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Land Sparing Can Maintain Bird Diversity in Northeastern Bangladesh

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Abstract: One of humanity's most significant challenges in the process of attaining the established sustainability goals is balancing the growing human demand for food and the need to conserve biodiversity. This challenge requires appropriate land uses that are able to conserve biodiversity while ensuring ample food supply. This study compares bird species diversity and abundance in areas undergoing land sharing and land sparing in northeastern Bangladesh (West Bhanugach Reserved Forest). Birds serve as useful biologic indicators because of their presence within different trophic levels and their well-studied ecology. To survey birds, we selected a total of 66 sampling sites within land-sharing (33) and land-sparing (33) land-use areas. Between May and June 2017, we observed and recorded bird calls within a 50-m radius around each sampling site. We counted 541 individuals from 46 species of birds. The Shannon bird diversity was higher in the land-sparing sites (1.52) than in the land-sharing sites (1.23). We found approximately 30% more bird species (39 vs. 30) and 40% more individuals (318 vs. 223) in the land-sparing areas than land-sharing areas. Three bird species, *Arachnothera longirostra*, *Micropternus brachyurus* and *Copsychus malabaricus*, were significantly associated with the land-sparing sites. This study shows that land sharing negatively affects bird diversity, richness and abundance compared to land-sparing. The use of chemical fertilizers and the lack of food, such as insects, for birds can explain the lower diversity, richness and abundance of birds in the land-sharing areas. Although land sharing is an effective means of producing food, land sparing is the most effective land-use practice for preserving bird diversity in northeastern Bangladesh.

Keywords: agriculture; biodiversity; conservation; habitat loss; forestry; land sharing; land use; sustainability; wildlife

1. Introduction

Rapid growth in the human population (reached 7.8 billion in 2020) and associated intensive exploitation of land and resources has resulted in the degradation of ecosystems [1], which consequently affecting biodiversity [2]. Technological advances allow a more rapid and larger-scale exploitation of ecosystems than traditional methods. The concept of sustainability has emerged, the goal of which is to achieve a balance between resource exploitation and ecosystem conservation [3]. Biodiversity provides essential ecological services for the survival and functioning of human societies, including the production of food, fiber and fuel [4]. Over the last century, however, global biodiversity has rapidly declined, mainly due to the loss of natural habitats [5,6]. Conserving biodiversity while securing food for everyone on Earth therefore represents an enormous and vital challenge for ensuring sustainability [7].

In addition to the increased demand for land, government policies and decisions related to land-use planning greatly affect biodiversity conservation [8]. Agricultural needs for maximizing food production must be balanced with conservation objectives that strive to preserve biologic diversity [9,10]. A solution to this conundrum has been the creation of two common land-use alternatives: land sharing and land sparing [11]. Land sharing (or wildlife-friendly farming systems) integrates both biodiversity conservation and food production objectives [12]. Land sparing focuses on maximizing yields on existing farmlands while establishing protected areas dedicated to biodiversity conservation [5,13]. The land-use choice depends on the regional socioeconomic conditions and biodiversity, among many other factors [14].

The effect of land sharing/sparing on biodiversity is highly context and scale-dependent, and the related effects on biodiversity are often contradictory [15]. Two studies reported that land sharing successfully maintained higher plant diversity on farmland in Indonesia [16] and bird diversity in Argentina [17] compared to land sparing. In contrast, land sharing in some countries has failed to sustain biodiversity. Land-sharing practices have negatively affected trees and birds in India [13], birds in Ghana [18], Uganda [19], Uruguay [20] and Colombia [21], as well as birds, dung beetles and ants in Brunei [22]. Given the great diversity of land-use practices across and between territories, it is important to conduct regional studies to determine appropriate land-use practices for specific areas.

This study focuses on northeastern Bangladesh—a country with the 10th-highest population density in the world (1265 inhabitants/km^2) [23,24]. By the year 2050, the population of Bangladesh is projected to reach approximately 200 million [25], which will result in a higher demand for food, reduce the revenue from foreign exports and increase dependency on foreign imports. Bangladesh also has some of the highest rates of biologic diversity on the planet [26]. The country is situated in the Indo-Burma region and is recognized as a global biodiversity hotspot; furthermore, it harbors more than 7000 endemic plant species [27]. The country also has unique ecosystems, such as the world's largest continuous mangrove forest in southwestern Bangladesh, a large tract of evergreen to semi-evergreen hill forests in eastern Bangladesh and numerous wetlands and rainforests in the northeastern part of the country [28]. The combination of a highly dense human population and rich biodiversity makes the challenge of producing food while preserving biodiversity particularly crucial in Bangladesh; the region therefore represents an interesting study area for the evaluation of the effect of land-use practices on biologic diversity.

Future sustainable land-use policies in Bangladesh will be even more critical, as the country is extremely vulnerable to climate change [29]. Climate change will heighten risks from floods, insect outbreaks, wildfires, windthrows, droughts, hailstorms, salinity intrusions and sea-level rise [30–34]. These factors will affect agricultural production and ecosystems in Bangladesh [23,35]. Although Bangladesh has achieved self-sufficiency in rice production through intensive farming [36], the adverse effects of climate change and population growth will threaten food security. Therefore, crop productivity must be increased to ensure food security for the expected population without increasing the extent of cultivated land.

Ecosystems are vulnerable to climate change, and the state of tropical forest in Bangladesh is likely to worsen due to the effect of this changing climate [37,38]. Biodiversity will therefore be negatively affected by increased temperatures and precipitation, increased groundwater salinity due to rising sea level and extreme weather events [29]. Thus, to ensure an adequate food supply and maintain biodiversity in the context of climate change, establishing long-term land-use plans and policies is essential [5,8]. Therefore, it is necessary to understand the effects of land use on biodiversity, and useful ecological indicators must be developed.

Birds commonly serve as biologic indicators because of their well-studied ecology [39], the clear links between their behavior and ecosystem type [40,41], their presence and abundance within different trophic levels in the food chain of a forest ecosystem and their easy identification. As birds feed on insects, invertebrates, small vertebrates, nectar, fruits or seeds, land-use practices seriously affect their diversity and conservation status [11,42]. Many studies have thus evaluated land-use strategies using birds as biologic indicators [11–13,19].

Here, we studied birds as indicators for assessing the effect of land use on biodiversity conservation in northeastern Bangladesh. Our main objective was to assess the abundance, species richness and diversity of bird species within two types of land use: land sharing and land sparing. Based on previous studies in similar habitats, we expected to observe a negative effect of land sharing on birds in this region of Bangladesh [11]. The diversity of most wild species is negatively affected when their habitats are converted to land-sharing land use [43]. Therefore, we hypothesized that land-sparing areas would have higher a bird abundance, species richness and diversity compared with land-sharing locations [11,43].

2. Materials and Methods

2.1. Study Area

This study was conducted in the West Bhanugach Reserved Forest, northeastern Bangladesh (24°19′11″ N, 91°47′1″ E). Apart from having anthropogenic land use in the buffer zone, the 2740 ha forest reserve contains two major land-use systems: land sharing and land sparing. The section of this forest having a high conservation value is designated as the core zone (land sparing) and has an area of 1250 ha. This core is surrounded by a 5-km-wide buffer zone (land sharing) where traditional agroforestry land use is practiced following the traditional methods of the neighboring villages [27]. This buffer zone is itself surrounded by various land uses, including agricultural lands, human settlements, roads and rail lines, all of which alter the existing habitat and wildlife [44]. The southeastern, southern and eastern parts of the core are bounded by agricultural lands, including tea gardens, rubber plantations, pineapple groves and lemon gardens. We identified a portion of this boundary area as representing land-sharing land use. Few trails and tracks are found within the forest; the existing paths were created by the local people for collecting firewood from the forest [45].

The West Bhanugach Reserved Forest is classified as subtropical rain forest and has a semi-evergreen forest composition [46]. The forest originally supported a native foliage cover of mixed tropical evergreen forest, [47], but this cover has been transformed into a secondary forest. The interior of this forest has a maximum average daily temperature of 27 °C (June to September) and a minimum average daily temperature of 16 °C (January). The average rainfall is approximately 3000 mm; most rain falls in the rainy season from June to September [44]. Relative humidity is high (74%) throughout the year, and this forest experiences frequent rains and occasional cyclonic storms [48]. The soils of the West Bhanugach Reserved Forest are generally a brown, sandy clay loam [49]. Abundant streams flow through the forest.

The forest composition of the West Bhanugach Reserved Forest is mixed, with an average tree density of 528.5 trees·ha^{-1} [50]. The forest land, considered as land sparing in this study, consists of a wide area of mixed and monospecific plantations; however, it is rare to find monospecific plantations inside land sparing because of natural succession. Mixed plantations include native plantations, such as chaplash (*Artocarpus chaplasha*), white thingan (*Hopea odorata*), toon (*Toona ciliata*), gamhar (*Gmelina arborea*), mahogany (*Chikrassia tabularis*), woolly cassia (*Cassia hirsuta*), silk cotton tree (*Bombax ceiba*) and Burma ironwood (*Xylia dolabriformis*) [51,52]. The monospecific and exotic [53] plantations are mainly ear-leaf acacia (*Acacia auriculiformis*), teak (*Tectona grandis*), mangium (*Acacia mangium*) and eucalyptus (*Eucalyptus* spp.). A large amount of invasive fast-growing acacia has been planted in the area to quickly recover areas of degraded forest. The tree composition density in land sharing is less than in land sparing because of farming practices and resource extraction by local people (Figure 1). Vegetation in the land-sharing areas is quite different and includes tree species, such as areca palm

(*Areca catechu*), agarwood (*Aquilaria agallocha*), jackfruit (*Artocarpus heterophyllus*), neem (*Azadirachta indica*), Burmese grape (*Baccaurea ramiflora*), *eucalyptus* (*Eucalyptus* spp.) and arjun (*Terminalia arjuna*), along with agricultural crops, including taro (*Colocasia esculenta*), rattan palm (*Demonorops jenkensiana*), pineapple (*Ananas sativus*), tea (*Camellia sinensis*), lemon (*Citrus limon*) and Indian timber bamboo (*Bambusa tulda*).

The forest contains approximately 167 plant, 16 amphibian, 30 reptile, 246 bird and 20 mammal species [54–56]. This forest provides the habitat for some endangered wildlife, including the hoolock gibbon (*Hoolock hoolock*), Indian pangolin (*Manis crassicaudata*), Phayre's leaf monkey (*Trachypithecus phayrei*), Red-Breasted Parakeet (*Psittacula alexandri*) and elongated tortoise (*Indotestudo elongata*) [57].

Figure 1. Photographs of the (**A**) regional landscape and (**B**) a within-forest water trail in the land-sparing area. A lemon and banana plantation with (**C**) native forest trees and a tea garden with (**D**) shade trees, both located in the land-sharing areas.

2.2. Experimental Design

We selected 33 sampling sites (Figure 2) for each land-use type. We determined the optimal number of sampling sites using species-area accumulation curves—the total number of identified species in relation to the number of sites (Figure 3). After setting the initial sampling site, we selected the other sites systematically. All sampling sites were inside the boundary of the West Bhanugach Reserved Forest excluding agricultural land and land sparing sites were inside the nearby national park (Lawachara National Park). Each sampling site was at least 250 m apart from each other in all directions. With at least 250 m between each adjacent sampling sites. For each site, we established a 50-m radius zone around the center, which we consider as the approximate distance within which bird calls can be recorded and be associated with the sampling site.

We used the point count method. Advantages of the point count approach included the observers being able to focus fully on observing birds without having to watch where they walk and the observers having more time to identify contacts. The point sampling method also provided a greater likelihood of detecting cryptic and skulking species and facilitated relating a bird occurrence to specific habitat features. Covering the total forest area with 66 plots of 50 m radius each (33 sites × 2 types × 50 m radius/2740 ha × 100%), we obtained a sampling intensity of approximately 2%.

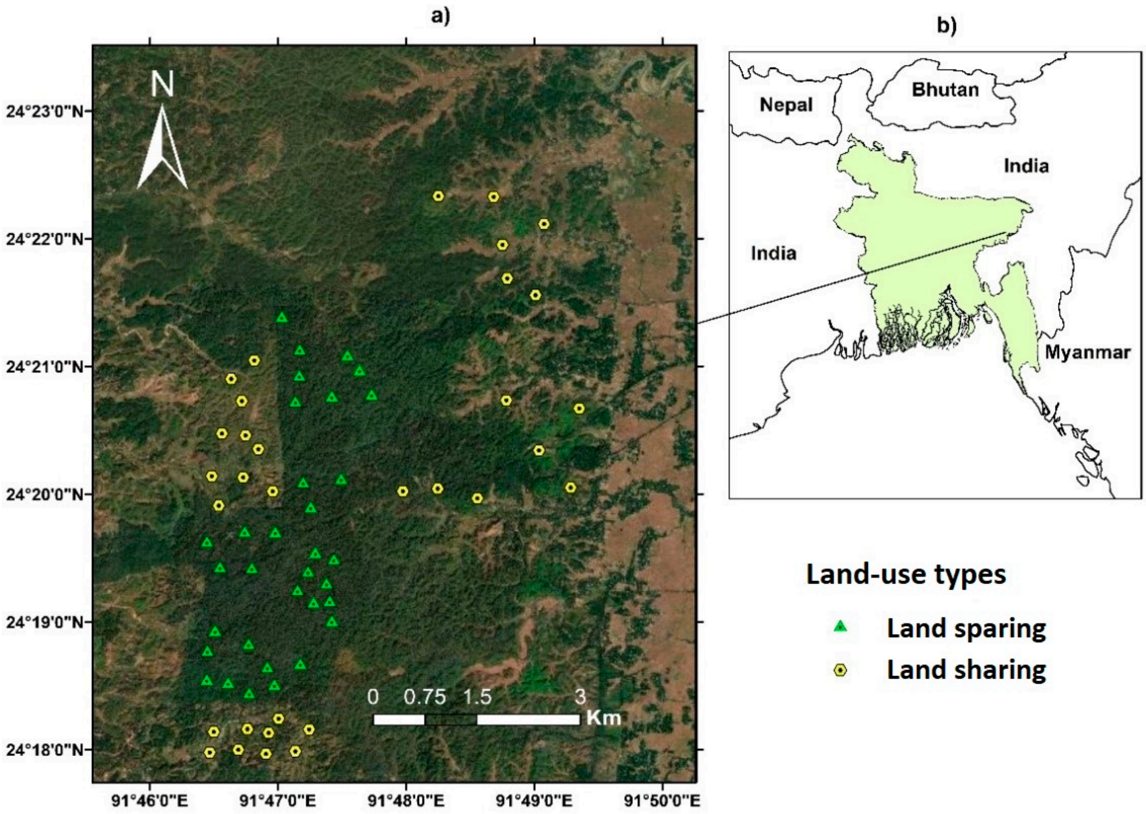


Figure 2. (**a**) Sampling sites in the West Bhanugach Reserved Forest; (**b**) location of the study area in Bangladesh.

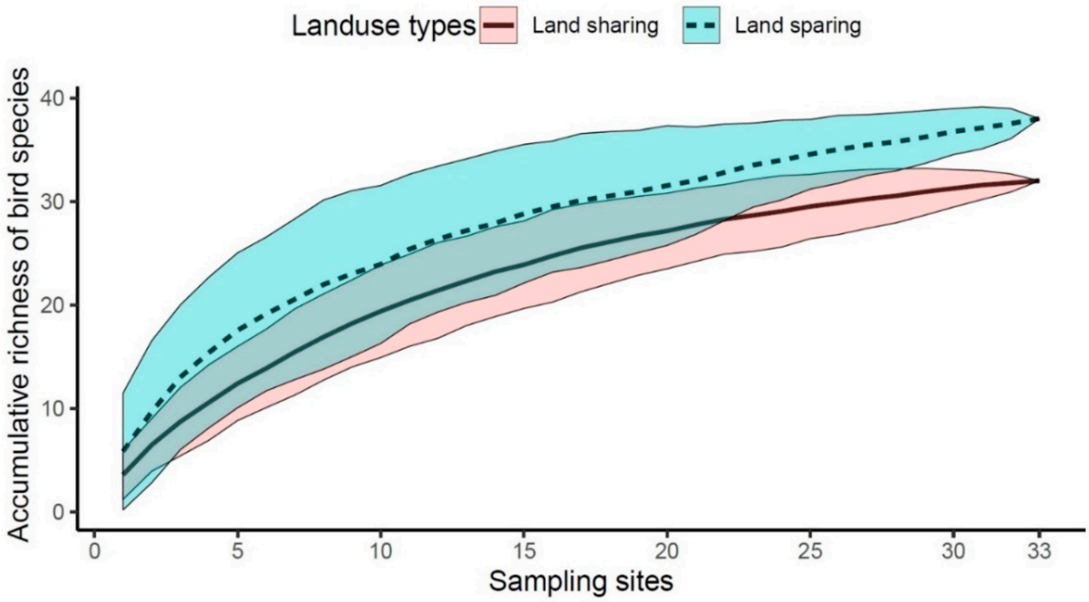


Figure 3. Accumulative richness of bird species for land-sharing and land-sparing land use in relation to an increasing number of sampling sites. Pink- and blue-shaded polygons indicate the 95% confidence intervals of the accumulative species richness for the land-sharing and land-sparing land uses, respectively.

2.3. Bird Identification and Counting

An exploratory survey identified that bird activity was very high after sunrise and before sunset. Therefore, we began data collection at 6 a.m., about 30 min after sunrise and continued until 9 a.m. when bird activity normally declined [58]. We surveyed again before dusk, between 1:30 p.m. and 6:30 p.m. Moreover, we kept the peak time for bird availability the same for both land-use types. During this bird survey, we counted and identified each individual visually and/or aurally. Our bird survey ran from 9 May 2017 to 8 June 2017 for four consecutive weeks. To ensure a high number of visited sites, each sampling site was surveyed once during this period. It should be noted, however, that birds were usually very vocal and active during the dawn survey period and that this study only focuses on diurnal species that we can either see or hear.

We recorded calls using a Zoom IQ7 audio recorder (Zoom North America, New York, USA) on an iPhone for four minutes to reduce the bias between the two sites having different canopy coverage and visibility [59]. Any bird spotted within the 50-m radius was identified and noted regardless of its activity (flying over, singing, feeding or nesting). The bird-call recordings were used for cross-checking and detecting further species. To identify the bird call, we relied on reference bird-call libraries such as xeno-canto and the Macaulay Library [60]. We were able to identify almost all of the individuals on the basis of their calls. To limit any bias from undetected birds, we also cross-checked the recording of several bird identifiers ($n = 44$), and we did not record birds already included at previous sampling sites to eliminate double counting. We also used an equal number of sites for each land-use type and applied the same methods at all sites.

2.4. Data Analysis

The normality of the residuals and the homoscedasticity of our data allowed us to run Welch's *t*-tests to compare mean differences in bird diversity and abundance at the land-sharing and land-sparing sites. Data analyses were performed using R version 3.5.2 [61] with the package 'vegan' [62] to calculate the species accumulation curves for both land-use types and to calculate the Shannon diversity index (H) for each sampling site. To assess the strength and the statistical significance of the relationship between species abundance and land-use type, we used the R-package 'indicspecies' [63]. Evaluating the occurrence of a small set of indicator species is akin to sampling the entire community, which was particularly useful in long-term environmental monitoring for conservation. We used the 'ggplot2' R-package to generate graphs [64].

3. Results

3.1. Abundance

We recorded 541 individuals of 46 bird species across all land-use types. Land-sharing sites accounted for 223 of these individuals, an average of 6.8 ± 4.2 (all results given as mean ± SD, unless noted otherwise) individuals per sampling site. We counted 318 individuals in the land-sparing sites, an average of 9.6 ± 5.4 individuals per sampling site. A Welch's *t*-test confirmed that mean bird abundance at land-sparing sites was significantly higher ($p < 0.01$) than that for the land-sharing sites (Figure 4).

3.2. Richness and Diversity

Sample-based rarefaction and extrapolation curves showed a higher bird species richness in the land-sparing sites (39) than in the land-sharing locations (30) (Figure 4). The mean Shannon diversity index value in land-sparing sites was 1.5 ± 0.5, a higher mean value than that recorded at the land-sharing sites (1.2 ± 0.3) (Table 1).

Table 1. Bird abundance, species richness and Shannon diversity (*H*) for all land-sparing and land-sharing sampling sites (33 for each land-use type).

Sampling Sites	Land Sparing Abundance	Species Richness	Species Diversity (*H*)	Land Sharing Abundance	Species Richness	Species Diversity (*H*)
1	14	3	0.9	10	4	1.4
2	7	4	1.3	3	2	1.1
3	10	5	1.5	4	3	1
4	7	4	1.3	3	3	1.1
5	2	2	0.7	5	2	0.7
6	21	10	2.1	8	4	1.3
7	4	3	1	17	7	1.8
8	3	2	0.6	7	4	1.3
9	8	5	1.5	4	4	1.3
10	14	7	1.8	2	2	0.7
11	8	5	1.5	16	5	1.4
12	13	7	1.7	8	3	0.9
13	5	4	1.3	8	4	1.2
14	5	2	0.5	10	3	0.8
15	10	7	1.9	17	6	1.7
16	13	9	2.1	5	4	1.3
17	12	6	1.7	5	3	1.1
18	7	5	1.5	4	4	1.4
19	14	7	1.9	10	4	1.3
20	14	8	1.9	7	5	1.5
21	9	6	1.7	8	3	1
22	10	5	1.6	8	3	1.1
23	15	10	2.2	7	3	1.1
24	21	10	2.1	8	4	1.3
25	20	11	2.3	6	4	1.3
26	4	3	1	4	4	1.4
27	6	4	1.3	5	3	1
28	6	5	1.6	3	3	1.1
29	7	5	1.5	3	3	1.1
30	6	4	1.3	4	4	1.4
31	7	6	1.7	5	5	1.6
32	12	7	1.9	4	4	1.4
33	3	3	1.1	6	5	1.6
Average ± SD	9.6 ± 5.4	5.6 ± 2.5	1.52 ± 0.45	6.8 ± 4.2	3.7 ± 1.2	1.23 ± 0.27

Land-sharing sites had a total species richness of 30, with 3.7 ± 1.2 species per observation site, whereas land-sparing sites had a total richness of 39, with 5.6 ± 2.5 species per observation site, significantly higher ($p < 0.01$) than in land-sharing sites (Figure 4).

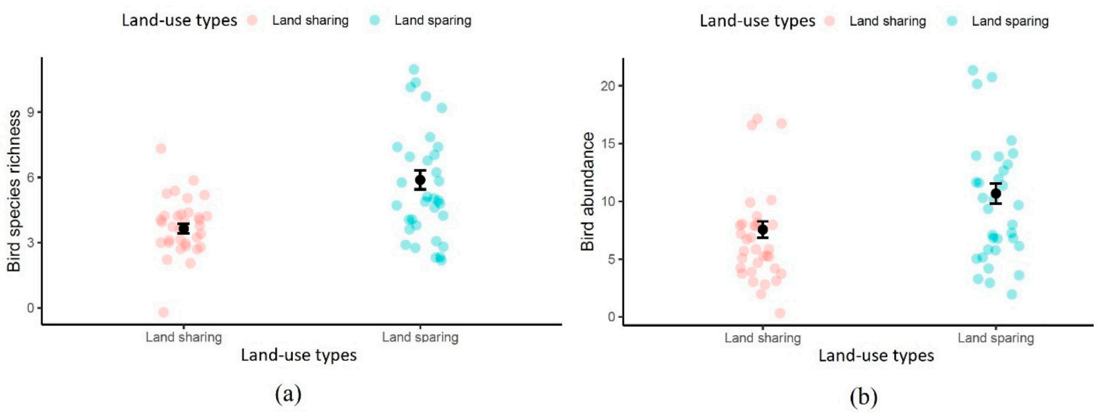
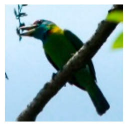
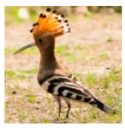
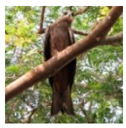


Figure 4. (**a**) Species richness and (**b**) species abundance for birds identified in the land-sharing (pink dots) and land-sparing (blue dots) land uses in the study area. Black dots represent the respective mean (± standard error) for each land-use type.

3.3. Indicator Species

The Little Spider-Hunter (*Arachnothera longirostra*), Rufous Woodpecker (*Micropternus brachyurus*) and White-Rumped Shama (*Copsychus malabaricus*) were significantly ($p < 0.01$) associated with land-sparing areas (Table 2), as was the Ashy Bulbul (*Hemixos flavala*) ($p < 0.05$). We found no particular bird species significantly associated with land-sharing areas ($p > 0.05$).

Table 2. Mean abundance (± standard deviation) of selected indicator bird species in the land-sparing and land-sharing sites. We present all species that had a significant difference in abundance between the land-use types as well as potential indicator species that did not differ significantly ($p > 0.05$).

Bird Species	Mean Abundance in Land Sparing	Mean Abundance in Land Sharing	*p*-Value (Welch's *t*-Tests)	Photographs of the Species
Arachnothera longirostra	15 ± 5.8	4 ± 2.7	0.007	
Micropternus brachyurus	18 ± 5.6	0 ± 2.6	0.013	
Copsychus malabaricus	20 ± 5.3	4 ± 2.7	0.050	
Hemixos flavala	11 ± 8.4	2 ± 3.5	0.088	
Megalaima asiatica	10 ± 8.6	2 ± 3.5	0.158	
Corvus macrorhynchos	0 ± 2.1	3 ± 1.9	0.208	
Upupa epops	0 ± 2.1	2 ± 2	0.227	
Milvus migrans	0 ± 2.0	2 ± 2	0.477	
Orthotomus atrogularis	2 ± 2.1	7 ± 2.6	0.480	
Dicrurus leucophaeus	0 ± 2.1	2 ± 2	0.490	

4. Discussion

We live in a critical situation at the global level where habitat loss due to human activities is profoundly altering the balance between ecosystem services, health and economy (e.g., COVID-19) [65]. This study comparing land-sparing with land-sharing land uses provides a platform to discuss forest land-use priorities, i.e., to increase food production or conserve local biodiversity. Bangladesh, the most densely populated developing country, is an ideal study area because of its rapidly growing population and high biologic diversity [23]. This study, which is the first to compare biodiversity in land-sharing and land-sparing practices in Bangladesh, shows that land sparing is associated with a higher bird abundance, species richness and diversity than land sharing. We also identified bird species that were associated with land-sparing sites.

The practice of land sharing, as a widely accepted land-use system, has been practiced in Bangladesh since 1979 [66] and has been widely used in recent years to improve food production. Although land-sharing systems permit keeping up with the growth in regional food demand, we also found that this form of land use has a lower bird abundance, species richness and species diversity relative to land-sparing systems. Studies in Ghana, India [13] Brazil [20], Uganda [19], Romania and Moldova [67] also found greater bird diversity in land-sparing sites. Land sharing involves extensive farming to maximize crop yields without concerning biodiversity and is associated with drastic reductions in habitat diversity due to monoculture [68]. Monospecific and intensive plantations (e.g., lemon, banana, tea, ginger, pineapple, turmeric and orange) are characterized by homogeneity and a simplification of forest structure, thereby causing a marked decrease in habitat availability and bird diversity. Because habitat destruction and fragmentation are the main causes of biodiversity loss [69,70], it is very likely that these factors are also major causes of the decrease in bird diversity and richness in the West Bhanugach Reserved Forest. Intensive farming involves the heavy use of pesticides [68]; the resulting lack of food sources for insectivorous birds is also an important factor in explaining bird declines [71]. Land sharing also involves frequent human disturbances that can affect bird reproduction, complicate communication and increase the vulnerability of birds to predation [72]. A combination of these factors is likely causing the lower number of detected species in the land-sharing sites.

Some species, such as the black-crowned night heron (*Nycticorax nycticorax*) and Black Kite (*Milvus migrans*), were only found in the land-sharing sites. Their presence can be explained by their respective diets; Black-Crowned Night Herons feed on fish, insects, and crustaceans [73], whereas black kites feed on birds, small mammals, insects, and they can sometimes act as scavengers [74]. The Purple Sunbird (*Cinnyris asiaticus*) and Black Drongo (*Dicrurus macrocercus*) had a much higher abundance in the land-sharing sites. Regardless, the low absolute abundance of these species did not permit to significantly associate them with the bird community of land-sharing areas. A study of the larger home range of the birds and the microhabitats used by specific indicator bird species would help explain this lack of association of the observed birds with land-sharing sites.

The land-sparing practice can ensure biodiversity conservation and food production by minimizing the adverse effects of agriculture on bird communities [12]. Our results show that land-sparing sites have a higher bird diversity, richness and abundance, confirming our hypothesis. Land sparing provides a higher diversity of habitats and a higher abundance of food resources for birds than land sharing [75,76]. We observed a greater diversity of trees in land-sparing sites than land-sharing sites. Land-sparing sites offer a wider range of resources for the various bird species: seeds and fruits and habitats for potential bird prey items, including macroinvertebrates (e.g., insects, worms, mollusks) and vertebrates (e.g., amphibians and small reptiles). This diversity can favor the higher diversity and richness of bird communities within land-sparing areas.

Of the 39 bird species found in land-sparing sites, three (*Arachnothera longirostra, Micropternus brachyurus, Copsychus malabaricus*) were strongly associated with land-sparing. The little spider-hunter is a pollinator species, which feeds on nectar [77] and is most commonly found in old-growth forests, such as the West Bhanugach Reserved Forest [78,79]. These forest ecosystems also have a high level of heterogeneity and stability, contrary to the land-sharing forests. The little spider-hunter requires flowers with nectar to feed; these plants are not available in many land-sharing areas, which are characterized by plant species lacking accessible nectar (e.g., *Ananas comosus*, *Eucalyptus robusta*). The rufous woodpecker was also identified as an indicator species of land-sparing areas, and this species is commonly found in secondary forests [80,81]. This woodpecker feeds on insects; insects are likely more abundant in land-sparing than land-sharing areas because of pesticide use in the latter. Finally, the strong association of the white-rumped shama with land sparing can be explained by a habitat preference for dense undergrowth [82]. In the land-sharing sites of West Bhanugach, the understory is cleared to increase agricultural production, whereas undisturbed land-sparing forest ecosystems develop a very dense undergrowth, which contains a diverse collection of herbs, shrubs and climbing plants. The countrywide forest logging ban since 1970 in Bangladesh boosted forest conservation [83] and, therefore, possibly contributed to preserving this highly sensitive species. This study advocates for the protection of the forest, which contributes greatly to the conservation of regional biodiversity. However, this study did not consider species habitat or information related to the vegetation (e.g., species height, volume, composition and complexity). Further study could reveal information on habitat or land use preference of certain indicator species.

Bangladesh is one of the most vulnerable countries to the effects of climate change and sea-level rise [84]. The country has recently experienced a 26% decrease in overall agricultural production because of climate change and sea-level rise [23]; as a country having an agriculture-based economy, this change is a serious threat to overall food security. Land-use policies in Bangladesh will be crucial in balancing food production and biodiversity conservation. Crop productivity must be improved to ensure food security; however, one major challenge for improving crop productivity is the poor land management system in Bangladesh [85].

5. Conclusions

Existing land-use practices are major drivers of biodiversity loss. Globally, land sharing has become popular because it ensures a high level of food production. Although it is often called a wildlife-friendly farming system, numerous studies show that it can negatively affect biodiversity. Protected areas in a land-sparing system, however, provide more adequate environments for preserving bird communities. Our study found a higher bird species richness, diversity and abundance in land-sparing sites than land-sharing sites. In Bangladesh, forests are converted into farmland because of increased food demand. Despite the positive effect on human livelihood and even some environmental aspects (e.g., carbon storage), this loss of forest negatively affects biodiversity through the loss and fragmentation of suitable habitats, direct human disturbances, the use of chemical fertilizers and pesticides and lower amounts of understory vegetation in these land-sharing systems. We identified three bird species (*Arachnothera longirostra, Micropternus brachyurus, Copsychus malabaricus*) that were significantly associated with bird communities of land-sparing areas. Thus, these species can be used as potential ecological indicators to evaluate the effect of land-use type and land-use change on biodiversity.

We conclude that land sparing is a promising practice to adopt in the West Bhanugach Reserved Forest to preserve an abundant, rich and diverse bird community and preserve ecologically sensitive species that require land sparing to survive.

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References

1. Foley, J.; Defries, R.; Asner, G.; Barford, C.; Bonan, G.; Carpenter, S.; Chapin, F.S., III; Coe, M.; Daily, G.; Gibbs, H.; et al. Global consequences of land use. *Science* **2005**, *309*, 570–574. [CrossRef] [PubMed]
2. Rands, M.; Adams, W.; Bennun, L.; Butchart, S.; Clements, A.; Coomes, D.; Entwistle, A.; Hodge, I.; Kapos, V.; Scharlemann, J.; et al. Biodiversity conservation: Challenges beyond 2010. *Science* **2010**, *329*, 1298–1303. [CrossRef] [PubMed]
3. Quarrie, J. (Ed.) *Earth Summit' 92: The United Nations Conference on Environment and Development*; The Regency Press: London, UK, 1992.
4. Gabriel, D.; Roschewitz, I.; Tscharntke, T.; Thies, C. Beta diversity at different spatial scales: Plant communities in organic and conventional agriculture. *Ecol. Appl.* **2006**, *16*, 2011–2021. [CrossRef]
5. Tscharntke, T.; Clough, Y.; Wanger, T.C.; Jackson, L.; Motzke, I.; Perfecto, I.; Vandermeer, J.; Whitbread, A. Global food security, biodiversity conservation and the future of agricultural intensification. *Biol. Conserv.* **2012**, *151*, 53–59. [CrossRef]
6. Martin, M.; Girona, M.M.; Morin, H. Driving factors of conifer regeneration dynamics in eastern Canadian boreal old-growth forests. *PLoS ONE* **2020**, *15*, 0230221. [CrossRef]
7. Godfray, H.C.J. Food and biodiversity. *Science* **2011**, *333*, 1231–1232. [CrossRef]
8. Wilkinson, J.B. The State Role in Biodiversity Conservation. *Sci. Technol.* **1999**, *15*, 71–77.
9. Frison, E.; Jeremy, C.; Hodgkin, T. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability* **2011**, *3*, 238. [CrossRef]
10. FAO. *Sustainable Agriculture for Biodiversity*; FAO: Rome, Italy, 2018.
11. Fischer, J.; Abson, D.J.; Butsic, V.; Chappell, M.J.; Ekroos, J.; Hanspach, J.; Von Wehrden, H. Land sparing versus land sharing: Moving forward. *Conserv. Lett.* **2014**, *7*, 149–157. [CrossRef]
12. Green, R.; Cornell, S.; Scharlemann, J.; Balmford, A. Farming and the fate of wild nature. *Science* **2005**, *307*, 550–555. [CrossRef]
13. Phalan, B.; Onial, M.; Balmford, A.; Green, R.E. Reconciling food production and biodiversity conservation: Land sharing and land sparing compared. *Science* **2011**, *333*, 1289–1291. [CrossRef] [PubMed]
14. Trisurat, Y.; Shirakawa, H.; Johnston, J.M. Land-use/land-cover change from socio-economic drivers and their impact on biodiversity in Nan province, Thailand. *Sustainability* **2019**, *11*, 649. [CrossRef]
15. Kremen, C. Reframing the land-sparing/land-sharing debate for biodiversity conservation. *Annal. N. Y. Acad. Sci.* **2015**, *1355*. [CrossRef] [PubMed]
16. Steffan-Dewenter, I.; Kessler, M.; Barkmann, J.; Bos, M.M.; Buchori, D.; Erasmi, S.; Faust, H.; Gerold, G.; Glenk, K.; Gradstein, S.R.; et al. Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 4973–4978. [CrossRef] [PubMed]
17. Mastrangelo, M.E.; Gavin, M.C. Trade-Offs between Cattle Production and Bird Conservation in an Agricultural Frontier of the Gran Chaco of Argentina. *Conserv. Biol.* **2012**, *26*, 1040–1051. [CrossRef] [PubMed]
18. Wade, A.S.I.; Asase, A.; Hadley, P.; Mason, J.; Ofori-Frimpong, K.; Preece, D.; Spring, N.; Norris, K. Management strategies for maximizing carbon storage and tree species diversity in cocoa-growing landscapes. *Agric. Ecosyst. Environ.* **2010**, *138*, 324–334. [CrossRef]
19. Hulme, M.F.; Vickery, J.A.; Green, R.E.; Phalan, B.; Chamberlain, D.E.; Pomeroy, D.E.; Nalwanga, D.; Mushabe, D.; Katebaka, R.; Bolwig, S.; et al. Conserving the Birds of Uganda's Banana-Coffee Arc: Land Sparing and Land Sharing Compared. *PLoS ONE* **2013**, *8*, e54597. [CrossRef]
20. Da Silva, T.W.; Dotta, G.; Fontana, C.S. Structure of avian assemblages in grasslands associated with cattle ranching and soybean agriculture in the Uruguayan savanna ecoregion of Brazil and Uruguay. *Condor* **2015**, *117*, 53–63. [CrossRef]

21. Gilroy, J.J.; Woodcock, P.; Edwards, F.A.; Wheeler, C.; Uribe, C.A.M.; Haugaasen, T.; Edwards, D.P. Optimizing carbon storage and biodiversity protection in tropical agricultural landscapes. *Glob. Change Biol.* **2014**, *20*, 2162–2172. [CrossRef]
22. Edwards, D.P.; Gilroy, J.J.; Woodcock, P.; Edwards, F.A.; Larsen, T.H.; Andrews, D.J.R.; Derhe, M.A.; Docherty, T.D.S.; Hsu, W.W.; Mitchell, S.L.; et al. Land-sharing versus land-sparing logging: Reconciling timber extraction with biodiversity conservation. *Glob. Change Biol.* **2014**, *20*, 183–191. [CrossRef]
23. Mainuddin, M.; Kirby, M. National food security in Bangladesh to 2050. *Food Secur.* **2015**, *7*. [CrossRef]
24. United Nations Department of Economic and Social Affairs Population Division. *World Population Prospects 2019*; UN: New York, NY, USA, 2019.
25. UN Population Division. *World Population Prospects: The 2012 Revision, Economic & Social Affairs*; UN: New York, NY, USA, 2013. [CrossRef]
26. Mukul, S.; Biswas, S.; Rashid, A.Z.M. *Biodiversity in Bangladesh. Global Biodevirsity*; Apple Academic Press: Palm Bey, FL, USA, 2018. [CrossRef]
27. Mittermeier, R.A.; Myers, N.; Thomsen, J.B.; Da Fonseca, G.A.; Olivieri, S. Biodiversity hotspots and major tropical wilderness areas: Approaches to setting conservation priorities. *Conserv. Biol.* **1998**, *12*, 516–520. [CrossRef]
28. Khan, M.T. The Nishorgo Support Project, the Lawachara National Park, and the Chevron seismic survey: Forest conservation or energy procurement in Bangladesh? *J. Polit. Ecol.* **2018**. [CrossRef]
29. Huq, S. Climate change and Bangladesh. *Science* **2001**, *294*, 1617. [CrossRef]
30. Montoro Girona, M.; Morin, H.; Lussier, J.M.; Ruel, J.C. Post-cutting mortality following experimental silvicultural treatments in unmanaged boreal forest stands. *Front. For. Glob. Change* **2019**, *2*, 4. [CrossRef]
31. Lavoie, J.; Montoro Girona, M.; Morin, H. Vulnerability of conifer regeneration to spruce budworm outbreaks in the Eastern Canadian boreal forest. *Forests* **2019**, *10*, 850. [CrossRef]
32. Labrecque-Foy, J.P.; Morin, H.; Girona, M.M. Dynamics of territorial occupation by North American beavers in Canadian boreal forests: A novel dendroecological approach. *Forests* **2020**, *11*, 221. [CrossRef]
33. Montoro Girona, M.; Navarro, L.; Morin, H. A secret hidden in the sediments: Lepidoptera scales. *Front. Ecol. Evol.* **2018**, *6*, 2. [CrossRef]
34. Navarro, L.; Morin, H.; Bergeron, Y.; Girona, M.M. Changes in spatiotemporal patterns of 20th century spruce budworm outbreaks in eastern Canadian boreal forests. *Front. Plant Sci.* **2018**, *9*, 1905. [CrossRef]
35. Seidl, R.; Fernandes, P.M.; Fonseca, T.F.; Gillet, F.; Jönsson, A.M.; Merganičová, K.; González-Olabarria, J.R. Modelling natural disturbances in forest ecosystems: A review. *Ecol. Model.* **2011**, *222*, 903–924. [CrossRef]
36. Reid Bell, A.; Bryan, E.; Ringler, C.; Ahmed, A. Rice productivity in Bangladesh: What are the benefits of irrigation? *Land Use Policy* **2015**, *48*, 1–12. [CrossRef]
37. FAO; CIFOR. *FAO Framework Methodology for Climate Change Vulnerability Assessments of Forests and Forest Dependent People*; FAO: Rome, Italy, 2019.
38. Pachauri, R.K.; Reisinger, A. *Climate Change 2007: Synthesis Report; Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate*; IPCC: Geneva, Switzerland, 2007.
39. Padoa-Schioppa, E.; Baietto, M.; Massa, R.; Bottoni, L. Bird communities as bioindicators: The focal species concept in agricultural landscapes. *Ecol. Indic.* **2006**, *6*, 83–93. [CrossRef]
40. Keast, D.; Newsholme, E.A. Effect of mitogens on the maximum activities of hexokinase, lactate dehydrogenase, citrate synthase and glutaminase in rat mesenteric lymph node lymphocytes and splenocytes during the early period of culture. *Int. J. Biochem.* **1990**, *22*, 133–136. [CrossRef]
41. Versluijs, M.; Hjältén, J.; Roberge, J.M. Ecological restoration modifies the value of biodiversity indicators in resident boreal forest birds. *Ecol. Indic.* **2019**, *98*, 104–111. [CrossRef]
42. Koutsos, E.A.; Matson, K.D.; Klasing, K.C. Nutrition of birds in the order Psittaciformes: A review. *J. Avian Med. Surg.* **2001**. [CrossRef]
43. Phalan, B. What have we learned from the land sparing-sharing model? *Sustainability* **2018**, *10*, 1760. [CrossRef]
44. Rahman, S.C.; Rashid, S.M.A.; Datta, R.; Mro, P.; Roy, C. Status, exploitation, and conservation of freshwater turtles and tortoises in Chittagong Hill Tracts, Bangladesh. *Chelonian Conserv. Biol.* **2015**, *14*, 130–135. [CrossRef]
45. Feeroz, M.M.; Islam, M.A. Primates of the West Bhanugach Forest Reserve: Major threats and management plan. In *Bangladesh Environment 2000*; Feeroz Ahmed, M., Ed.; BAPA: Dhaka, Bangladesh, 2000; pp. 239–253.

46. Halim, M.A.; Shahid, A.; Chowdhury, M.S.H.; Nahar, M.N.; Sohel, M.S.I.; Nuruddin, M.J.; Koike, M. Evaluation of land-use pattern change in West Bhanugach Reserved Forest, Bangladesh, using remote sensing and GIS techniques. *J. For. Res.* **2008**, *19*, 193. [CrossRef]
47. Alam, M.K. *Annotated Checlist of Woody Flora of Sylhet Forests. Bulletin 5*; Plant Taxonomy Series; Bangladesh Forest Research Institute: Chattogram, Bangladesh, 1998.
48. Mehedi, M.A.H.; Kundu, C.; Chowdhury, M.Q. Patterns of tree buttressing at Lawachara National Park, Bangladesh. *J. For. Res.* **2012**, *23*, 461–466. [CrossRef]
49. Hossain, M.K.; Islam, Q.N.; Islam, S.A.; Tarafdar, M.A.; Zashimuddin, M.; Ahmed, A. *Assistance to the Second Agricultural Project-Bangladesh, Status Report on the Activities of the Silviculture Research Division*; BFRI: Chittagong, Bangladesh, 1989.
50. Muzaffar, S.B.; Islam, M.; Feeroz, M.; Begum, S.; Mahmud, M.; Chakma, S.; Hasan, M. Habitat characteristics of the endangered hoolock gibbons of Bangladesh: The role of plant species richness. *Biotropica* **2007**, *39*, 539–545. [CrossRef]
51. Uddin, M. Angiosperm diversity of Lawachara National Park (Bangladesh): A preliminary assessment. *Bangladesh J. Plant Taxon.* **2010**, *17*. [CrossRef]
52. Deb, J.C.; Roy, A.; Wahedunnabi, M. Structure and composition of understory treelets and overstory trees in a protected area of Bangladesh. *For. Sci. Technol.* **2015**. [CrossRef]
53. Uddin, M.B.; Steinbauer, M.J.; Jentsch, A.; Mukul, S.A.; Beierkuhnlein, C. Do environmental attributes, disturbances and protection regimes determine the distribution of exotic plant species in Bangladesh forest ecosystem? *For. Ecol. Manag.* **2013**. [CrossRef]
54. Reza, A.; Perry, G. Herpetofaunal species richness in the tropical forests of Bangladesh. *Asian J. Conserv. Biol.* **2015**, *4*, 100–108.
55. Rahman, S.; Rashid, S.M.A.; Das, K.; Jenkins, C.; Luiselli, L. Monsoon does matter: Annual activity patterns in a snake assemblage from Bangladesh. *Herpetol. J.* **2013**, *23*, 203–208.
56. Khan, M.; Monirul, H. *Protected Areas of Bangladesh: A Guide to Wildlife. Nishorgo Program, Wildlife Management and Nature Conservation Circle*; Bangladesh Forest Department: Dhaka, Bangladesh, 2008.
57. IUCN Bangladesh. *Red list of Bangladesh: Summary*; International Union for Conservation of Nature, Bangladesh Country Office: Dhaka, Bangladesh, 2015; Volume 1, p. 122.
58. Bibby, C.J.; Burgess, N.D.; Hill, D.A. Description and measurement of bird habitat. *Bird Census Tech.* **1992**. [CrossRef]
59. Haselmayer, J.; Quinn, J.S. A comparison of point counts and sound recording as bird survey methods in Amazonian Southeast Peru. *Condor* **2000**, *102*, 887–893. [CrossRef]
60. Scholes, E., III. *Macaulay Library Audio and Video Collection*; Cornell Lab of Ornithology: Ithaca, NY, USA, 2015. [CrossRef]
61. R Core Team. *R: A Language and Environment for Statistical Computing*; R Core Team: Vienna, Austria, 2013.
62. Oksanen, J.; Blanchet, F.G.; Friendly, M.; Kindt, R.; Legendre, P.; McGlinn, D.; Minchin, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; et al. Vegan: Community Ecology Package. Available online: https://CRAN.R-project.org/package=vegan (accessed on 26 July 2019).
63. De Cáceres, M.; Legendre, P. Associations between species and groups of sites: Indices and statistical inference. *Ecology* **2009**, *90*, 3566–3574. [CrossRef]
64. Wickham, H. ggplot2. *WIREs Comp. Stat.* **2011**, *3*, 180–185. [CrossRef]
65. Benayas, J.M.R.; Bullock, J.M. Restoration of biodiversity and ecosystem services on agricultural land. *Ecosystems* **2012**, *15*, 883–899. [CrossRef]
66. Ahmed, A. Issues in social forestry in Bangladesh: The betagi-pomora experiment. *J. Rural Dev.* **1988**, *7*, 263–274.
67. Kamp, J.; Urazaliev, R.; Balmford, A.; Donald, P.F.; Green, R.E.; Lamb, A.J.; Phalan, B. Agricultural development and the conservation of avian biodiversity on the Eurasian steppes: A comparison of land-sparing and land-sharing approaches. *J. Appl. Ecol.* **2015**. [CrossRef]
68. Arlettaz, R. The importance of habitat heterogeneity at multiple scales for birds in European agricultural landscapes. In *Birds and Habitat: Relationships in Changing Landscapes*; Cambridge University Press: Cambridge, UK, 2012; p. 177.
69. Tilman, D.; Fargione, J.; Wolff, B.; D'Antonio, C.; Dobson, A.; Howarth, R.; Swackhamer, D. Forecasting agriculturally driven global environmental change. *Science* **2001**, *292*, 281–284. [CrossRef] [PubMed]

70. Krauss, J.; Bommarco, R.; Guardiola, M.; Heikkinen, R.K.; Helm, A.; Kuussaari, M.; Steffan-Dewenter, I. Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels. *Ecol. Lett.* **2010**, *13*, 597–605. [CrossRef]
71. Mineau, P.; Whiteside, M. Pesticide acute toxicity is a better correlate of U.S. grassland bird declines than agricultural intensification. *PLoS ONE* **2013**, *8*, e57457. [CrossRef]
72. Bujoczek, M.; Rybicka, J.; Bujoczek, L. Effects of disturbances in a subalpine forest on its structural indicators and bird diversity. *Ecol. Indic.* **2020**, *112*. [CrossRef]
73. Quiroga, M.; Leon, E.; Beltzer, A.; Olguin, P. Diet of black-crowned night-herons (Nycticorax nycticorax) in a Wetland of the Parana River's Alluvial Valley. *Ekoloji* **2013**, *22*, 43–50. [CrossRef]
74. Zawadzka, D. Feeding habits of the Black Kite *Milvus migrans*, Red Kite *Milvus milvus*, White-tailed Eagle *Haliaeetus albicilla* and Lesser Spotted Eagle *Aquila pomarina* in Wigry National Park (NE Poland). *Acta Ornithologica* **1999**, *34*, 65–75.
75. Noss, R. Protected areas: How much is enough? In *National Parks and Protected Areas: Their Role in Environmental Protection*; Wright, R.G., Ed.; Blackwell Science: Cambridge, MA, USA, 1996.
76. Martino, D. Buffer zones around protected areas: A brief literature review. *Electron. Green J.* **2001**. [CrossRef]
77. Liu, A.-Z.; Li, D.-Z.; Wang, H.; Kress, W.J. Ornithophilous and chiropterophilous pollination in *Musa itinerans* (*musaceae*), a pioneer species in tropical rain forests of Yunnan, Southwestern China. *Biotropica* **2002**, *34*, 254–260. [CrossRef]
78. Daniels, R.J.R.; Malati, H.; Madhav, G. Birds of man-made ecosystems: The plantations. *Proc. Animal Sci.* **1990**, *99*, 79–89. [CrossRef]
79. Nature Conservation Management (NACOM). *Co-Management of Tropical Forest Resources of Bangladesh: Secondary Data Collection for Pilot Protected Areas: Lawachara National Park*; USAID/Bangladesh Ministry of Environment and Forest: Dhaka, Bangladesh, 2003.
80. Santharam, V. Display behavior in woodpeckers. *Newslett. Birdwatchers* **1997**, *37*, 98–99.
81. Winkler, H.; Christie, D.A. Rufous woodpecker (*Micropternus brachyurus*). In *Handbook of the Birds of the World Alive*; Del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A., De Juana, E., Eds.; Lynx Edicions: Barcelona, Spain, 2020.
82. Rasmussen, P.C.; Anderton, J.C. *Birds of South Asia: The Ripley Guide*; Smithsonian Institution and Lynx Edicions: Barcelona, Spain, 2005; pp. 395–396. ISBN 8487334679.
83. Sarker, S.; Deb, J.C.; Halim, M.A. A diagnosis of existing logging bans in Bangladesh. *Int. For. Rev.* **2011**, *13*, 461–475. [CrossRef]
84. Younus, M.A.F.; Harvey, N. Community-based flood vulnerability and adaptation assessment: A case study from Bangladesh. *J. Environ. Assess. Policy Manag.* **2013**. [CrossRef]
85. Wanjari, R.H.; Mandal, K.G.; Ghosh, P.K.; Adhikari, T.; Rao, N.H. Rice in India: Present status and strategies to boost its production through hybrids. *J. Sustain. Agric.* **2006**. [CrossRef]