humans such as Odum (*Milicia excelsa*) and mahogany (*Khaya ivorensis*) are regarded as smaller gods and possess special spiritual powers [24]. This prevents them from being felled without performing some rituals and thus contributes to the protection. Mgumia [25] also found similar high tree species richness and diversity in sacred groves in Miombo woodlands compared to state forest reserves in Central Tanzania and suggested that their observation is a reflection to different management approaches. Most sacred groves are considered as refuge for endangered species [26, 27].

The apparent similarity in species evenness distribution in the two habitats was probably due to the spatial patterns of stands that enable them to effectively utilize resources such as sunlight, soil fertility, and species coexistence from the same functional group. Variations in basal area could be attributed to differences in age of plants, type of species, ability to compete for limited resources, and other environmental mediating factors in the two habitats. Similar variations in plant attributes have been reported in sacred groves and forest reserves in Tanzania [28]. Overall, positive correlation in tree diameter and basal area in JSG and the NFR suggests that differences in conservation approach did not in any way influence resource availability and equitable utilization among species.

Insects' higher diversity in the state managed NFR than in JSG could be attributed to the slight habitat perturbation, log dumps, and the open canopy, which allowed light penetration into the forest floor. This observation suggests that disturbance tends to create an favourable condition for the colonization of diverse insects, while simultaneously negatively impacting plant species. This compensatory role of disturbance in ecosystem functioning appears to contribute to harnessing biodiversity integrity. Secondly, it is thought that the diversity of insects in NFR could be due to the presence of some palatable species, leaf litter, and dead wood/twigs, brought about by logging, farming activities, and charcoal production. Thus, their presence and abundance help to speed up the decomposition process of leaf litter and dead wood, leading to improved soil fertility. The relationship between leaf palatability to insect herbivores and litter decomposability is one of the important factors determining the direction of effects of insect herbivores on ecosystem processes [29]. But [22] showed that the large area of the forest reserves could account for higher insect species richness than the sacred groves. Other studies suggest that forest condition or level of degradation can be determined by observing some insect species that are more specialized in either degraded or nondegraded forest ecosystems [30]. These species could be used as an early warning indicator for conservation purposes [31].

6. Conclusion

The importance of sacred groves as a tool for in situ conservation of biodiversity has widely been acknowledged. Their complex sociospiritual or sociocultural associations with deities and spirits of dead ancestors have contributed to the protection of some ecosystems. Overall, our results showed that sacred groves, a traditional conservation approach, supported more species turnover than the conventional state managed forest reserve. Given the recent human-led disturbance and climate change impacts on ecosystems, it will be prudent to direct effort at sustaining traditional beliefs about sacred groves, since they serve as a haven for both endangered species. Environmental organizations such as IUCN, Convention on Biological Diversity, should consider declaring sacred groves as global "*hotspots*" of biodiversity significance.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper, especially from the organization that provided logistical support for this study.

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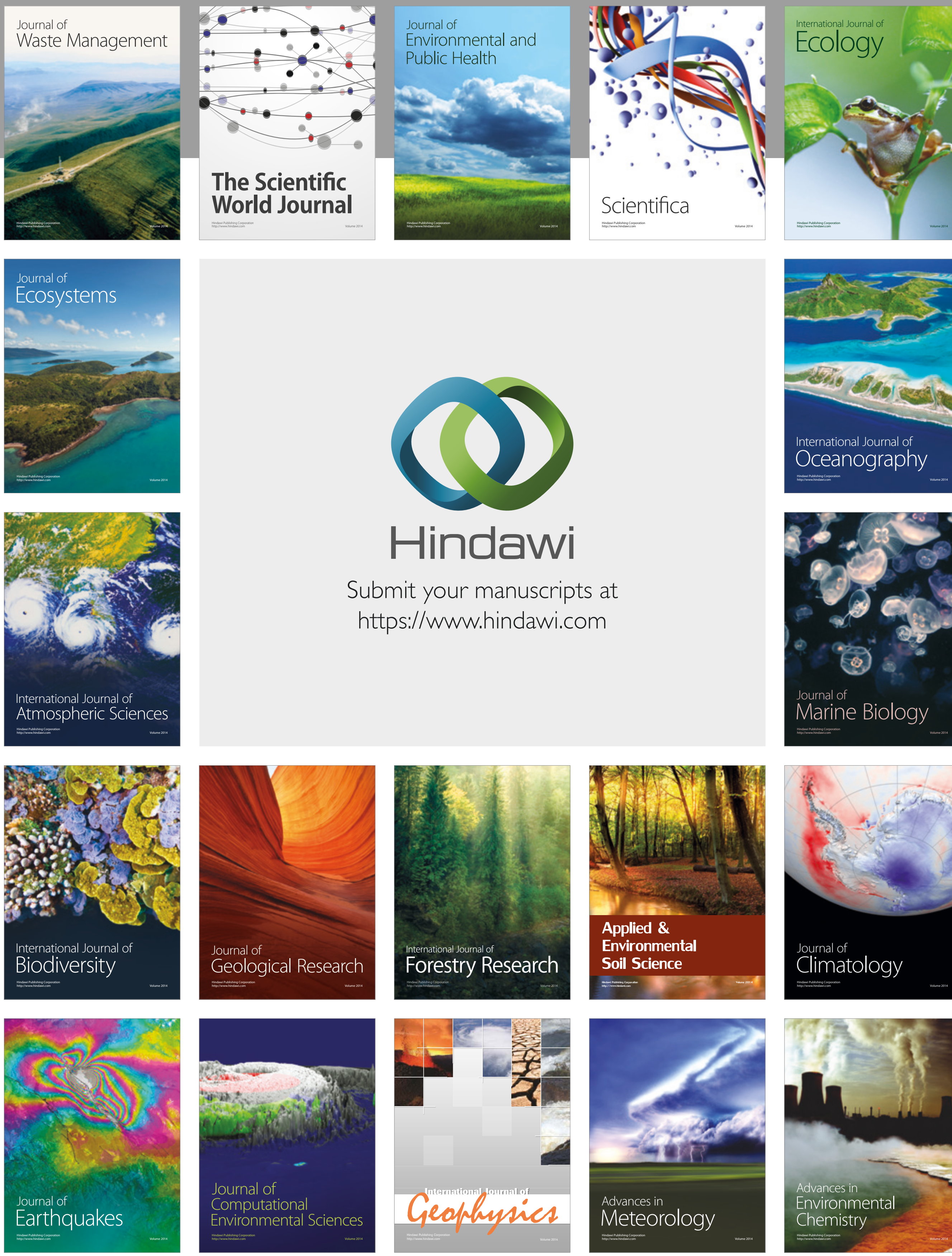
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