Restoration of degraded forest ecosystem through non-forestry livelihood supports: experience from the Chunati Wildlife Sanctuary in Bangladesh

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ABSTRACT
Lack of non-forestry income sources for the forest-dependent community was one of the major causes of continued biodiversity loss in Chunati Wildlife Sanctuary (CWS). A livelihood support program was implemented from July 2012 through June 2015 to reduce people’s forest-dependence for their livelihoods. We evaluated the efficacy of this program in enhancing the biodiversity health of CWS. An Ordinary Least Square regression framework was used to estimate the difference in difference of the income between the control and the treatment households. Alongside, the biodiversity attributes of the CWS were measured in 2012 and 2015 and were compared. The intervention increased a treatment household’s monthly non-forestry income by BDT11,781 and decreased its monthly forest income by BDT2128. In contrast, with increased natural regeneration of 8.43%, 12 out of the 16 major species at CWS showed increased importance value index (IVI). The IVI increased by 48.03% for Acacia auriculiformis and decreased by 56.30% and 31.76% for Dipterocarpus turbinatus and Tectona grandis, respectively. As confirmed by the households, this biodiversity improvement could be attributed to the livelihood intervention program at CWS. Continued monitoring is important to sustain the successes of the program.

Introduction
Protected Areas (PAs) are the last remaining vital natural resource systems that support ecological and economic developments in Bangladesh. PA coverage in Bangladesh has increased from 1.67% in 2008 (Mukul et al. 2008) to 1.80% of the land surface in 2015, which is among the lowest in the world (BFD 2015). Even though the PAs cover a small percentage of the land surface of Bangladesh, a large number of the rural poor are PA-dependent for their subsistence (Roy and DeCosse 2006; Sharma 2011). The Government of Bangladesh has so far declared 49 PAs of which 17 have been taken under the umbrella of co-management (BFD 2015). Chunati Wildlife Sanctuary (CWS) is one of the most important among the co-managed PAs in the country, supporting the livelihoods of 50,000 people living in 9400 households in the area (IPAC 2011).

The success of any biodiversity restoration effort is subject to the livelihood development of the forest-dependent people. According to Shylendra (2002), rehabilitating the forest-dependent people is a viable strategy to conserve biodiversity. In a study conducted in Satchari National Park, a PA in northeastern Bangladesh, Mukul and Quazi (2007) reported that 37% of the forest-dependent people in the PA were extremely poor with monthly household income below BDT2000 (US$1 = BDT78). Relative to this, the situation was even worse for the forest dwellers at CWS. A wealth ranking exercise conducted among the forest-dependent people of CWS showed that 70% people in CWS were poor, 19% were extremely poor, 10% were middle class, and 1% were rich (Mollah et al. 2004). Most of the people in this area were either day laborers (62%) or non-wage agricultural workers (21%) (Bari and Dutta 2003; Hoque 2009).

CWS communities were also characterized with a significant unemployment rate (17%) (Bari and Dutta 2003; Hoque 2009). Mollah et al (2004) identified that extreme poverty, unemployment, and weak law enforcement made the local poor heavily dependent on forest resources for their livelihoods. This dependency was causing serious destruction of CWS forest resources (Mollah et al. 2004). Government and non-government organizations have taken a couple of initiatives to slow down the destruction of CWS in the last three decades. In association with the Bangladesh Forest Department (BFD), the United States Agency for International Development (USAID) initiated co-management activities in CWS in 2004 through the Nishorgo Support Project (Roy 2009) to promote community protection efforts for wildlife and their habitats by restoring the forests of CWS (BFD 2006). Another project, Integrated Protected Area Co-management (IPAC), was implemented to help the BFD involve local people to co-manage CWS. IPAC initiated alternative income generation activities (AIGAs) through payments for ecosystem services (PES) (Fox and Mustafa 2013). However, this project did not have any direct livelihood support component that could effectively reduce forest-dependent people’s need to exploit forests for their livelihoods (GIZ 2015).

Thus, we hypothesized that, if the forest-dependent people in the degraded forest area of CWS were guaranteed livelihood supports through AIGAs, it would reduce their demand for CWS resources. The reduced pressure on forest resources would eventually help restore the biodiversity of CWS. With this assumption, this study was designed to evaluate the changes of biodiversity status of CWS over time attributed to...
the non-forestry livelihood supports extended to the forest-dependent people in that area. This study has put forth an alternative but effective strategy on how to restore the biodiversity of degraded forest areas in Bangladesh.

**Materials and methods**

**Description of the study site**

CWS is located in the southeastern region of Bangladesh (Figure 1). Due to its environmental and socioeconomic significance, it has seen more research activities and development initiatives than any other PA in the country (Mahmood 2008). Located at 21°58’N and 92°04’E, CWS was a 7764 ha reserved forest until it gained its present legal status of wildlife sanctuary through a government gazette notification in 1986 (IPAC 2011). It belongs to the tropical evergreen and semi-evergreen mountainous forest landscape (Mollah et al. 2004) near the Bay of Bengal. The sanctuary is administered under the Wildlife and Nature Conservation Division of the BFD. It has two ranges – Chunati and Jaldi. The former has three forest beats while the latter has four. CWS was dominantly a *Dipterocarpus turbinatus* forest and an important roaming area for Asian elephant and hoolock gibbon. Now there is a little natural forest left with a few scattered *D. turbinatus* patches (Feeroz 2013). This area has been left with secondary growth, herbs, and shrubs. Extensive areas of CWS are either grassland or bare land. Some of the natural forests have been replaced with fast growing exotics. The area was gradually denuded due to human settlement, illicit felling, and conversion of land to cultivation (Feeroz 2013).

**Initial selection of control and treatment households and AIGAs**

The livelihood support program at CWS was funded by Arannayk Foundation, Bangladesh through the field supports from the Society for Health Extension and Development (SHED). The selection of control and treatment households was done by SHED in 2012. A participant selection key was used for selecting the treatment households. The key was designed in such a way that the households with higher forest-dependency and lower total household income were more likely to be selected for the livelihood support program. Thus, a total of 1398 treatment households were selected for the livelihood support program in 2012 by SHED, 676 were from Jaldi Range and 722 from Chunati Range. The same procedure was followed to select 201 control households (100 from the Jaldi range and 101 from the Chunati range) from the adjacent areas and, of course, from outside the Village Conservation Forums (VCFs). The households with total income and forest-dependency similar to those of the treatment households were selected as controls by SHED. The treatment households were provided with financial and technical intervention supports to start AIGAs such as livestock rearing, poultry farming, doing small business, handicraft making, and home gardening. The other non-forestry sources of household income were labor sales, remittances, service, and agriculture. In contrast, the control households were not provided with any type of intervention supports. The livelihood interventions were launched in July 2012 and continued until June 2015.

**Collection and analysis of biodiversity data**

The initial data on biodiversity attributes were available through SHED and Arannayk Foundation, Bangladesh. A total of 142 permanent plots (PPs) of size 10 m × 10 m each with clearly delineated geo-point for each PP to study the biodiversity status of CWS at time zero (that is in 2012). However, in each PP, one sample plot of size 2 m × 2 m was evaluated for the study of natural regeneration status of CWS. SHED estimated a number of biodiversity attributes
including forest regeneration per hectare, basal area per hectare, relative density, relative frequency, relative dominance, and importance value index (IVI) in CWS in 2012. We studied the same biodiversity parameters on the same plots 3 years later during April–May, 2015. We estimated the parameters using the standard formulas given in Table 1. It was followed by the estimation of percent change in each of the biodiversity attributes between 2012 and 2015. The change was captured through a polynomial trend analysis.

**Collection and analysis of socioeconomic data**

We collected socioeconomic data simultaneously with the biodiversity data in 2015. Before we proceeded to the socioeconomic data collection, we conducted three focus group discussions, had a meeting with the co-management committee, VCF members, and other development organizations working in the CWS areas to get a comparative overview on the performance of the control and treatment households. We sampled 120 control households, 60 from each range and 300 treatment households, 150 from each range. Thus, in the post-treatment survey, we studied 420 households from the two ranges of the CWS (Table 2).

In the post-treatment socioeconomic data collection, we were interested in a number of variables on top of the variables that SHED actually worked with. So, we opted to use a recall method to collect pre- and post-treatment data on the following socioeconomic variables: existing household income; monthly income from forestry sources; AIGA sources; and all other non-forestry members of a household in a month; choice of, and experience with, VCF members, and other development organizations.

We employed the following regression framework to catch up with the impact of an intervention on a participant household by eliminating the time-varying impacts on all the groups that were not impacted by the intervention. Let, the state of the household k under study be $S_k$ and the period when intervention occurs be $P_t$. Here, $S_k = 1$ if k is a participant of the livelihood support program and 0 (zero) if non-participant or control. Similarly, $P_t = 1$ if $t$ indicates the period of measuring the response variable, $Y_{k,t}$ of the household k at the end of the intervention program and 0 before the intervention. Thus, the regression takes the form of:

$$Y_{k,t} = \alpha + \beta_1 S_k + \beta_2 P_t + \beta_3 (S_k P_t) + \epsilon_{k,t} \quad (1)$$

where, $(S_k P_t)$ is the interaction term of intervention and period, $\alpha$, $\beta_1$, $\beta_2$, and $\beta_3$ are the parameters to be estimated and $\epsilon_{k,t}$ is the normally distributed error term with mean zero and constant variance. After estimating $Y_{1,1}$, $Y_{1,0}$, $Y_{0,1}$, and $Y_{0,0}$ from Equation (1), we can capture the difference in in $Y_{k,t}$ for household k in an income generating activity $i$ using Equation (2).

$$DiD_i = (Y_{1,1} - Y_{0,1}) - (Y_{1,0} - Y_{0,0}) = \beta_3 \quad (2)$$

For the estimation of Equation (1), we assume that the growth of the attributes under consideration for participants and control groups is linear and the control households are free from spillover impacts of the treatments.

**Results and discussion**

**Forest dependency and non-forestry livelihoods**

The main objective of the livelihood support program was to reduce people’s dependency on forest resources for their livelihoods. Household income analysis by income sources showed that the livelihood support program has significantly reduced the forest dependency of the CWS community. A treatment household’s net income from AIGA sources was BDT2816 a month, which was significant at the 5% level (Table 3). All other non-forestry income sources added a net monthly income of BDT8965. Thus, the net increase of a treatment household’s monthly income from non-forestry sources over the intervention period was BDT11,781 a month and this was significant at the 5% level (Table 3).

This large and significant increase in non-forestry income was critical to lower people’s dependency on forestry resources. That is, a decrease in income from forestry sources was...
obvious. As expected, income from forestry sources declined by BDT2128 a month for a treatment household, which was significant at the 1% level. Thus, the net income increased by BDT9653 a month for a treatment household (Table 3). Since forest dependency is decreased, it should also reduce anthropogenic pressure on the biodiversity resources of CWS. Thus, an improvement in the biodiversity status of CWS was expected. The following sections describe if such improvements have resulted in CWS biodiversity health.

Changes in biodiversity attributes

Natural regeneration

On average, the regeneration rate on the CWS forest floor was 77,028 seedlings per ha in 2012. The regeneration rate in 142 sample plots across the CWS reached an average of 83,520 seedlings per ha in 2015. This translates into a net increase in natural regeneration rate of 8.43% (Table 4). Thus, the outcome of the present study clearly indicates that anthropogenic disturbance in CWS has fallen, which in turn has improved the natural regeneration rate from 2012 to 2015. This result also suggests that CWS has quite a good potential to regenerate naturally. Thus, it can be suggested that the restoration of CWS biodiversity might be enhanced if people’s dependency on this important protected area of the country could be significantly reduced. Our study is in line with the study conducted by Sunderlin et al (2005) which found a reciprocal relationship between rural livelihood improvement and forest conservation. That is, the forest ecosystem health and regeneration can be enhanced if people’s livelihoods are upgraded with alternative income generation activities.

Table 4. Status of beat specific natural regeneration of forest tree species in Chunati Wildlife Sanctuary, Bangladesh.

| Beat          | Natural regeneration (seedlings per hectare) |
|---------------|-----------------------------------------------|
|               | Forest beats                                |
|               | Baseline Present Change (%)                 |
|               | NA** 145600                                  |
|               | 78400                                      |
|               | 65600                                      |
|               | 115200                                     |
| Mean**        | 83520 +8.43%                                |

Notes: *Beat level baseline information is not available; **Nath (2012) and all species combined; ***each value in the ‘Present’ column under natural regeneration is the mean of 142 observations.

Basal area per hectare

Since natural regeneration condition was improving, it was also boosting the biodiversity health of the CWS areas. In the selected PPs, 16 major timber species were recorded. All the species came up with an increased basal area per ha (BAPH) except *D. turbinatus* and *Eucalyptus* spp. (Figure 2). The BAPH for these two species decreased during the intervention period. The reduction of basal area coverage of *D. turbinatus* may be attributed to the removal of matured *D. turbinatus* trees with relatively larger basal area. The participants of the livelihood support program were aware enough about the negative impacts of exotic species like *Acacia auriculiformis* and *Eucalyptus* spp. on the food and habitat supports for wildlife. Thus, the reduction of *Eucalyptus* spp. BAPH was well reasoned. However, why the BAPH for *A. auriculiformis* increased was a question with a very different answer. There were several dozen brickfields around the CWS where *A. auriculiformis* timber was the major fuel. These brickfield owners were local leaders who had encroached large tracts of CWS land for *A. auriculiformis* monoculture. Since this species grows faster to ensure sufficient fuelwood supply in the quickest possible time, the brickfield owners opted for massive monoculture of this
species at and around CWS. The field data shows that the overall basal area has increased by 4.22 square meter per ha across the beats of CWS. This is a major improvement in the ecosystem health of the CWS area.

Relative dominance
As evident from Figure 3, the relative dominance of four species declined while the remaining 12 species showed increased relative dominance over the intervention period. The largest percentage fall in relative dominance was exhibited by *D. turbinatus* (44.02%) followed by *Tectona grandis* (11.25%), *Gmelina arborea* (2.91%) and *Eucalyptus* spp. (2.63%). Among the 12 species with positive percentage change in relative dominance over the intervention period, *A. auriculiformis* showed the largest increase (41.06%), followed by *Swietenia mahogoni* (31.16%), *Albizia procera* (4.66%), and *Senna siamea* (2.10%) (Figure 3). Since most of the species were showing increased relative dominance over the intervention period, we can relate this improvement to the introduction of the non-forestry livelihoods in the area. Some other studies conducted in the other parts of the world have reported similar results. Bowler et al. (2011) reported evidence of AIGA supports being associated with greater tree density and basal area. Similarly, Sudtongkong and Webb (2008) reported that forests were in a significantly better condition in terms of height and basal area when communities are involved in the forest management process through livelihood support programs.

Relative density
Of the 16 major tree species reported in the study area, 11 got increased percentage growth of relative density during the intervention period while the remaining five species showed negative change in their relative density locale (Figure 3). The decrease in the relative density of *T. grandis*, *G. arborea*, *Syzygium grandis*, and *D. turbinatus* were 15.26%, 3.98%, 1.17%, and 1.15%, respectively. The highest relative density increment was showed by *Terminalia chebula* (3.55%), which was closely followed by *A. auriculiformis* (3.27%). As explained in relative dominance, the reduced relative density of *D. turbinatus* and *T. grandis* could be attributed to their bigger size and slow growth rate. However, higher timber value had made these species in greater demand in the timber market. As a result, they were on the verge of total disappearance in the area. The same was the case for *S. grandis*. Overall, a complete shift in species diversity was clearly visible. However, the existing plantation programs in the study area were more focused on planting indigenous species rather than exotics such as *A. auriculiformis* and *Eucalyptus* spp.

Relative frequency
In the permanent sample plots, 10 species showed increased relative frequency and the remaining six showed decreased relative frequency (Figure 3). The most frequent species in the study area was *Senna siamea* with an increase in the relative frequency of 4.05% over the intervention period. It was followed by *Hopea odorata* (3.75%), *A. auriculiformis* (3.70%), and *Chickrassia tabularis* (3.36%). In contrast, an alarming situation was observed with the frequency of *D. turbinatus* which fell by 11.13% from its initial value in 2012. The CWS area was the biggest *D. turbinatus* habitat in Bangladesh. If this situation continues, CWS will no longer remain famous for *D. turbinatus*.

Importance value index
Most of the species showed increased IVI in 2015 compared to 2012 except *T. grandis*, *D. turbinatus*, *Eucalyptus* spp., and *Gmelina arborea* (Figure 3). *Acacia auriculiformis* became the most important species in the CWS area with an increase of 48.03% in its IVI. It was followed by *Chickrassia tabularis* (8.49%), *Senna siamea* (7.44%), *Swietenia mahogoni* (7.07%), and *Polyalthia longifolia* (6.40%). Even though only four species fell from their previous IVI level, this finding is alarming for the indigenous species of the CWS area. This area, as
outlined in the previous sections, was once dominated by *D. turbinatus*, an old and indigenous tree species in Bangladesh. Now it has become one of the least-trace species in this area with a decline of 56.30% in its IVI from 2012 to 2015. Similarly, *T. grandis* and *Gmelina arborea* saw their IVIs fall by 31.76% and 6.31%, respectively. However, on average, the other major species in the region have shown increased IVIs in the evaluation year 2015.

The study aimed to establish a link between a reduction in people's forest dependence and enhancement of biodiversity attributes in the study area. The study outcomes clearly depict that the overall biodiversity status in CWS area has improved when the area has been brought under the livelihood support program with alternative income generating activities. Our study outcomes are further strengthened with the similar findings of other research work across the world. Chazdon (2008) argued that taking care of the forest floor and forest trees is not enough for effective forest restoration, it requires alternative income supports for forest-dependent people. Another study (Kaimowitz 2003) conducted in sub-Saharan Africa claimed that the local community should be compensated with livelihood supports from government and non-government agencies for biodiversity conservation. Similarly, Shyldendra (2002) and Lamb et al. (2005) reported that improving the livelihoods of the forest-dependent poor is a viable strategy to rehabilitate degraded forest resources, since forest resources form a primary source of livelihood support for forest-dependent communities.

**Conclusion and recommendations**

The non-forestry livelihood support program has significantly increased the households’ non-forestry income and decreased forest-related income. Thus, each household’s net monthly income has been almost doubled in 2015 compared to that in 2012. The livelihood supports lessened the need to exploit forest reserves to survive. This has reduced anthropogenic disturbances to the biodiversity resources in CWS. This in turn has contributed to profound natural regeneration. The analysis of forest biodiversity data clearly showed that overall forest stock has increased in the CWS area.

Combining these, we can conclude that the increase in household income through livelihood supports has effectively reduced households’ forest dependency, which in turn has helped improve the biodiversity status in CWS. We have verified the link between household income increment from non-forestry sources and the biodiversity status through the interviews of the treatment households during our fieldwork. All the households agreed that they felt less need to go to the forest for their livelihoods since they had an increased household income from non-forestry income sources. Less frequent visits to the forests has left the forests less disturbed, which they believe has improved the overall biodiversity of CWS. Thus, we conclude that the livelihood support program has effectively enhanced the biodiversity health of CWS.

The biggest challenge the CWS community is going to face is to sustain the success of the livelihood support program. One way of sustaining this success could be to institutionalize the activities the program and the community have done together. We recommend that an integrated management of financial resources and AIGAs can immensely contribute to the creation and conservation of biodiversity resources in the CWS areas. Creation and mobilization of a cooperative fund is expected to make the community self-reliant to meet their financial needs to diversify their income sources. Apart from the fund management locale, the BFD might help the community, not only with technical support to create and manage biodiversity resources at and around their households, but also to build awareness about biodiversity conservation. All these combined will ultimately make the community less dependent on forest resources for their livelihoods, which in the end would help sustain the ecosystem health of CWS.

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**References**

Bari A, Dutta U. 2003. Co-management of tropical forest resources in Bangladesh: secondary data collection for pilot protected area, Chunati Wildlife Sanctuary. Dhaka: USAID-Bangladesh and Ministry of Environment and Forests, Government of Bangladesh.

Bertrand M, Dufo E, Mullainathan S. 2004. How much should we trust differences-in-differences estimates? The Q J Econ. 119:249–275.

BFD. 2006. Management plans for Chunati Wildlife Sanctuary. Dhaka: Nishorgo Support Project.

BFD. 2015. Success in Co-management: Bangladesh Forest Department. Available from http://www.bforest.gov.bd/site/page/7894ca97-a221-401e-9ca7-68706499357/Co-management.

Bowler DE, Buyung-Ali LM, Healey JR, Jones JP, Knight TM, Pullin AS. 2011. Does community forest management provide global environmental benefits and improve local welfare? Front Ecol Environ. 10:29–36.

Chazdon RL. 2008. Beyond deforestation: restoring forests and ecosystem services on degraded lands. Science. 320:1458–1460.

Dallmeier F, Kabel M, Rice R. 1992. Methods for long-term biodiversity inventory plots in protected tropical forests. In Dallmeier F, editor. Proceedings of the long-term monitoring of biological diversity in tropical forest areas methods for establishment and inventory of permanent plots. Paris: MAB digest II, UNESCO.

Feeroz MM. 2013. Wildlife diversity monitoring in Chunati Wildlife Sanctuary of Bangladesh. Savar, Bangladesh: B Arannayk Foundation.

Fox J, Mustafa MG. 2013. Co-management initiatives implemented by IPAC in wetlands and forests of Bangladesh. Proceedings of the connecting communities and conservation: co-management initiatives implemented by IPAC in wetlands and forests of Bangladesh. Bangladesh: USAID, IPAC.

GIZ. 2015. Management of natural resources and community forestry at Chunati Wildlife Sanctuary. Dhaka: (MNRCF-Chunati) Project.

Hoque ME. 2009. Evaluating co-management as a tool for the reduction of poverty and inequality in Chunati Wildlife Sanctuary. In:
