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Forest Restoration through Village Common Forests in the Chittagong Hill Tracts of Bangladesh: The Role of NGO Interventions

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Abstract: Non-Governmental Organizations (NGOs) are widely recognized for their support of biodiversity conservation and forest restoration in tropical developing countries. In the Chittagong Hill Tracts (CHTs) of Bangladesh, ethnic forest-dependent communities have long maintained the Village Common Forest (VCF), an ancestral forest managed for community well-being. In recent years, some VCFs in the CHT have received support from local and international NGOs due to their perceived role in supporting biodiversity, ecosystem services, and improving local livelihoods. Although such support remains limited, its impacts on forest restoration and vegetation are not yet fully investigated. In the present study, we used remote sensing techniques and field surveys to measure vegetation cover changes and tree diversity in selected VCFs in the area. Our findings indicate that vegetation condition and tree diversity were better in NGO-supported VCFs compared with those without NGO intervention. Based on our study, we recommend increasing NGO involvement in VCF management with a more holistic and ecosystem-based approach, fostering institutional cooperation addressing land ownership issues, developing a market for forest ecosystem services, and improving local capacity for science-based forest management and ecosystem restoration in the CHT.

Keywords: ecosystem services; forest restoration; Village Common Forests; Normalized Difference Vegetation Index; tree diversity indices

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Citation: Bari, M.S.; Ali, M.M.; Alam, M.J.; Bashir, M.A.; Sarkar, O.T.; Mukul, S.A. Forest Restoration through Village Common Forests in the Chittagong Hill Tracts of Bangladesh: The Role of NGO Interventions. *Sustainability* **2024**, *16*, 8490. https://doi.org/10.3390/su16198490

Academic Editor: Sandra Notaro

Received: 25 July 2024
Revised: 15 September 2024
Accepted: 26 September 2024
Published: 29 September 2024

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1. Introduction

Globally, over 1.6 billion people rely on forests for timber, food, fuelwood, and shelter [1]. It is estimated that annually, the forestry sector contributed more than USD 539 billion directly and more than USD 1298 billion overall to the global GDP [2]. However, over half of the tropical forests worldwide have already been destroyed with nearly 1.5 billion hectares of forests heavily degraded [3]. Forest and Landscape Restoration (FLR), a deliberate process that restores ecological integrity and improves human well-being in deforested or degraded forested areas, is essential for greater ecosystem services and achieving Sustainable Development Goals [4]. The "United Nations Decade on Ecosystem Restoration (2021–2030)" also prioritized this endeavor as a global significance [5]. Nonetheless, it is challenging to optimize forest and landscape restoration to benefit all relevant stakeholders

and the ecosystem while balancing varied interests, governance, capability, and financial constraints [6].

The Chittagong Hill Tracts (CHTs) hold most of the hill forests in Bangladesh and are home to at least 16 ethnic communities [7]. Among the forest management systems in CHTs, the Village Common Forest (VCF) is a historical one that is entirely managed by ethnic communities. There are around 700–800 VCFs in CHTs, each with an average area of 20–120 hectares [8,9]. VCFs in CHTs serve as essential habitats for multiple flora and fauna and protect streams, natural springs, and other aquifers, which serve as the natural repositories of biodiversity [10–12].

Besides forest conservation and ecosystem services benefits, VCFs allow forest-dependent communities to maintain their customs and practices, representing a distinctive ecological and socio-cultural identity [13]. CHT highlights the intricate connection between these communities and the forest ecology as the forest shapes their culture and livelihood [14,15]. The hill people rely on VCFs' bamboo and timber resources for house construction, medicinal resources, and other sustainable biomass needs [16]. The extensive deforestation within the VCFs, however, threatens ecosystem services supply and ethnic communities' quality of life [11]. Due to unsustainable resource usage, many VCFs have lost significant biodiversity and witnessed environmental deterioration over the past decades [17]. Population pressure, unplanned development, unsustainable agricultural practices, lack of cultivable land, and alternative income-generating sources also have resulted in the overexploitation of VCF resources [18,19].

In 1992, the Rio Earth Summit laid the foundation for environmental NGOs [20]. Since then, environmental NGOs and their local partners have become crucial to reducing environmental degradation in tropical developing countries [21]. Considering the increasing forest degradation in CHTs, local NGOs have engaged as one of the key players to restore and conserve the forests while improving the livelihoods of forest-dependent people [6,7]. The role of NGOs in environmental conservation in Bangladesh has been widely documented [22,23].

In CHT, NGOs have worked collaboratively with local communities, the government, and other stakeholders to conserve and restore Village Common Forests (VCFs) [6]. In addition to supporting tree planting and post-plantation management, NGOs provide financial assistance to VCF members, many of whom are forest-dependent, through microcredit schemes or easy loans [11]. They also offer training for alternative income-generating activities such as handicraft production, ecotourism, poultry rearing, pig fattening, and vegetable gardening [9]. Moreover, NGOs play a role in facilitating the marketing of local products by developing value chains [24]. However, despite their efforts to promote VCF management in the CHT, NGO interventions can sometimes conflict with the customary rights and practices of indigenous communities. These interventions may overlook indigenous knowledge, which can compromise the long-term sustainability and acceptance of NGO-led projects [25]. Another significant issue is the overlap in project locations [22]. NGOs in the CHT often focus on VCFs where they see a higher likelihood of success or those with relatively easy accessibility through transportation means [6].

The initial conditions under which NGOs become involved in VCF management vary depending on factors such as resource availability, relationships with local indigenous communities, and national conservation priorities—such as the recent commitments to forest restoration under the Bonn Challenge or the UN Decade on Ecosystem Restoration [7]. Effective NGO interventions in VCFs require not only strong governance and decision-making frameworks but also sufficient resource allocation and timely project implementation [26].

The conservation and restoration of VCFs in CHT is a crucial issue that requires further research [16]. Although NGOs have been involved in managing VCFs in the CHT since the 2000s, there have been limited studies assessing their performance [27]. Previous research has primarily focused on local livelihood needs and biodiversity preservation,

but critical concerns regarding the impacts of NGO interventions on forest restoration and conservation remain underexplored [10,13].

A deeper understanding of these interventions and their outcomes could offer valuable insights to improve current strategies and policies. Therefore, this study seeks to evaluate the role of NGO efforts in forest restoration and conservation within the CHT. We employed both satellite data and field surveys, with satellite data being used to assess vegetation coverage through the Normalized Difference Vegetation Index (NDVI) in VCFs with and without NGO involvement. Field surveys were conducted to measure biodiversity indices and phytosociological attributes in selected VCFs. We believe this research has the potential to enhance restoration outcomes, contributing to both environmental sustainability and improved livelihoods for local communities in the CHT, as well as in other regions with similar socio-ecological contexts.

2. Materials and Methods

2.1. The Study Area

The CHTs, with an area of 13,183 km^2, comprise of Bandarban, Khagrachari, and Rangamati districts (Figure 1) and occupy approximately 12% of Bangladesh's total land area [7]. The area also contains almost 40% of the country's forestlands [6]. India surrounds the CHT to the north and east, Myanmar to the southeast, the Chattogram district of Bangladesh to the west, and Cox's Bazar district to the southwest [19]. The topography of the CHTs is characterized by hills, valleys, and cliffs [6]. About two-thirds area of CHT is characterized by steep to moderate slopes, ranging between 10° and 70°, and the remaining area is gently sloping [28]. The climate of the region is tropical to subtropical, with a mean monthly maximum temperature between 25 °C and 34 °C. The annual average rainfall ranges between 2032 and 3910 mm, with 80% of it occurring from May to September [29]. Being part of the greater Hindu-Kush Himalayan Region and Indo-Burma Biodiversity Hotspot, CHT is characterized by a rich diversity of flora and fauna [30]. Shifting cultivation, locally known as *jhum* along the hillslopes, is the predominant form of agricultural land use in the CHT [31].

2.2. VCF Selection

The VCFs in three districts of CHT were listed using data from stakeholder consultations and focus group discussions (FGD). We also collected VCF lists from the UNDP-Bangladesh and VCF Network Office, which were complemented by interviews with relevant forest department officials, NGO representatives, and community leaders. Out of 314 documented VCFs in CHT, we sampled 30 VCFs. From each district, we sampled 10 VCFs (5 with NGO intervention and 5 without NGO intervention), and altogether, we sampled 15 VCFs with NGO intervention and 15 VCFs without NGO intervention (Table 1 and Figure 1). Most of the VCFs in CHT are highly inaccessible, and we believe our samples adequately represent the overall situation of VCFs in the region.

2.3. Vegetation Cover Analysis Using the NDVI

We measured the vegetation condition of the selected VCF using the NDVI. NDVI was chosen for this study because it is the most widely used for the detection of healthy vegetation [32], as its values are generated from the reflectance of healthy vegetation [33]. We used Landsat 5 and Landsat 8 data from the United States Geological Survey (USGS) website to compute each NDVI of each VCF for the years 2000, 2010, and 2021. Cloud-free multispectral Landsat images were used to avoid seasonal changes and cloud-related abnormalities. For research accuracy, images with less than 2% cloud coverage were used [34]. We preprocessed data with ArcGIS 10.6 and ERDAS Imagine 2015. A unique equation converted Digital Number (DN) values into surface reflectance.

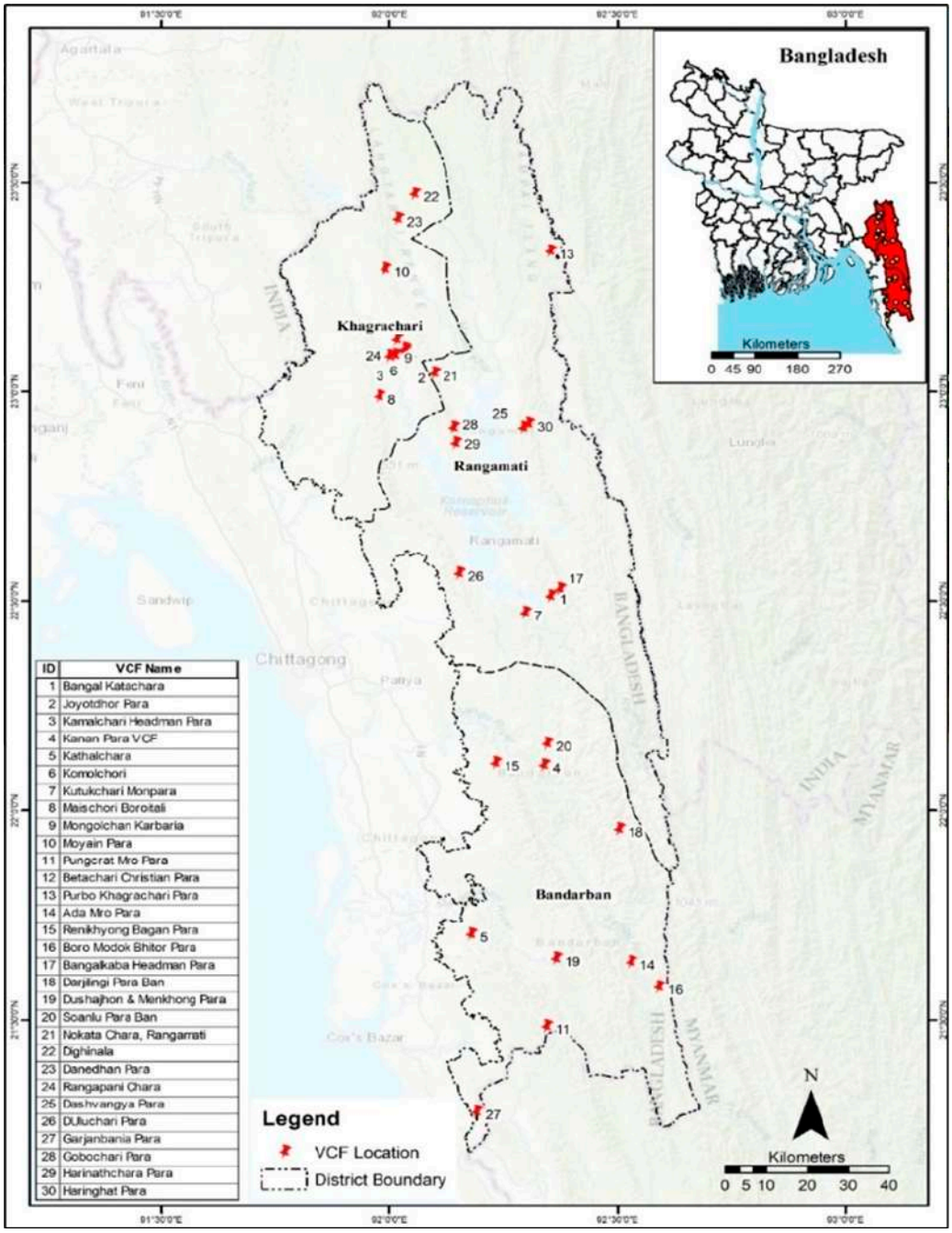

Figure 1. Map showing the study VCFs with and without NGO intervention in three hill districts in CHT, Bangladesh.

NDVI values were calculated using the following equation.

$$\text{NDVI} \frac{(\text{NIR} - \text{ERD})}{(\text{NIR} + \text{RED})} \quad (1)$$

where NIR represents the near-infrared surface reflectance, and RED is the red band reflectance.

NDVI values range from −1 to +1, where a value closer to −1 indicates no vegetation and a value closer to +1 indicates healthy vegetation. NDVI thresholds were found in several literatures. Four NDVI classes were identified and used in this study (Table 2).

Table 1. List of VCFs with and without NGO intervention in CHT, Bangladesh.

District	Name of the VCF	
	With NGO Intervention	**Without NGO Intervention**
Bandarban	Boro Modok Bhitor Para Darjiling Para Kathalchara Pungcrat Mro Para Sonalu Para	Ada Mro Para Dushajhon Menkhong Para Garjanbania Para Kannan Para Renikhyong Bagan Para
Khagrachari	Danedhan Para Kamalchari Headman Para Komolchori Maischori Boroitali Moyain Para	Betchari Christian Para Dighinala Tarunbon Joyotdhor Para Mongolchan Karbari Para Rangapani Chara
Rangamati	Bangal Katachara Duluchari Para Harinatchara Para Nokata Chara Purbo Khagrachari Para	Bangalkaba Headman Para Dashvangya Para Gobochari Para Haringhat Para Kutukchari Mon Para

Table 2. NDVI ranges, corresponding vegetation density levels and colors used to represent them on the map.

NDVI Range	Vegetation Type	Color
0 to 0.33	Low density of vegetation	Red
0.33 to 0.48	Moderate density of vegetation	Yellow
0.48 to 0.66	High density of vegetation	Light green
0.66 to 1	Very high density of vegetation	Dark green

Figure 2 presents the methodological framework followed during the vegetation analysis using NDVI.

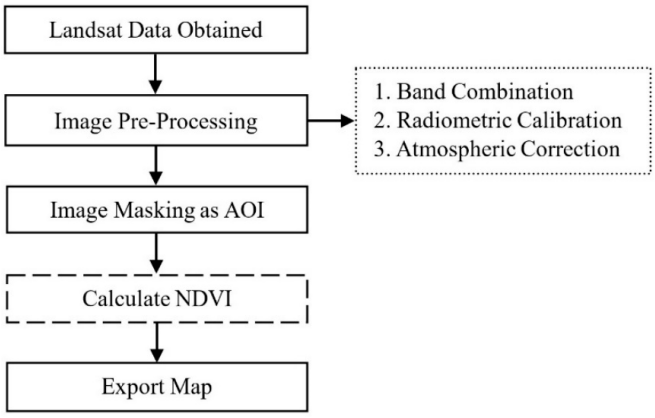

Figure 2. Methodological framework used for the NDVI analysis in the present study.

2.4. Field Surveys and Analysis of Phytosociological Attributes

Field surveys were undertaken from May 2021 to October 2022 with the help of indigenous leaders and local NGO staff. Due to the time constraint and site accessibility issue, vegetation surveys were conducted only in 10 VCFs (5 with NGO intervention and 5 without NGO intervention). In each VCF, we established ten 10 m × 10 m squared plots to assess phytosociological attributes related to tree diversity and forest health conditions [35]. We identified and measured trees having a DBH of greater than 10 cm as followed by Gotelli

and Colwell [36]. Each species within the plot was identified and recorded using the naming criteria described in Pasha and Uddin [37]. We calculated species richness, Simpson's index (D), Shannon–Wiener index (H), and species evenness (E) using the equations in Table 3 [38]. We also measured stem density and basal area per hectare for each of the 10 VCF.

Table 3. Phytosociological parameters used for tree biodiversity analysis in the present study in VCFs in CHT.

Biodiversity indices	Description
Basal area per hector (BA/ha)	=(∑BA/area of all plots) × 10,000 m^2 =(∑BA/1000) × 10,000 m^2 (10 plots of 10 m × 10 m size in each VCF)
Stem density—SD (plant/ha)	=(Number of plants/1000 m^2) × 10,000 m^2
Species evenness index (E)	$=(H')/\log(S)$ Where S = number of species
Shannon–Wiener index (H)	$=-\Sigma \{pi \times \ln (pi)\}$, where Pi is the number of individuals of one species/total number of individuals in the species.
Simpson's index (D)	$=\Sigma\{ni(ni-1)/N(N-1)\}$ where ni = total number of organisms of a particular species, and N = total number of organisms of all the species.
Simpson's index of diversity (1 − D)	$=1-[\Sigma\{ni(ni-1)/N(N-1)\}]$

3. Results

3.1. Vegetation Cover Changes in VCFs in CHT

We used NDVI as an indicator of forest health conditions where higher NDVI values are correlated with healthier and denser vegetation. Using time series data from 2000, 2010, and 2021, we analyzed NDVI values of 30 VCFs in CHT with and without NGO intervention (Figures 3–8). NDVI values of VCFs in CHT might be varied due to various reasons other than NGO intervention. In the Rangamati Hill District, Bangal Katachara, a VCF with NGO intervention, had an NDVI value of 0.531 in 2000, which dropped to 0.449 in 2010 (Figure 5). However, in 2021, the NDVI value of Bangal Katachara increased to 0.579, suggesting a recovery in forest cover and healthier vegetation condition, which could be attributed to improved management and active NGO intervention after 2010 in that VCF. In contrast, in Dighinala Tarunbon, a VCF without NGO intervention in the Khagrachari Hill District, the NDVI value dropped from 0.492 in 2000 to 0.447 in 2010 and 0.351 in 2021, likely due to lack of external support and forest management guideline (Figure 7).

Overall, VCFs with NGO intervention had higher mean NDVI values than VCFs without NGO intervention, indicating better forest health conditions and vegetation density in the former category (Figure 9). From 2000 to 2021, the mean NDVI of Darjiling Para, a VCF in Bandarban Hill District, increased. Harinatchara Para VCF in Rangamati also showed a similar trajectory. In 2010, the mean NDVI of Kamalchari Headman Para, a VCF in Khagrachari Hill District, dropped, indicating a period of diminishing vegetation cover; however, this trend reversed by 2021, probably due to NGO intervention. While there was a consistent pattern in changes in mean NDVI values in most VCFs with NGO intervention, VCFs without NGO intervention lack any clear trend. For example, Ada Mro Para, Dighinala Tarunbon, and Renikhyong Bagan Para VCFs observed a sharp decline in mean NDVI throughout the study period (2000–2021), while mean NDVI values rose in Rangapani Chara and Garjanbania Para VCFs (Figure 9).

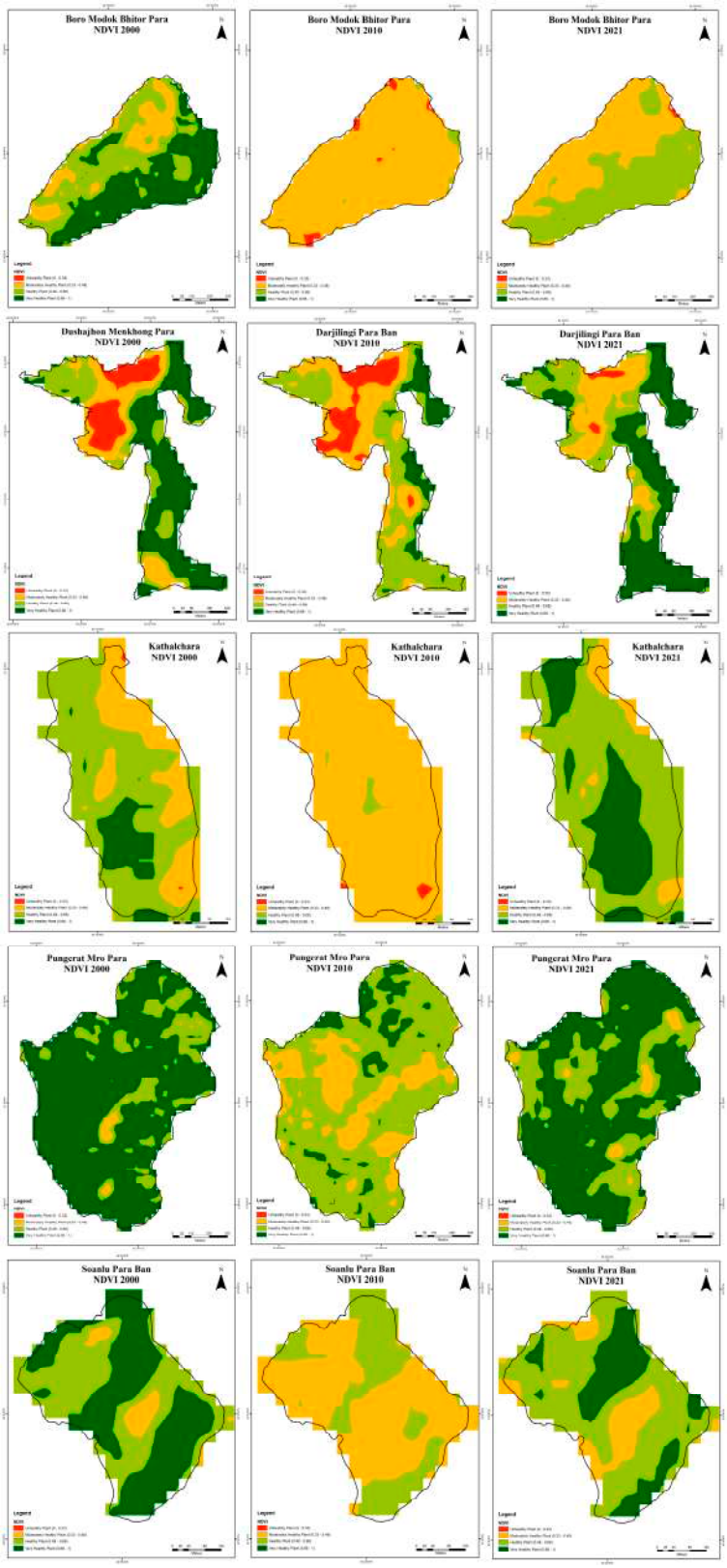

Figure 3. Vegetation changes in 5 VCFs with NGO intervention in Bandarban Hill District, CHT.

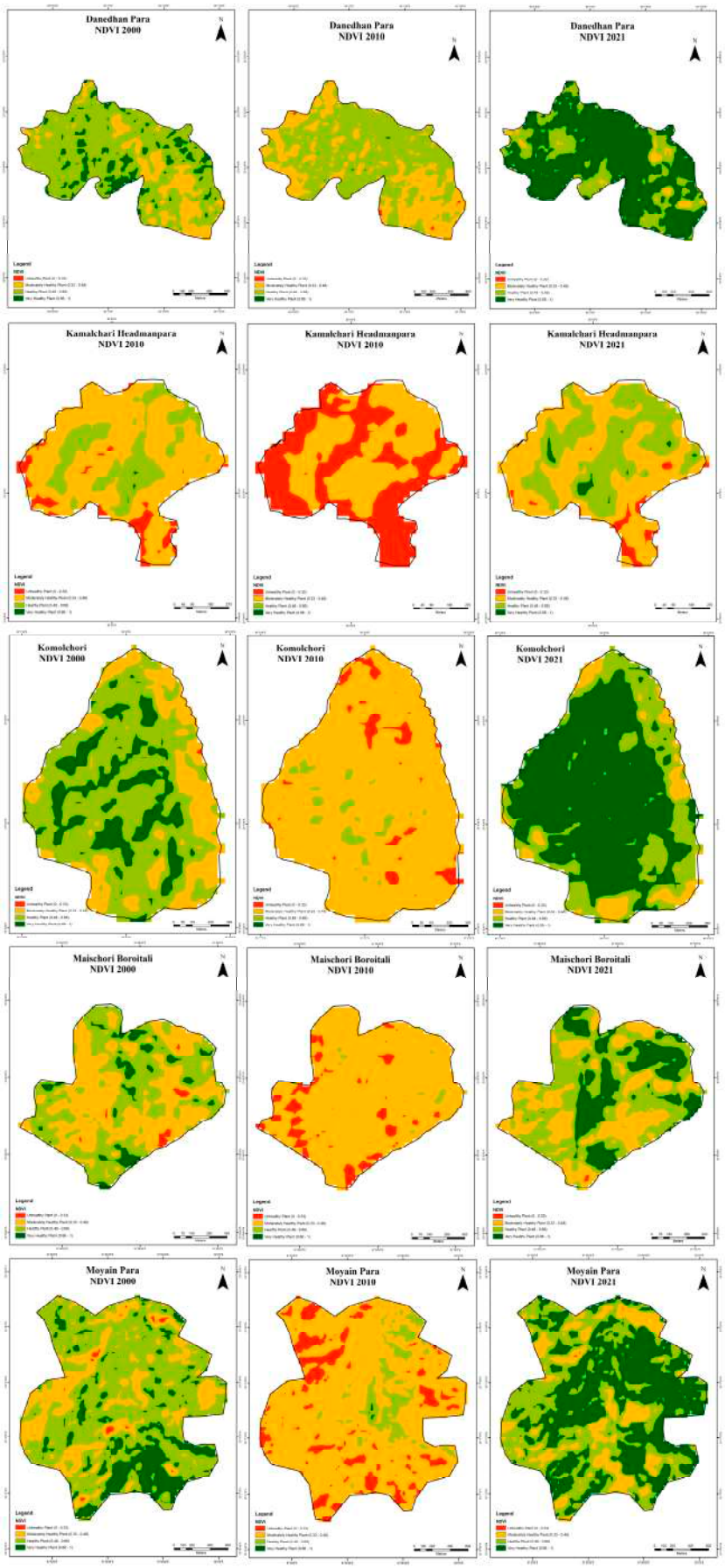

Figure 4. Vegetation changes in 5 VCFs with NGO intervention in Khagrachari Hill District, CHT.

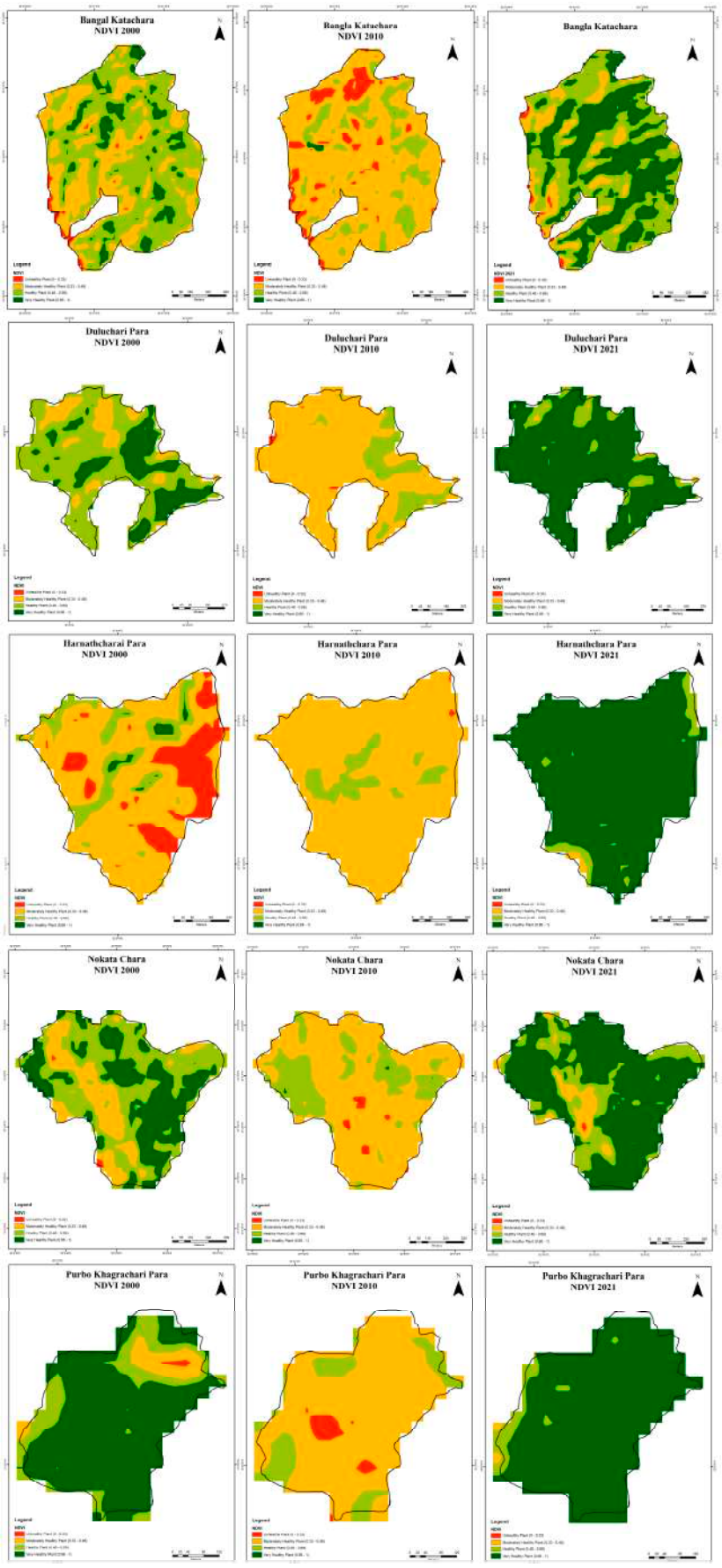

Figure 5. Vegetation changes in 5 VCFs with NGO intervention in Rangamati Hill District, CHT.

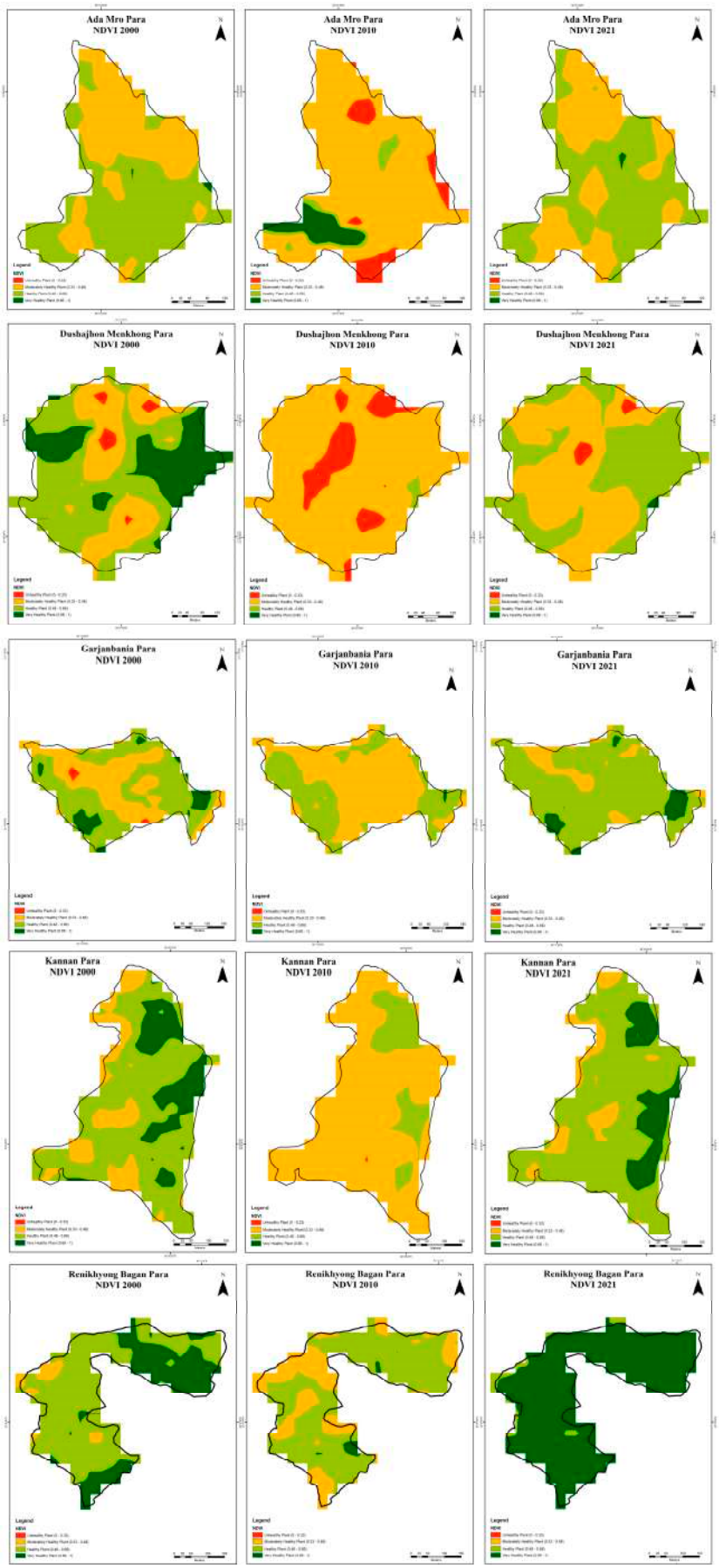

Figure 6. Vegetation changes in 5 VCFs without NGO intervention in Bandarban Hill District, CHT.

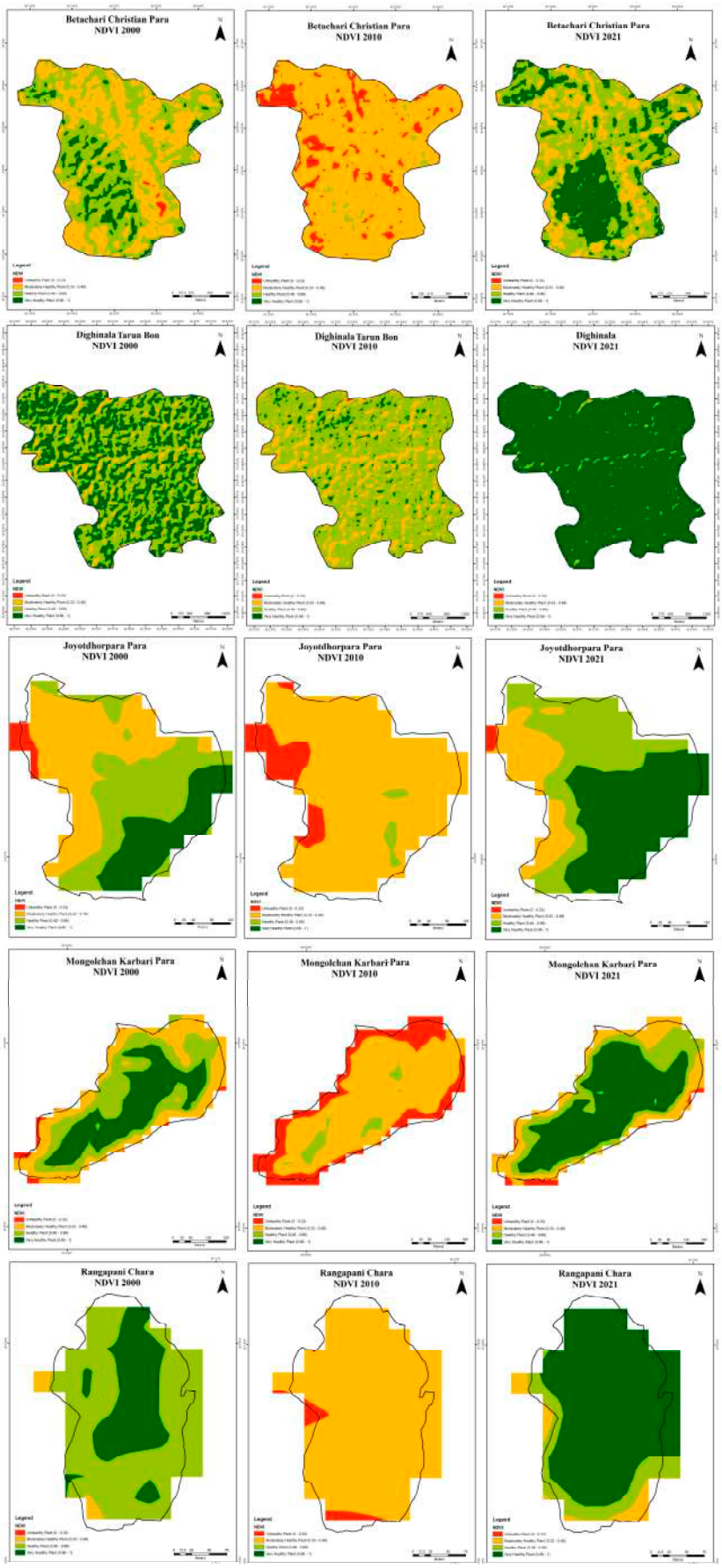

Figure 7. Vegetation changes in 5 VCFs without NGO intervention in Khagrachari Hill District, CHT.

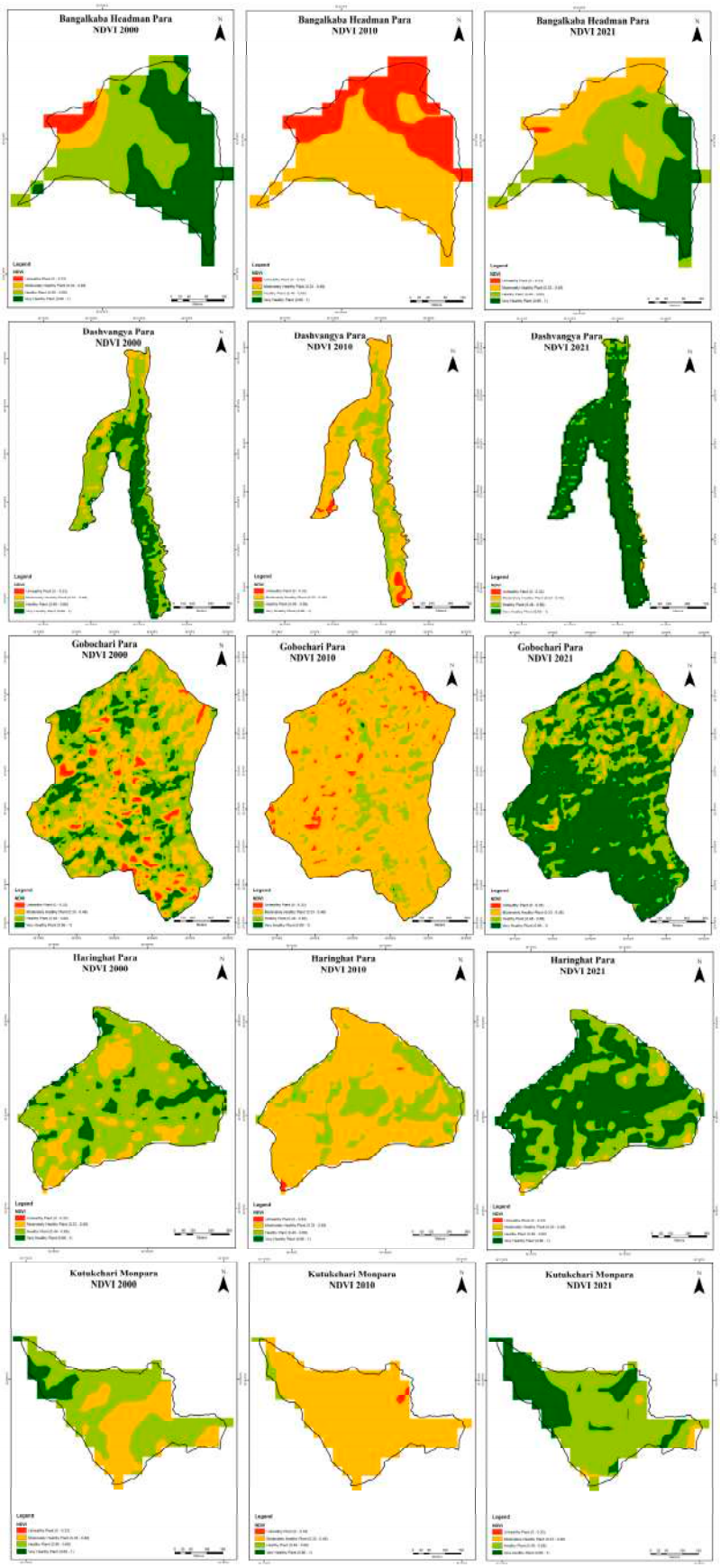

Figure 8. Vegetation changes in 5 VCFs without NGO intervention in Rangamati Hill District, CHT.

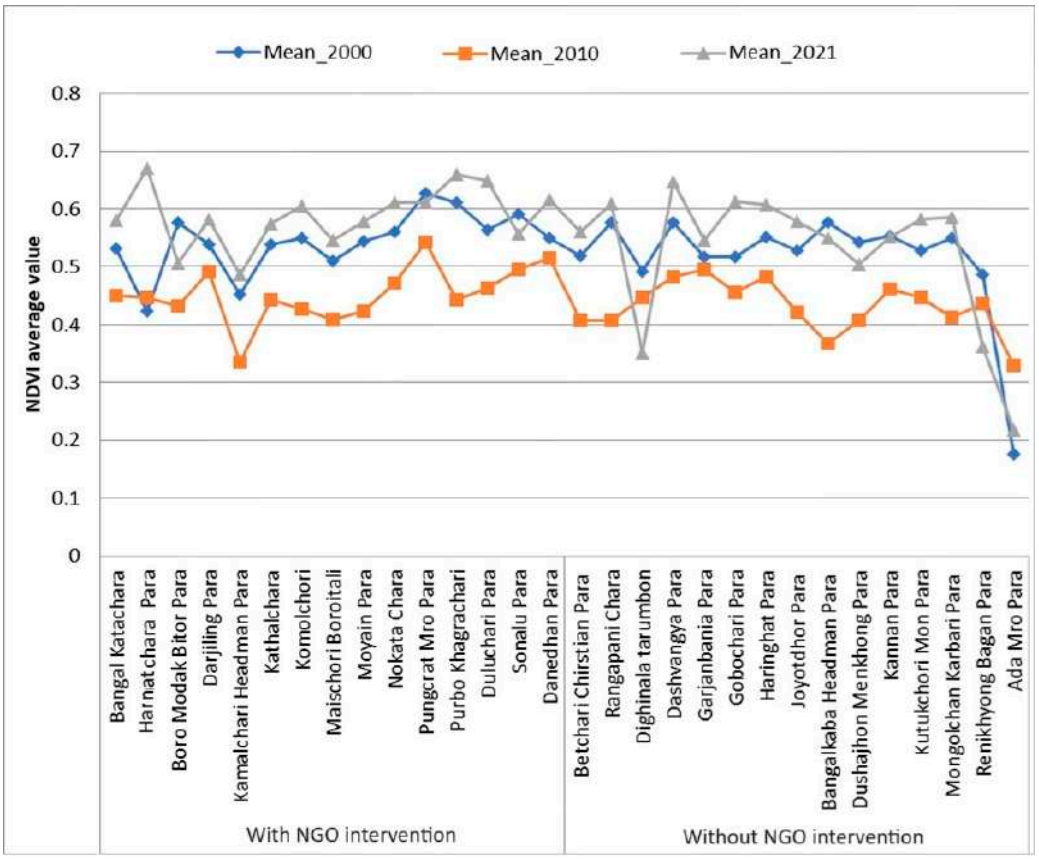

Figure 9. The observed mean NDVI values in different VCFs with and without NGO intervention in CHT from 2000 to 2021.

The mean NDVI values of VCFs with and without NGO intervention were 0.544 and 0.512, respectively, indicating a reasonably good vegetation density (Figure 10). The mean NDVI values of both categories dropped in 2010 and were 0.452 and 0.430, indicating a lower vegetation cover than in 2000. The mean NDVI value in both categories showed progress between 2010 to 2021, where VCFs with NGO intervention had a higher mean NDVI value of 0.588 in 2021. Our findings thus demonstrate that NGO intervention has improved vegetation density. VCFs with NGO intervention also show a faster recovery of forest health conditions by 2021 compared with VCFs without NGO intervention (Figure 10).

3.2. Phytosociological Attributes of Forest Communities in VCFs in CHT

We analyzed phytosociological attributes of forest communities using data from our field surveys (i.e., 100 10 m × 10 m plots). Table 4 summarizes the key diversity metrics calculated using ground-based sampling and vegetation data from 10 of our VCFs with and without NGO intervention. Our study demonstrates that VCFs with NGO intervention had relatively higher species richness. We find species richness between 10 (in Sonalu Para) to 50 (in Kathalchara) in VCFs with NGO intervention. On the other hand, species richness varies between 8 (in Renikhyong Bagan Para) to 36 (in Kannan Para) in VCFs without NGO intervention. The Simpson's index (D) evaluates the probability that two randomly picked individuals are distinct species, where lower D values indicate increased variety and less species domination. Our study suggests no distinct species dominance pattern in the studied VCFs. The Shannon–Wiener index (H) is another indicator of biodiversity where diverse and balanced communities have higher H values. In our study, Kathalchara Chara and Darjiling Para VCFs had higher H values, 3.57 and 2.98, respectively, indicating a diverse tree community in VCFs with NGO intervention (Table 4). Interestingly, Kanan

Para, a VCF without NGO intervention, also has relatively good H values of 3.30. In our study, VCFs with NGO intervention exhibited higher stem density and basal area per hectare, indicating a higher tree density and overall trunk area. Several VCFs without NGO intervention (Kutikchari and Dushajhon Menkhong Para) also have high basal areas, indicating that NGO management may not be the only determining factor (Figure 11).

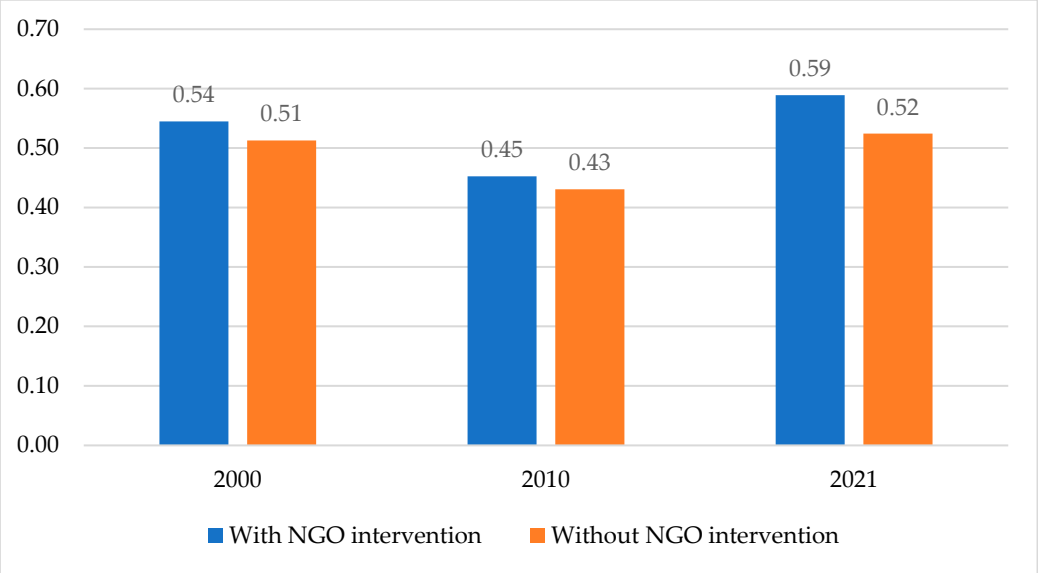

Figure 10. The mean NDVI values of VCFs with and without NGO intervention during the years 2000, 2010, and 2021.

Figure 11. Photos from the field (clockwise): (**a**) a VCF with NGO intervention in CHT; (**b**) bamboo groves in a VCF in CHT; (**c**) healthy VCFs provide critical ecosystem services like fresh water in CHT; (**d**) natural regeneration and green coverage inside a VCF in CHT (photo credits: Md. Shafiqul Bari).

Table 4. Phytosociological attributes of forest communities in VCFs in CHT, Bangladesh.

VCF Type	VCF Name	Area (Ha)	Species Richness	Simpson's Index	Simpson's Index of Diversity	Shannon-Weiner Index	Species Evenness	Stem Density	Basal Area/Ha
With NGO intervention	Darjiling Para	100	26	0.06	0.94	2.98	0.91	1160.00	36.98
	Kathalchara	30	50	0.05	0.95	3.57	0.91	1080.00	29.22
	Komolchori	316	14	0.12	0.88	2.36	0.89	550.00	132.22
	Purbo Khagrachari	60	32	0.17	0.83	2.54	0.73	1760.00	29.74
	Sonalu Para	30	10	0.11	0.89	2.24	0.97	680.00	39.16
Without NGO intervention	Dighinala Tarunbon	40	14	0.10	0.90	2.47	0.94	250.00	16.04
	Renikhyong Bagan Para	25	8	0.16	0.84	1.97	0.95	110.00	10.21
	Kannan Para	25	36	0.05	0.95	3.30	0.92	740.00	16.78
	Kutukchari Mon Para	15	23	0.08	0.92	2.83	0.90	970.00	35.78
	Dushajhon Menkhong Para	25	30	0.04	0.96	3.25	0.96	600.00	33.35

4. Discussion

Our findings suggest that forest vegetation and tree cover, as indicated by NDVI, decreased between 2000 and 2010 in VCFs in CHT with and without NGO intervention. This steady drop from high to moderate density of vegetation cover indicates unfavorable conditions or land-use changes during that period. Moreover, NGO intervention was not common in CHT due to political unrest before 2010 [7]. Vegetation cover may have also been impacted due to ongoing environmental, economic, and political stress [6,39]. Anthropogenic pressure, including logging and agricultural expansion, negatively influences vegetation cover [40]. Climate change can also affect plant photosynthesis, growth, and survival, such as higher temperatures and changing precipitation patterns, thus affecting vegetation density [41]. After the 1997 Chittagong Hill Tracts Peace Accord, many ethnic people returned to communities and started new settlements [42]. They extracted a substantial amount of VCF resources, which may have contributed to forest degradation to some extent in some VCFs [25,43].

Studies have shown contrasting trends in forest cover loss and gain in the CHT due to many factors [19,44]. In the present study, vegetation cover increased from 2010 to 2021 in most VCFs in the CHT with NGO intervention, whereas the trend was not consistent in VCFs without NGO intervention. NGO interventions in the CHT mostly involve forest conservation, reforestation, and tree-plantation programs [43,45], which have great potential to improve vegetation cover [46,47]. Miah and Ahmed [27] also found that NGO intervention positively contributes to the conservation of biodiversity in CHT, Bangladesh. However, contrary to our study, Ullah et al. [48] found that NGO intervention did not contribute to vegetation cover gain in a neighboring forest-protected area in the Teknaf Peninsula. In addition, NGOs mobilize resources, raise awareness, and effectively implement sustainable agriculture and land-use practices that can promote better ecosystem health [24,49].

The relatively better phytosociological attributes or plant biodiversity indices in our VCFs with NGO intervention may be due to more active and scientifically based forest management and conservation awareness driven by NGO activities [50]. Ecosystem health is closely related to forest resilience which may vary with local environmental conditions like soil fertility [41]. Despite a lack of NGO intervention, the fewer species variety in some of our VCFs may also be attributed to poor soil quality, anthropogenic disturbances, and lack of active forest management [51,52]. In areas with fewer species, illegal logging, land encroachment, and forest degradation may have also reduced species diversity [53]. Natural disasters like landslides from heavy rain are very common across the CHT region and may also influence forest restoration efforts [28]. Our findings on tree diversity indices in VCFs in CHT are comparable with the findings of Uddin et al. [10], Kamrul et al. [54], and Khan et al. [55] from the same region. Rahman et al. [50] also reported a positive influence of NGO intervention in phytosociological attributes in forest-protected areas in

Bangladesh, while Mukul et al. [53] reported a positive change in stem number and tree density in forests due to economic incentives in northeast Bangladesh.

Lack of incentives and institutional support resist positive changes in natural resources management, including forests, and are crucial for effective forest restoration and conservation [53,56]. NGO-led training helps rural communities manage forests more effectively [57]. NGO intervention, typically among rural populations, also improves information sharing, community engagement, and decision-making, which positively affects natural resources management and, thus, forest health, vegetation condition, and biodiversity [58].

5. Conclusions

Our study underscores the critical role of NGO intervention in supporting the long-standing, community-led forest management system in CHT, Bangladesh. The findings reveal that VCFs with NGO involvement have healthier ecosystems and greater biodiversity compared with those without, highlighting the necessity of NGO participation in managing and preserving these forests. However, it is essential to prioritize remote VCFs in the CHT that may be underserved due to their inaccessibility and distance from urban centers.

Restoring VCFs in the CHT requires a multifaceted approach. A key challenge in the region is the issue of land tenure, which can hinder forest restoration efforts, weaken community cohesion, and lead to disputes over resource access and benefit-sharing. Future restoration initiatives should address these land tenure issues through capacity-building programs and training aimed at improving livelihoods and ensuring food security. Moreover, restoration efforts should focus not only on increasing forest cover but also on promoting ecosystem integrity, ecological functionality, and long-term environmental sustainability.

Author Contributions: Conceptualization, M.S.B., S.A.M. and M.M.A.; methodology, M.S.B., M.M.A. and S.A.M.; formal analysis, M.S.B. and M.A.B.; investigation, M.S.B. and M.M.A.; resources, M.S.B.; data curation, M.S.B., M.J.A. and M.A.B.; writing—original draft preparation, M.S.B. and S.A.M.; writing—review and editing, M.M.A., M.J.A., O.T.S. and M.A.B.; supervision, M.S.B. and S.A.M.; project administration, M.S.B.; funding acquisition, M.S.B., M.M.A. and S.A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by SANDEE "Grant number RP6 (SANDEE); Cost Center: 6-948-224-0-P-948-02-02-21-A-901" through the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Datasets generated during this study are available from the corresponding author upon request.

Acknowledgments: We thank the Bangladesh Forest Department, Department of Agriculture Extension, and Arannayk Foundation for their cooperation during the study. Traditional leaders and local people in each hill district in CHT have provided us with incredible support. Their enthusiasm allowed us to visit remote areas, make real connections, and organize exciting community meetings that tremendously improved our research. The UNDP offices in Dhaka, Khagrachari, Rangamati, and Bandarban districts offered us significant logistical help. SANDEE's funding through ICIMOD is greatly acknowledged. Finally, we thank SANDEE advisers Mani Nepal and François Libois for their guidance during the study, which significantly improved our research outcomes. The valuable comments and feedback from four anonymous reviewers improved the quality of our manuscript.

Conflicts of Interest: The authors declare no conflicts of interest. The authors also declare that the statements and/or opinions reflected in this manuscript are solely those of the authors and not of the funding body (i.e., SANDEE, ICIMOD).

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