Economic Valuation of the Provisioning Services Provided by the Sundarban in Bangladesh

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Abstract

The Sundarban provides various types of resources for an estimated four million people living in and around this mangrove forest in its Bangladesh parts. This study was carried out to quantify the value of forest income in these communities with the aim of understanding the contribution and importance of forest resources to the livelihoods of the poor, and their possible role in poverty alleviation. Eight key different resources such as fish, shrimp fry, crab, fuel-wood, wood for the construction of house and boat, thatching materials, honey and wax were identified in this study and their economic value estimated at US$145.2 million/year. It was also revealed that the households depended on mangrove resources for their livelihoods, with the lower and the middle-income households being heavily dependent. The households belonging to the lowest income group had neither land nor agricultural or livestock resources for generating income, therefore, a greater proportion of their income came from the forest, making them highly dependent on forest resources for survival. Given a population of about 4 million people residing in 17 upazilas (sub-districts) close to the Sundarban Reserve Forest, and their higher dependence on forest resources, sustainable management of the common pool resources provided by the forest is essential for alleviating extreme poverty. Management regimes for the Sundarban Reserve Forest need to be ensured continued access of the local residents to forest resources, especially of those who are the poorest, for sustaining livelihoods. In this regard, co-management of resources could be a pro-poor strategy if it does not compromise the livelihoods of the poorest living in and around the Sundarban.

Keywords: sundarban, mangrove, livelihood, provisioning resource

Introduction

Natural forests provide various goods, services and benefits to communities living close to the forest areas. In Bangladesh only 6.7% of the country's surface is covered by forest, and that weak environmental legislation and a pressure of a growing population results in the loss of about 2,000 hectares of forest each year (FAO, 2009). The Sundarban of Bangladesh - the largest single tract of mangrove formation in the world - is also undergoing accelerated deforestation, which weakens the ability of the forests to provide important ecosystem services, including the key livelihood resources for the forest-dependent communities.

The Sundarban Reserve Forest is situated in the south-western part of Bangladesh and it provides valuable services to the local people that are essential for their life and livelihood. Around four million people directly or indirectly depend on the Sundarban for wood (*i.e.,* timber) and non-wood forest resources (*i.e.,* fuel-wood, nipa leaves, fish resources, honey, crab and medicine plants) (FAO, 2015). The Bangladesh Forest Department (BFD) allows people to extract fish, nipa leaves and honey. Extraction of other natural resources, such as shrimp fry and timber, are banned, but marginalized people living adjacent to the Sundarban seek resources including the banned resources for a living.

In recent years, excessive extraction of both wood and non-wood forest resources has degraded the Sundarban Reserve Forest. If the extraction rate of the resources is equal to biological growth rate of the resources, then the forest and the associated goods and services could be sustainable. On the other hand, if the rate of the resource collection is higher than the growth of the services, then the resource may become depleted. If the local people are not able to make their ends meet, either through sustainable and regulated collection of resources or through other means, then illegal logging and over-exploitation of resources would probably take place, leading to faster degradation of forest resources.

Since 1989, it has been illegal to collect logs from the Sundarban. Only limited and controlled harvesting of non-wood forest resources from outside the wildlife sanctuaries are allowed to meet local needs. Allowable harvest is prescribed by the Integrated Resources Management Plan (IRMP) for the Sundarban (2010-2020), but in practice, extreme poverty, coupled with hardships due to frequent natural disasters; drive the coastal people to become heavily dependent on the Sundarban's ecosystem resources for their livelihoods. Furthermore, unlawful practices, such as, payment of illegal fees to the local musclemen, pirates/robbers and corrupt departmental officials add pressures on poor people to extract more and more resources from the Sundarban. Under such situations, conservation initiatives are ineffective.

It was found in some studies (Miah *et al.,* 2010) over the last few years, that forest users have lost their traditional livelihoods due to unsustainable natural resource exploitation in the coastal belts of Bangladesh. At the same time, major agricultural activities have been jeopardized by increased salinity in soil and water, water-logging, drought, etc., forcing the farmers to switch from rice to non-rice crop production (Rahman *et al.,* 2011). Marginal coastal household communities suffer from social and economic vulnerability in the post-disaster periods (Alam and Collins, 2010) that limit their income opportunities. This phenomenon is common when there are fewer natural resources essential for sustaining livelihoods (Barnett and Adger, 2007). Issues related to these poor communities and their relation to cyclones were looked at in several studies, for example, health securities (Ray-Bennett *et al.,*2010), physical injuries (Paul, 2010), cyclone-warning systems (Paul and Dutt, 2010) and community-coping mechanisms (Parvin *et al.,* 2008) for those people living in the south-western coastal region of Bangladesh. The focus in none of the previous studies, however, was on the patterns of forest-resource dependency for livelihoods of disaster-affected communities. Hence, the inter-relationship between the households' livelihood status and natural-resource dependency has not been fully examined.

The Sundarban Reserve Forest plays a significant role in the local, regional and national economy of Bangladesh, as well as in the biodiversity conservation of the mangrove ecosystems. Yet policymakers do not know the value of provisioning services provided by the Sundarban, nor do they understand breadth and magnitude of forest dependency of local people. Thus, this study was carried out focusing on the following issues: (i) quantifying the economic value of the Sundarban in terms of forest resources collected from the forest by "Resource-based Communities"; and (ii) measuring the importance of forest resources from the perspective of resource-dependent people by monetary value and the proportion of income that people derive from collecting forest resources. These data contribute to the overall valuation of the Sundarban and can encourage policy makers to expand the plantation and conservation of mangrove forests. In this study, however, will be laid out how resource-dependent communities use the forest resources, so that conservation authorities understand the impact of degradation or losing the forests.

The main aim of this study is on the economic valuation of wood (*i.e.,* timber) and non-wood forest resources (*i.e.* fuel-wood, honey, wax, nipa leaves, fish, shrimp, shrimp fry and crabs), which are important for the livelihoods of the communities living near the Sundarban Reserve Forest. In this connection, the case will be made for recognizing the economic value of these resources within the forests and within the lives of local people. It is already recognized that protected forest areas cannot be conserved without engaging the local people, understanding their needs and practices, and identifying how to work with them (Gillingham and Lee, 1999). Thus, this study is important for policy makers in order to understand the social and economic aspects of forest management, as they relate to the conservation of forest resources, as well as to the livelihoods of local communities. In light of the above circumstances, the major objectives of this study were to: (i) assess the value of the provisioning services provided by the Sundarban Reserve Forest, (ii) recognize the importance of provisioning services on local communities' livelihoods in relation to their socio-economic and demographic condition, (iii) understand the formal and informal resource-collection behaviour of Sundarban-dependent communities, (iv) investigate the frequency of access with duration and extent of dependency on the Sundarban, and (v) provide recommendations for reducing the dependency on the Sundarban by the resource collectors.

Materials and methods

Sampling sites

In total, 363 households were surveyed in six upazilas (sub-districts) of Bagerhat [i.e. Sharankhola (n = 56), Mongla (n = 48) and Morelgong (n = 27)], Khulna [i.e., Dacope (n = 46) and Koira (n = 65)], Satkhira [i.e., Shyamnagar (n= 16)] and Barguna [i.e., Barguna Sadar (n = 8), Pathorghata (n = 42) and Taltoli (n =55)] districts. Three upazilas were adjacent to the Sundarban Reserve Forest and other three upazilas in Barguna district were located a little away from the forest.

Data collection and analysis

A systematic sampling technique was used for collecting data through interviewing respondents across the study sites. At first, one household was selected at random near the embankment, which was located adjacent to the Sundarban and then the other households were selected at an interval of 300m away from the embankment. For each household, the GIS (Global Information System) coordinates were recorded. Thereafter, a well-structured questionnaire was administered for collecting socio-economic and demographic data from each household. The questionnaire included information related to resource collection behaviour, types and quantity of resources collected, collection period and monthly frequency of resource collection, proportions of resources used for household consumption and sold for cash income, and local market price of each resource per unit. Another questionnaire was designed to collect information related to payment of entry fees for each trip for collection of each resource, number of people involved in each trip for collection of resource, travel time spent and distance covered by the resource collectors for each trip.

After coding and digitizing the collected data, analyses were performed by using SPSS version 20.0 (SPSS, Chicago, USA). The differences in socio-economic and demographic profiles, and resource collection behaviour of forest-dependent people were explored by using two-way ANOVA and Chi-square (χ^2) tests. The level of significance was set at $p = 0.05$.

Tools for estimating the value of the forest resources

The producer's surplus method was used to estimate the total economic value of forest resources that the resource-dependent communities extract from the Sundarban. After identification of the forest resources that are being collected by the local communities living across the study sites, the study assessed the value of resources by subtracting the minimum amount that the resource collectors are willing to receive. It is important to note that the total cost of resource collection includes the cost of permits, wages and food for day labourers, and the revenue charges for the collected resources levied by the Bangladesh Forest Department. The underlying assumption of the producer's surplus function is that the collection of resources from the Sundarban can be defined as a production or supply of both intermediate and final goods to the consumers in the market. Thus, the producer's surplus can be defined as a gap between the earnings from collected resources and the maximum willingness to accept, which is equivalent to the collection costs of the resources. In addition, the resource abundant areas of the eight resources were identified based on the information of the resource collectors from which areas of the forest they collect the respective resource.

Theoretical model of the producer's surplus method

The theoretical model for estimating producer's surplus is as follows:

$$PS = Actual\ value\ of\ sales - Minimum\ willingness\ to\ accept\ or\ receive$$

$$= P_R Q_R - \int_0^{Q_R^*} S(Q_R)\,dQ_R$$

$$= TR(Q_R) - \int_0^{Q_R^*} S(Q_R)\,dQ_R \text{----------} (1)$$

Here, PS is producer's surplus; TR is total revenue earned from the collected resource (Q_R) and the remaining part of the equation – (1) is the minimum amount that the resource collectors are willing to accept or receive (WTA) from selling the resources. The total revenue is the product of quantity of the collected resource and the price of the resource, whereas the minimum willingness to accept or receive is the integrated area from the origin (zero) to equilibrium level of resources (Q*) under the supply curve (Figure 1). Thus, estimation of supply curve provided the minimum amount that the resource collectors are willing to receive. The following equation was considered for estimation of the actual value of the sales (total revenue):

$$TR = Q_R * P_R$$

$$= Q_R * MC\ ; Since, P = MC\ at\ the\ equilibrium\ level \text{----------} (2)$$

The marginal cost of the resource collection derived from the total cost function is explained in the equation 3 below. The resource price eqivalent to these marginal costs was considered which was derived from that cost function. In this study, the total cost of resource collection was estimated annually through adding permit costs, labour wages and revenue paid to the BFD for each of the collected resources. Information regarding different variables of producer's surplus (PS) method was collected from the primary survey. Thereafter, we calculated the average annual producer's surplus/boat for each of the collected resources. To get the annual producer's surplus and earnings per person or per family, we divided the average annual producer's surplus per boat by the earnings of the total number of persons involved in the collection of resources in each boat.

The total resource value of the Sundarban Reserve Forest was calculated by adding all resource values. The individual resource value was then calculated through multiplying the average producer's surplus of each resource by the number of permits issued by each forest station and the number of forest stations. The calculation of producer's surplus and minimum willingness to receive of the resource collectors are shown in the following theoretical graph (Figure 1), where, area above the marginal cost curve shows the producer's surplus and the area under the marginal cost curve shows the earnings of the resource collectors. It is important to note that the resource collectors spent some part of their earnings as permit cost and revenue payment to the BFD.

The total producer's surplus for the Sundarban was then calculated by multiplying the producer's surplus for all the resources with the total number of forest stations. After estimating the surplus value of each of the collected resources, each was divided by the estimated resource abundant area for each of the resource collected from the Sundarban. During survey, respondents were asked about the distances that they travelled from home to the Sundarban for the collection of different resources. Based on that information, we identified the coverage of areas from where they collected different resources. Thereafter, we calculated total coverage of areas in hectare for each of the collected resources to estimate the contribution of resources/hectare (Figure 2). Based on the information collected from the resource collectors, the resource-abundant areas were then identifed for each of the resources in the Sundarban, which is shown in the results section (Figure 2. a-f).

While valuing the resources, all the resources that are being collected from the Sundarban mangrove were considered. Then the quantity of the shrimp fry was estimated in thousand pieces per year, while for the quantification of other resources we used quintal per year. The costs of collected resources were considered as the function of a common set of explanatory variables. Thereafter, we estimated the marginal cost to calculate the value or surplus for each of the resources collected from the Sundarban. A common function, which we applied to calculate the total cost for each of the collected resources is shown below:

$$TC_R = f(Q_R, Frq_{per\,month}, TL, Travldist) ---------- (3)$$

Here, TC_R is the total cost of collected resource in BDT, Q_R is the quantity of the resources in quintal/year, $Frq_{permonth}$ is the frequency of collected resources/month, TL is the total number of people involved and $Travldist$ is the distance between household and the extraction sites of resource collection.

Results

Value of the provisioning services within the Sundarban Reserve Forest

Estimation of the costs of resource collection

Based on the interviews, eight different types of forest resources harvested from the Sundarban Reserve Forest were identified (Table - 1). Resource collectors need permission from the BFD prior to collecting resources and a total of 16 forest stations in the Sundarban issue permits. The quantity of resource collection and associated revenue varies with the types of resources, particularly with the size of boat or with the number of resource collectors. Collection time of some resources, such as nipa leaves, crabs, honey and wax is fixed. Thus, the permits for the extraction of those resources are being issued following the time of extraction. The collection period of different resources, number of permits issued by a station, maximum limit of collection for each of the resources and the associated revenue, being charged for the collection of per unit resources are shown in Table 1. However, each boat with a capacity of 10 quintals has to pay BDT 5 plus 15% value-added-tax to collect boat license. The entry fee for catching fish and shrimp is BDT 7 plus 15% value-added-tax, while for crab collection the entry fee is BDT 6 plus 15% value-added-tax/day/person. The permit for the collection of fish, shrimp and shrimp fry and crab is valid for 7 days.

Estimation of the value-addition of the collected resources

To estimate the economic value of the collected resources, the total-cost function was used, which is the cost of collecting resources for one year. A step-wise linear regression analysis examine the variations in cost function of different resources as dependent variable was tested with four independent variables such as TQ_R (the quantity of the resource per year), $Frq_{per\ month}$ (the frequency of collected resource/month), *TL* (the total number of people involved in the collection of each resource) and *Traveldist* (the distance between household and the extraction sites for each of the resource collection). The estimated results are summarized in Table 2. The analysis shows that the total quantity of resources collected per year was one of the significant contributors to explain the variations in cost functions of all collected resources. The total number of people involved in the collection of different resources was another important predictor to explain the variations in cost functions of fuel wood, honey, wax, fish, shrimp and crab other than nipa leaves and shrimp fry. The frequency of collected resource/month was also another significant contributor to explain the variations in cost functions for the collection of honey, wax, fish and shrimp, but insignificant with other collected resources such as, fuel wood, nipa leaves, shrimp fry and crabs. The last predictor (*i.e., Traveldist*) of independent variables only explained the variation in the cost functions of fish and shrimp, but insignificant with other collected resources. The coefficient of determination (*i.e.,* R^2) was high in each regression model. On the other hand, R^2 and adjusted R^2 are large enough for all regressions, which imply that models fitted well and F-values are significant. Afterwards, results from the regressions analysis were used to estimate the producer's surplus for each of the collected resources. It would have been easy to use these estimated results, if we had the non-linear cost function from where we could have derived the marginal cost function. By the theory, marginal cost is equal to price, if a competitive market prevails. Since the estimated cost functions are found to be as significant as in linear functional forms, we cannot equate marginal cost with the price. As a result, we cannot use the coefficient of quantities in estimated cost functions (*i.e.,* marginal costs) in valuing the producer surplus. Thus, we proceed with the mean quantities and prices of the resources for calculating the total revenues and then continue with the previously-explained method. The calculation of the value for each resources collected from the SRF are shown in Table 3.

When considering the cost of labour, entrance fees, fuel costs and other collection costs, the annual marginal cost of resource collection for each boat varied between resources. The marginal cost refers to the change in total cost due to the change in quantities. For example, as found in this study, the marginal cost of fuel wood was BDT 7.3, which means that the total cost of fuel-wood collection increases by BDT 7.3, if it increases by one quintal. The marginal cost and average selling price of fuel wood, nipa leaves, honey, wax, fish, shrimp, shrimp fry and crab are shown Table 3.

To calculate the average producer's surplus for each of the collected resources, the mean quantity and price of each resource from the sample data were considered and the total revenues were multiplied by 0.5 to get the area under the constant marginal cost-supply curve, which was the cost of supply. Producer's surplus was then calculated as the difference between the total value of revenue and the total minimum willingness to accept or receive (*i.e.,* the area under the supply curve). The producer's surplus/boat/year for fuel wood, nipa leaves, honey, wax, fish, shrimp, shrimp fry and crab is shown in Table 3. The resource-abundance areas for each resource were estimated (Figure 2 a-f); based on the distance between household and the extraction site of resource collection and the results are also shown in Table 3. However, based on the producer's surplus value, the total value of the collected resources from the SRF is US$145.2 million (Table 3), which is the contribution of collected resources from the SRF, but the values for all resources form each hectare of the resource-abundance area were also calculated (Table 3). That is, each hectare of SRF contributes US$793/year as provisional services. Additionally, the yearly earnings of each resource collector, including his/her opportunity cost of labour wage, entry fees and revenue paid to the BFD (*i.e.,* total value of area under the supply curve, as shown in Figure 1) were calculated. It is important to mention that yearly earning for fishers and fuel-wood collectors refers to 12 months and for the rest of the resources, it refers to the season or collection months only.

Importance of forest resources on local communities' livelihoods in respect of socio-economic and demographic condition

In addition to understanding the intrinsic value of forest resources within the Sundarban Reserve Forest, the importance of the forest resources on the livelihoods of communities living around and near the forests was also assessed. The findings of the respondent's socio-economic and demographic analysis show that more than half of the respondents were involved in agriculture (55.6%). Nearly one-third of respondents reported that they were involved in day labour activities (30.6%). Few respondents reported that they harvested fish and considered it as their major occupation (13.8%).

The relationship between the age groups, types of occupation ($\chi^2 = 3.85$, df = 6, p = 0.697) and education level ($\chi^2 = 8.87$, df = 9, p = 0.449) was not significant across the study areas. More than half of the respondents had either no education or dropped out before completing primary education (54.8%). The average size of household was 5 persons and ranged between 4-5 persons. The mean monthly income of the respondents was about BDT 4,500 per household and ranged between BDT 3,500 and 5,800.

Formal and informal resource collection behaviour of SRF-dependent communities

As mentioned, the respondents collected honey, wax, nipa leaves, fish, shrimp, shrimp fry, crab and fuel-wood from the SRF (Table 1). On average, the illegal collection of mangrove resources contributed around 50% of the total income of the lower-income households, and 29% and 12% for the middle- and higher-income households, respectively. Among the forest resources, both fry and fuel wood collection was legally prohibited, but contributed as much as 34% and 16% respectively to the total income for the lower-income households. Only the lower income households and some middle-income households participated directly in shrimp fry collection. The proportion of collected resources from the SRF, both legally and illegally, are shown in Figure 3. The respondents who collected resources (*i.e.,* nipa leaves, honey, fish, crab and shrimp), more than the amount allowed by the permit or who collected banned resources (*i.e.,* fuel-wood and shrimp fry), were considered as illegal-resource extractors.

Almost all households depend on the SRF resources directly or indirectly, with the majority involved in fishing (54%, 198 of 363) and crab collection (31%, 111 of 363). The resource-collection behaviour of the SRF-dependent communities is described in the Table6.Among the honey and wax collectors, only 17.4% reported that they occasionally extracted honey and wax from the SRF without permits, while, among nipa leaves collectors, 23.8% reported that they extracted more nipa leaves than allowed by the issued permit, to recover the cost related to so-called “tips” of forest officials and robbers. Around 23% respondents of surveyed fishers reported that they harvested fish from the SRF without permits, and among shrimp collectors, 9.2% reported that they collected shrimps without permits from the BFD. For the collection of shrimps nobody issued permits, since their collection is banned, but 29.5% crab collectors reported that they did not have permits from the local forest office for crab harvesting and, among the fuel-wood collectors, no one had a legal permit for commercial purposes, since it was banned by the government. However, they could collect some fuel wood per day for their family consumption. Using data collected from the areas adjacent to the settlement zones, the northern parts of the SRF are considered as being high fuel-wood extraction zones, while areas in the southern part have less fuel-wood extraction (GIS analysis, Figure 4).

Duration, frequency of access and extent of people's dependency on the SRF

As this study revealed, most of the SRF-dependent households earn their income from harvesting a variety of resources from the mangrove forest. Collection is seasonal, depending on the resource availability, which provides income throughout the year. For instance, the fishers catch hilsha and other white fish during July-October and after October when catching of fish becomes uneconomic, they catch mud crabs during November-December in the rivers and in canals in and around the SRF. During November-March, the resource collectors enter in the forest to extract nipa palms. Extraction of honey and bees-wax usually takes place during April – June, but all households collect shrimp fry all year round. Some fishers harvest crab when it is available and collect shrimp fry during its peak season and sell it to shrimp farmers. It was also found that, generally, the resource collectors enter deep into the forest for at least on a weekly basis. The resource collection behaviour of dependent communities is summarized in Table 4).

Discussion

Value of the resources

Because of decreasing incomes from agricultural activities, and inadequate non-forest sources of income, resource-dependent communities are increasingly moving to the SRF for cutting wood and fishing. Almost all resource collectors are fully dependent on the SRF for fuel-wood. Women, in groups of 8 to 9, go to the SRF on a weekly basis and collect wood to meet needs for cooking. It is important to note that no resource collector goes to the SRF for wood extraction with permission from the government, and neither the women nor children have permission to collect wood and cooking fuel (Siddiqi 2001). Most of the SRF-dependent households earn their income from harvesting a variety of resources from the mangrove forest. Some of them enter in the forest to harvest Malia (*Cyperus javanicus*) grass and hogla (*Typha elephantina*) grass (Siddiqi 2001). These two grasses have market value, and are used for preparing traditional mats and similar household goods. Nipa leaves also have good market value as roofing materials (Siddiqi 2001). On the other hand, when the fishers are unable to make enough money from fishing, they cut trees, and collect dry wood for their household purposes. However, local people are heavily dependent on eight key forest resources for their livelihoods - honey, wax, nipa leaves, fish, shrimp, shrimp fry, crab and fuel-wood (Singh *et al.* 2010; Uddin *et al.* 2013). So, in addition to other values of the SRF, such as its value to protect communities from storm surges, and its cultural/ tourism values, the SRF diverse resources have great value to the communities, living in and around this mangrove forest.

Importance of forest resource to local communities

Although collection of fuel-wood and shrimp fry has been banned by the government since 1995 and 1996 respectively, local people who lived across the studied upazilas continue to depend heavily on the SRF for these resources to sustain their livelihoods. This confirmed the findings of a study conducted by Abdullah *et al.,* 2016, who revealed that much of the income of the resource-dependent people was obtained from the illegally-harvested resources. The income earned from forest resources contributes significantly to the livelihoods of the local communities. As discussed in previous sections, almost all households depend on the SRF resources directly or indirectly, with the majority involved in fishing and crab collection. The fishermen have been passing through hardships, because of sharp declines in fish availability and many of them have failed to recover the investment made for fishing, because of insufficient harvest. Moreover, many fishermen are unable to afford the necessary gears, nets and boats for fishing, and are forced to taking loans in order to continue harvesting fish. For all these reasons, there is a need to reduce the dependence of local communities on fishing by introducing alternative livelihood supports. One probable alternative livelihood support could be employing these people in the manufacturing industry through priority basis. For example, government could think of these people for the ongoing Paira Port so that their dependence of SRF reduces. Reduced dependence on fishing will also help preserve threatened fish resources in and around the SRF.

Regarding shrimp resources, the respondents of the survey reported a decreasing trend in the availability of shrimp and shrimp fries, and only fewer percentages of shrimp collectors reported that they collected shrimp (Abdullah *et al.* 2016). Although there is a ban on catching of shrimp fries, it is one of the most important sources of income for most families, as male, female and even children can catch them in the rivers and canals near their homesteads. Currently, because of the sharp declines in availability in fish and shrimp resources, many members of the SRF's fishing community are forced to look for alternatives to fish-based livelihoods and they try to work as day labourers for repairing houses, excavation of ponds, and in fishing boats. For a typical 7-day trip to the Sundarban, the wage of a labourer is around BDT 2000 with food and other costs covered by the employer.

To reduce the pressure on the SRF's resources, the government, NGOs and the donors/ development partners have long been working with the vulnerable people by providing financial and Alternative Income Generating Activities (AIGAs) supports. Moreover, as part of reducing resource dependencies, the government can consider expanding buffer zones by planting valuable mangrove plant species at the edge of river banks along the coast near villages near the SRF, so that current households can collect resources outside the forest boundary. To manage the buffer zone, the government can involve resource collectors under the supervision of the co-management groups. Revenues generated by the SRF's cultural services can be used to expand the buffer zones. The resource collectors will manage their livelihoods until the maturation of the plantations of the expanded buffer zone. The buffer-zone plantations will also protect people and properties from cyclones and make the land more suitable for habitation. Through introducing social forestry programmes and reforestation of embankment areas in human-settlement zones, the gap between demand and supply of forest resources can be reduced by increasing the supply of forest resources. Special allocation from the government development budget for health, sanitation and education can reduce the resource-dependent family's quest for additional earnings and hence pressure on SRF. Action should be taken to enforce laws to protect mangrove plants through promotion of improved ovens in rural areas and introduction of biogas plants across the villages adjacent to the SRF.

Conclusion

The quantity of resource collection and associated revenue varies with the types of resources, particularly with the size of boat or with the number of resource collectors. Collection time of some resources, such as nipa leaves, crabs, honey and wax is fixed. Based on the producer's surplus value, the total value of the collected resources from the SRF is US$145.2 million and each hectare of SRF contributes US $793/year as provisional services. As this study revealed, collection of resources is seasonal, depending on the resource availability, which provides income throughout the year. To reduce the pressure on the SRF's resources, short-term financial and AIGAs support scheme to the vulnerable people could be one option. In addition, to minimize the dependency of local people over SRF's resources, the government can consider expanding buffer zones by planting valuable mangrove plant species at the edge of river banks along the coast near villages near the SRF as a long-term action.

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Figures

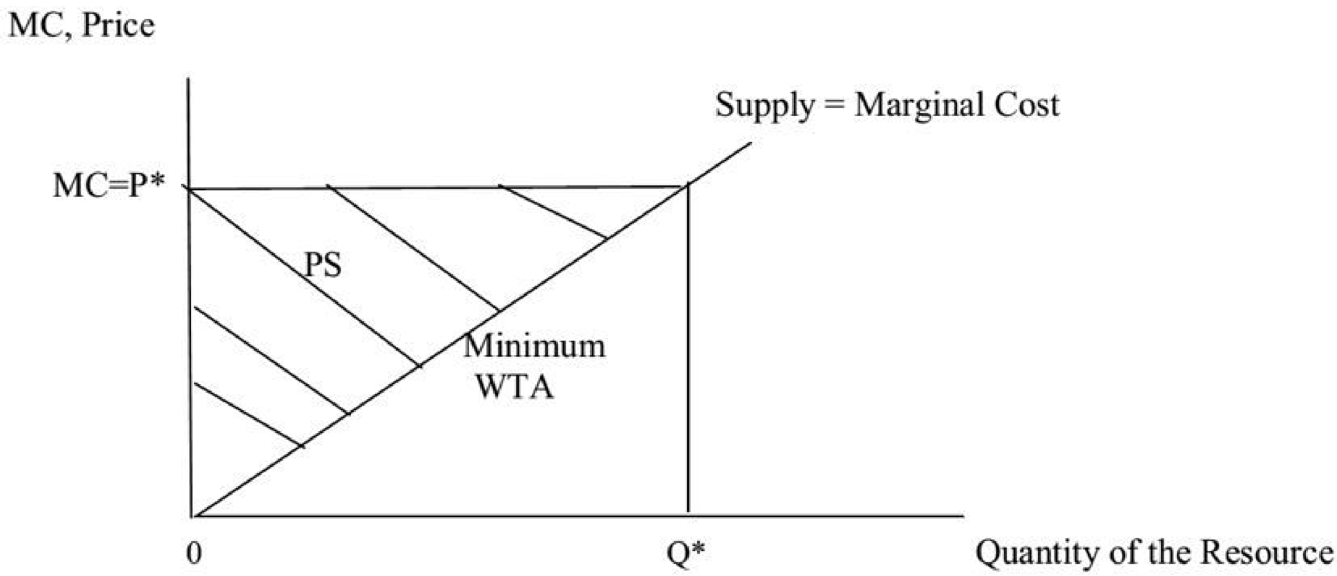

Figure 1

Theoretical sketch of marginal cost and producer’s surplus

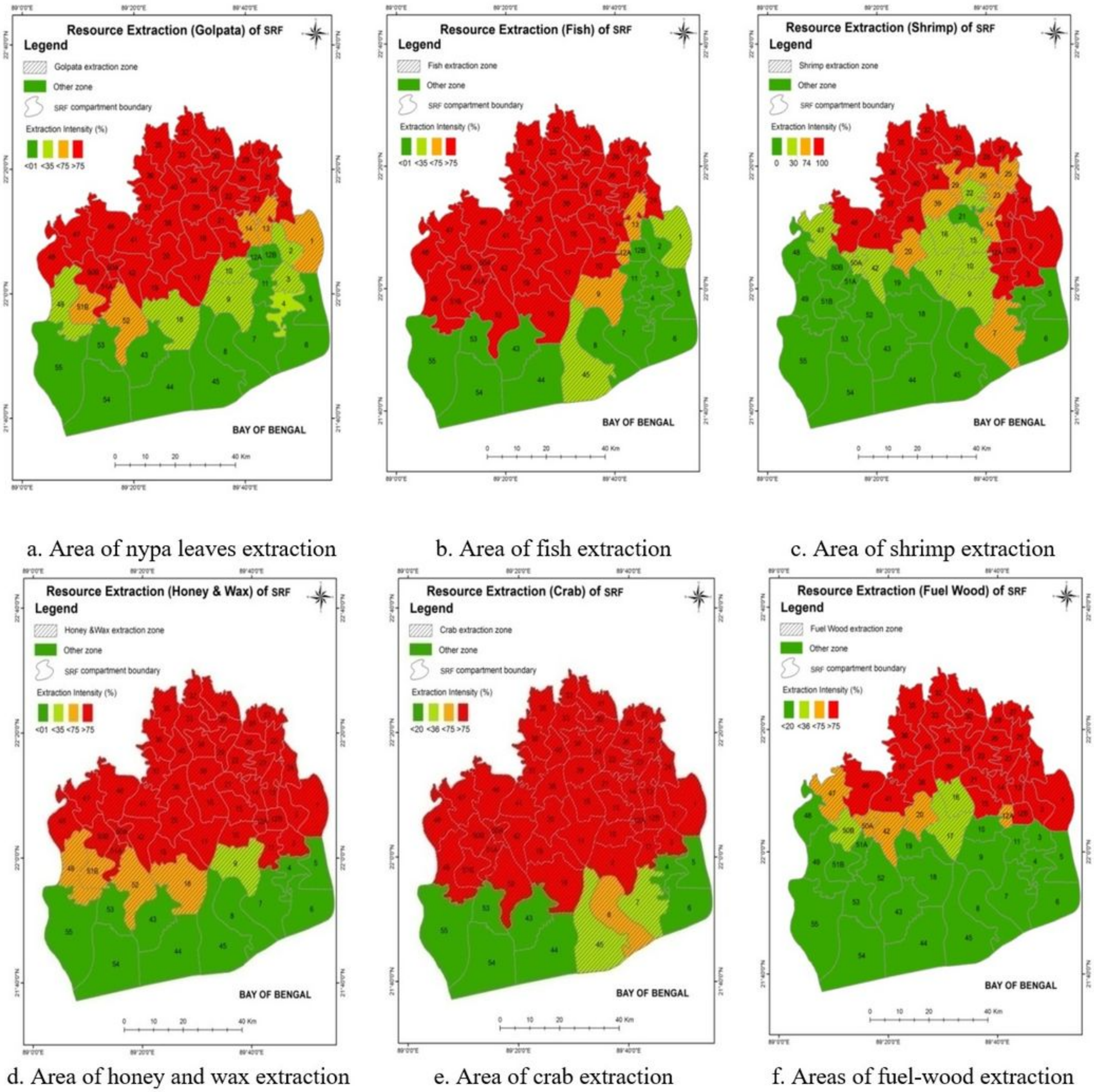

Figure 2

(a-f): Resource-abundance areas of the Sundarban Reserve Forest Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

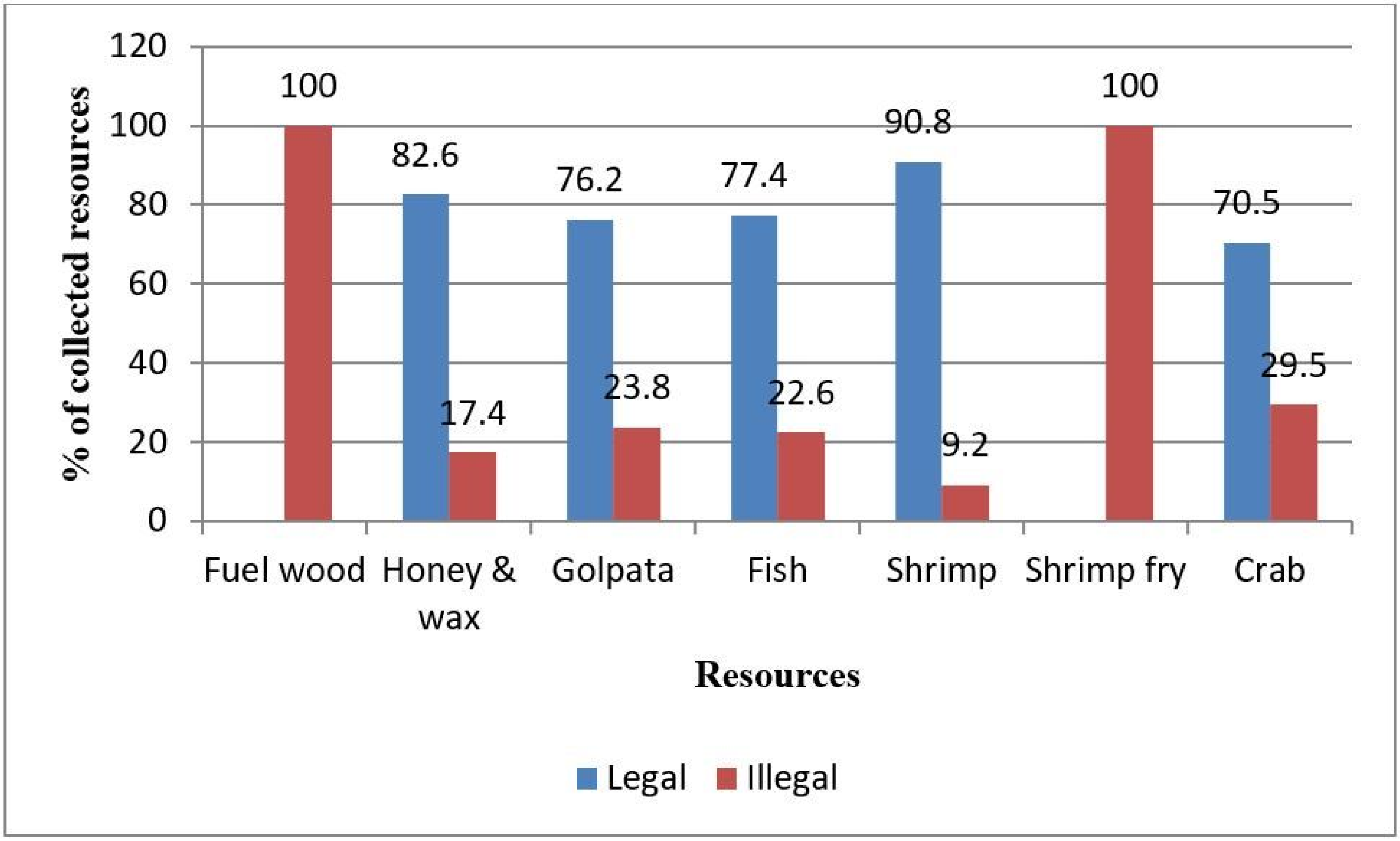

Figure 3

Proportion of legally and illegally collected resources from the Sundarban

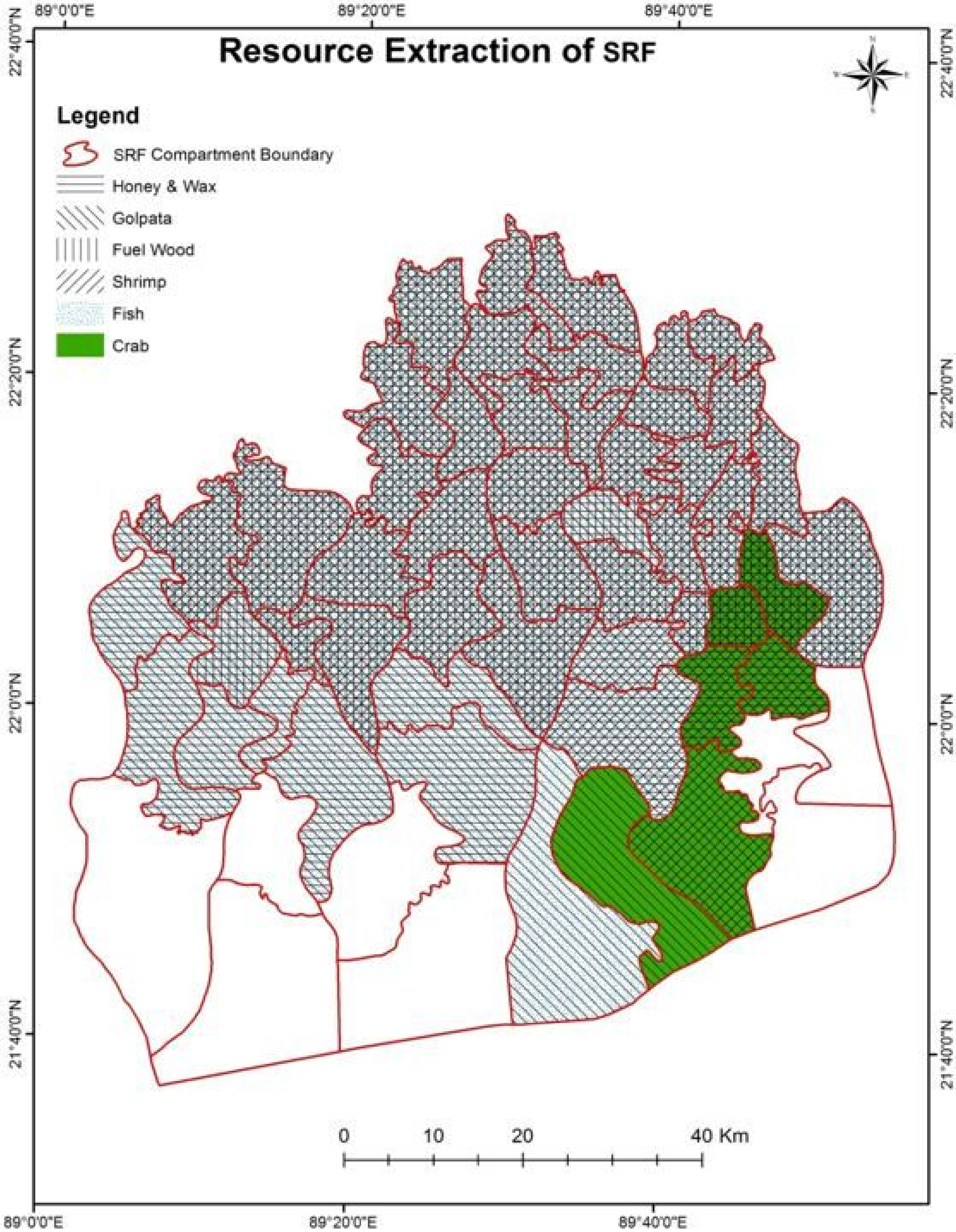

Figure 4

Areas of all resources extraction from the Sundarban Reserve Forest Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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