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Examining Private Participation in Embankment Maintenance in the Indian Sundarbans

Prasenjit Sarkhel

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Prasenjit Sarkhel
Department of Economics
University of Kalyani, West Bengal, India

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Comments should be sent to
Prasenjit Sarkhel
Department of Economics
University of Kalyani, West Bengal
India
Email: prasenjitsarkhel@gmail.com

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Abstract

This paper analyses the complementarities between land productivity and conservation investments in the context of river embankment maintenance in the Indian Sundarbans. The study finds that households whose principal occupation is aquaculture commit more resources to embankment maintenance relative to those in non-aquaculture employment. While conservation efforts are greater in all types of aquaculture plots irrespective of distance from the embankments, such efforts unambiguously decrease for agricultural plots that are located at a distance from the embankments. Private returns to aquaculture are much higher than returns to agriculture, enabling aquaculture households in invest in managing their local public good. However, there is evidence of free riding in canal-based aquaculture when users draw water from a single source. Head-enders with greater wealth as well as intense social networks tend to free-ride while tail-enders with less land holdings contribute more towards canal maintenance. Furthermore, public intervention in embankment maintenance may be crowding out private efforts. Thus, in primarily agricultural areas, productivity-enhancing policies may be more efficient than policies that fully subsidize public good maintenance.

Keywords: *Public good; Embankment maintenance; Voluntary contribution; Uncertainty; Sundarbans, India.*

Examining Private Participation in Embankment Maintenance in the Indian Sundarbans

1. Introduction

In most developing countries, inadequate provision of local public goods and poor conservation of common property resources have often led to private contribution towards the maintenance of these resources. This includes, for instance, the contribution of time and effort towards building check dams in watersheds (White and Runge, 1995; Gaspart et al., 1998) and participation in soil conservation measures (Gebremedhin and Swinton, 2003; Fenske, 2011). However, a large part of the literature on conservation of common property resources as well as local public goods aligns itself with the view that conservation efforts are more likely to be initiated if property rights are well defined. Thus, Lee (1980) and Feder et al. (1988) have argued, for instance, that security of land tenancy would encourage committing resources for soil conservation. But Pagiola (1993) inserted the caveat that when property rights are secure, there might be perverse incentives for conservation if the resource in question is relatively less productive. Although, according to Posner (1977), public intervention, in terms of making property rights transferable, can initiate conservation, public provisioning can also crowd out private contribution. As Browne and Hoyt (2000) and Kunreuther and Pauly (2004) have shown, government disaster protection programs can reduce private self-protection investments. Thus, private conservation expenditure can be conditioned by either of these factors, making the net effect ambiguous. The present study analyzes the linkage between property rights, productivity and private contribution expenditure in the context of a specific public good: the river embankments in the Indian Sundarbans.

1.1 The Indian Sundarbans

The Indian Sundarbans comprises an archipelago of 102 islands of which 54 are inhabited. It is interspersed with a complex network of tidal rivers leading to the Bay of Bengal located on its southern flank. The river embankments in the Indian Sundarbans came to be erected in the late 18th century when land reclamation began in the Sundarbans during the British colonial period for the purpose of protecting the agricultural land from diurnal tidal surges (Richard and Flint, 1990; Bandopadhyay, 2000). Since 1770, when land reclamation began in the Indian Sundarbans, the 3,500 km long embankments have served as a flood defence structure though repeatedly ravaged by extreme weather events. For instance, researchers have shown how sea-level rise has triggered the erosion, and subsequent collapse, of more than 100 square km of the embankments in erosion-prone areas in the last three decades (Ghosh et. al., 2003). Since the region is interspersed with tidal rivers, a more frequent disaster comes in the form of inundation of settlements from tidal surge which either topples the protecting dykes or breaches them. In fact, the mean tidal amplitude of the Sundarbans area (from 5.22 mm to 3.14 mm/yr) is much higher than the national average (between 1.06 and 1.75 mm/yr) (Unnikrishnan and Sankar, 2007). With regard to catastrophic events, this region has faced 31 severe cyclones between 1961 and 2000, with the majority of them having a velocity greater than 100 km/hr and at least 5 exceeding the velocity of 200 km/hr. Cyclone Aila in May, 2009, is one such example where almost 500 km of the embankment were washed away affecting over 6.77 million people and killing 137 people in the North 24 Parganas and South 24 Parganas parts of the Sundarbans in addition to either partially or completely destroying 926,000 semi-permanent houses (Development Research Communication and Service Centre, 2009).

While the responsibility for the maintenance and repair of the embankments still vests officially with the Department of Irrigation and Waterways (DIW), Government of West Bengal, it is beginning to transfer gradually the responsibility for maintenance to local level institutions such as the *panchayats* under the aegis of the central wage employment program called the Mahatma Gandhi National Employment Guarantee Act (MGNREGA) with many *panchayats* starting to take on the task of embankment maintenance.

Private efforts towards the maintenance of river embankments have remained almost negligible since the colonial period despite the fact that the collapse of embankments leads to saline water incursion into paddy fields and renders them unsuitable for cultivation until next few monsoons. Considering that over 80 percent of the Sundarbans inhabitants are engaged in agriculture, the absence of private efforts towards embankment maintenance becomes all the more surprising. It is rational to expect that each individual or household's incentive to conserve a river embankment is dependent on the extent of flood protection benefits received. In the case of the Indian Sundarbans inhabitants, although agriculture has been the dominant land use type since the colonial period of land reclamation—something that was aided by the securitisation of tenancy rights after independence through land reforms—agrarian productivity in the islands has remained low due to unfavorable environmental conditions and lack of irrigation facilities.[1] The productivity of paddy ranges between 1.5 to 2 tonnes per ha in the Indian Sundarbans (Center for Science and Environment (CSE), 2012) against a national average of 3.28 tonne per ha.

1.2 Land Use changes in the Sundarbans

In the last four decades, there has been an increasing conversion of paddy fields into aquaculture ponds (Chaturvedi, 2008) through transfer of land rights as the latter provides a higher return than agriculture (Chopra et al., 2009; Knowler et al, 2009). Since the potential for loss (or gains from avoided loss) due to flooding has increased, we expect this to increase the incentives for private conservation of embankments. To the best of our knowledge, this hypothetical relation between land productivity and inclination for embankment conservation in the Indian Sundarbans has not been investigated to date. The objective of this paper is to address this research gap and to compare private contribution behaviour under alternative land use choices.

The land conversion phenomenon has been occurring mostly in the northern part of the Sundarbans that is interspersed with tidal rivers (Chopra et al., 2009; Ray, 1993). Damage in these areas generally comes from breaching and overtopping of embankments by tidal surge. This damage could be reduced through increased private maintenance efforts. However, with large systemic shocks such as Cyclone Aila of 2009, restoration and stabilization of embankments do require state support. But with increasing pressure on public finances, the state's role in regular repair and maintenance work is expected to gradually phase down (see Figure 1).

The study addresses two specific questions in this context:

a) Does private contribution towards river embankments respond to differences in land productivity?
b) Does public intervention in embankment protection 'crowd out' private investment in maintenance activities? For example, do state-supported programs such as the MGNREGA potentially displace productivity-induced conservation efforts?

The remaining part of the paper has the following sequence. In the next section, we will describe the historical context of land use, property rights and embankment maintenance in Indian Sundarbans. In section 2 we discuss the factors that influence private contribution towards collective good. In section 3, the discussion will focus on the theoretical model for private maintenance activities followed by the econometric specification for the model estimation in section 4. Section 5 outlines and records the data collection and the estimation strategy. Section 6 discusses estimation results and section 7 offers concluding observations.

1.3 Embankment Maintenance in the Sundarbans

Agriculture in the Sundarbans appears counter-intuitive as a land use choice given the mud flats that are the natural outcome of the tidal regime. However, since agriculture had a tangible output and was easy to monitor, it found favor with the colonial regime as the produce could be easily taxed unlike fisheries (Deshmukh and Choudhury, 2002). To secure the returns from the agricultural fields against the threats of tidal inundation, the

[1] Only 12 percent of the cultivable land is irrigated in the Sundarbans: see http://www.sadepartmentwb.org/Socio_Econimic_1.htm

erection of mud embankments began in 1770 in tandem with land reclamation. Though the British colonial regime spelt out tenure agreements for the reclaimed land, they gave no explicit directives regarding the maintenance of river embankments. Even as the granting of tenure for reclaimed lands continued, private landlords over time encroached forestland in order to extend their landholdings beyond the leased plots by putting up 'private embankments'.

More than two decades later, the Permanent Settlement Act was enacted in 1793 to regulate property rights over the land, which also included, for the first time, clauses about the onus of embankment maintenance (Regulation XXXIII). The regulations recognized that while the government would undertake essential public works, it was also necessary for landholders to commit resources for the maintenance of embankments (called *poolbundy*) that were adjacent to their plots (Harrison, 1875). However, this attempt to involve private landlords in embankment maintenance did not succeed because the *Zamindars* [i.e., feudal landlords in British India] in the Sundarbans in particular refused to be a party to the covenant and therefore did not sign the undertakings (called *kooboolyuts*)[2]. The maintenance of the embankments was therefore handed over to the Embankment Committee in 1803 for the supervision of the repair and reconstruction of the embankments (Harrison, 1875). However, despite the decentralization of embankment management, private participation in maintenance work remained inadequate so that subsequently the maintenance of embankments was recognized as public works in the Bengal Embankment Act of 1873 (Harrison, 1875; Roy, 2010).

The reluctance of private landholders to maintain embankments may have arisen due to adverse climatic conditions and the concomitant uncertainty regarding returns from agriculture. In fact, land reclamation in the Indian part of the Sundarbans was slow and tedious due to the extremely hazardous nature of the site.[3] Public expenditure data on embankment maintenance for the districts of Bengal during the period 1857-67 reveals that, on average, embankments in the Sundarbans required higher repair expenditures per mile relative to other districts (Table 1)[4]. At the same time, there are reasons to suspect that the yield from agricultural lands was not enough to justify the maintenance expenditure on embankments. For instance, during the period 1914-1944, the major suppliers of rice for the Calcutta city population were the agricultural fields of the Indian Sundarbans. However, since 1944, rice for Calcutta had to be imported from districts like Midnapore, Bankura, Burdwan, Birbhum and Murshidabadh, the reason being the possible fall in productivity due to increasing soil salinity that failed to keep up with the growing demand for rice (Mitra, 1954, p. lv)[5]. Even in more recent times, the analysis of available block level data for the Sundarbans, for the period 1993-2008, shows that the mean yield of *aman* paddy (i.e., lowland rice grown in the wet season during June to November) for the Sundarbans has been consistently lower than the state average (see Figure 2)[6].

In the backdrop of relatively lower agricultural productivity, it is only natural that households would allocate land to alternative uses that promise a relatively higher return than agriculture[7]. The conversion of agricultural plots

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2 Prior to the Permanent Settlement Act, the government provided a cash subsidy to the *Zamindars* for embankment maintenance and repair. Thus during the 1781-87 period, the *Zamindars* received a subsidy of INR 16,786 per annum from the colonial administration although the efficacy of their maintenance work remained questionable. In fact, according to Harrison (1875), the salt manufacturers later procured this subsidy with the complaint that the *Zamindars* were neglecting the embankments.

3 Richard and Flint (1990) note that in 1905 only 40 percent of the land in the 24 Parganas of the Sundarbans had been reclaimed while settlement was almost complete in the Bakharganj and Khulna portions of the Sundarbans (which are now part of Bangladesh). At the time, the Sundarbans were defined as the area bounded on the northern side by the limits of the permanent settlement in the 24 Parganas, Jessore (later Khulna), and Bakarganj districts and in the south by the sea face stretching from the Hughli estuary to the Meghna river mouth.

4 The owners of the plots called the *lotdars* were asked to maintain at least 3/4th of the land fit for cultivation in their lease contract. In a way this implied that they ought to keep the embankments stable too and, thus, must engage in timely repairs. The *Zamindars* in fact appointed special guards to monitor the state of the embankments called *beldars* who would also initiate repairs of imminent breaches. However, their efficacy in embankment maintenance would not have been satisfactory considering the frequent complaints of neglect (Mitra, 1954, p.lvii).

5 The Planning Commission in its report in 1981 further asserted that monsoon dependence as well as increasing soil salinity coupled with weak irrigation facilities impairs the possibility of providing year-round livelihoods from agricultural activities in the Sundarbans (Report on the Development of Coastal Areas affected with Salinity, Indian Planning Commission, 1981).

6 The t-test on the equality of means is rejected at less than one percent level of significance against the alternative hypothesis that the average yield rate for the state is higher than in the Sundarbans area. Further, the relative dispersion (coefficient of variation) of the yield rates for this period is also higher for the Sundarbans area (.18) compared to the West Bengal state average (.10).These are figures for coefficient of variation.

7 Alternatively, with inelastic substitution possibilities across different land use, one option is to engage in non-farm employment. It is a fact that marginal workers in South 24 parganas part of the Sundarbans have increased by eight fold during the 1992 to 2001 period (Center for Science and Environment (CSE),2012) .

into brackish water aquaculture farms in some parts of the Sundarbans provides a prominent example of such reallocation of land use where tidal water carrying fish carp, which is unsuitable for irrigation due to its salinity,[8] is impounded for fish farming (Kumar,2012). In order to convert lands for this purpose, inlets are dug in the mud embankments and tidal water allowed to flow into the fields through an extensive network of private canals as well as derelict water-discharge canals. This conversion of paddy fields into brackish water aquaculture in the Indian Sundarbans was recorded as early as the 1930's although the process accelerated only after the seventies (Ray, 1993)[9]. In absolute terms, out of a total brackish water culture area in the Indian Sundarbans of 42,000 ha, more than 80 percent of the aquaculture farms are located in the North 24 Parganas part of the Sundarbans. About 7000 ha are located in Canning, Gosaba and Basanti blocks of the Sundarbans area located in the South 24 Parganas.[10,11]

While the aquaculture farms initially combined both paddy cultivation and fish culture in the same plot, this practice has been gradually replaced with perennial *bheries* (or fish ponds) with year-round operations of aquaculture (Ray, 1993). These aquaculture farms can be categorized into two groups depending on the source of brackish water withdrawal: (i) farms that are connected to multifarious plots through feeder canal networks supplying brackish water (hence forth called multiple source) and (ii) households that have their own inlet of brackish water (hence forth single source) to feed their ponds.

2. Voluntary Contribution in Embankment Maintenance

River embankments are a class of pure non-excludable public goods in terms of the locally universal benefits they offer in the form of flood protection. However, they also falls into the category of the "weakest link public goods" in that the total quantity available to each consumer is equal to the smallest contribution of the individual (Hirshleifer, 1983 and 1985). What this means is that the least maintained part of the dyke determines the welfare of the whole population. Cornes (1993) has, therefore, argued that, in equilibrium, there is normally under-provision of the public good.[12] However, if potential contributors are homogenous in terms of taste and endowment then providing a threshold amount of weakest link public good may result in an efficient provision (Sandler, 2002).

Individual contribution towards the provision of local public goods such as embankments would crucially depend upon the absolute level of wealth and its distribution (i.e., degree of inequality), and the array of available exit options. Studies have emphasized that unless wealth reaches a critical value no contribution would be forthcoming (Bergstrom et al., 1986). Here, a transfer from the contributor to the non-contributing agent (i.e., those having lower asset holdings) may be useful on normative grounds but may actually reduce the overall provision of public goods (Baland and Platteau, 1996).[13] In the specific context of coastal embankments in Goa, Mukhopadhyay (2005) obtains this result where an otherwise egalitarian land transfer has resulted in decreased interest among the traditional groups of big landholders towards embankment maintenance, thus providing disincentives for collective action. Similar wealth effects are described in Olson (1965) where the richer member in a privileged group would bear the conservation expenditures alone if his benefit share from the collective good exceeds the cost of provision. However, if the fixed cost of such infrastructure related public goods is high and the benefit shares for all agents fall short of the threshold that is required for the public good to yield any benefit, then there would be no voluntary

8 The increasing salinity of the river water in the Sundarbans is the result of most estuarine rivers becoming disconnected from the Ganges (the freshwater source) over time (Naskar and Mandal, 1999; Ray, 1993).

9 For instance,in Sandeshkhali II block in North 24 Parganas of Sundarbans vast tracts of agricultural land were leased out for aquaculture in the mid seventies following lower returns in paddy cultivation due to salinity and low ground water levels (Bhattacharyya and Ninan, 2011).

10 The policy dialogue for promoting sustainable shrimp aquaculture in the Sundarbans can be found in the WWF Report, available at: http://assets.wwfindia.org/downloads/annexure_3.pdf

11 Using the National Remote Sensing Agency (NRSA) data for land use change during the 1986-2004 period, Chopra et al. (2009) show that the transformation of paddy fields to aquaculture uses has been the highest in the North 24 Parganas part of the Sundarbans compared to the South 24 Pargana part of the Sundarbans. Further, when we obtained the correlation between the percentage of the area converted to aquaculture and the average yield rate of *aman* paddy, the principal agricultural crop for the chosen blocks (Chopra et al., 2009), it came to -0.36 showing that more than one-third variation in land conversion is negatively associated with changes in return from land.

12 In the weaker link version of the problem, the production function of the public good is given by $Q = \alpha \left[\sum_j^v \frac{q_j^v}{n} \right]^{\frac{1}{v}}$ where *QQ* is the total public good and q_j is the contribution of the j[th] individual. Utility maximization subject to the budget constraint solves for q as a function of income and unit cost of provision. Thus, individual contribution depends on the preference parameter ν, income of the individual and the cost of provision and is likely to differ for heterogeneous agents.

13 Ghosh and Karaivanov (2007) have shown that if all agents are homogenous, such reduction in public good provision in the presence of an increase in alternative income can actually reduce welfare.

nvestment. This Nash equilibrium corresponds to the phenomenon of co-ordination failure (Baland and Platteau, 1996).

Individual commitment towards public good such as embankments can also exist if there is a collective arrangement for embankment conservation. In such cases, individual contribution would be guided by commonly decided norms with possible exceptions in instances where there would be incentives to defect. In case of Indian Sundarbans, especially that in North 24 Parganas, there are traces of such coordinated arrangements where aquaculture farm owners with plots in canal based aquaculture collaborate in terms of collective payments for maintenance activities[14]. In addition, the landholders chose a few members from among them to constitute a committee that was empowered to adjudicate in disputes over land demarcation in the fishery fields, to estimate the annual maintenance and repair cost of the embankments, and to determine the mode of apportionment of the cost share. Nevertheless, cases where the choice of conservation was determined at the village level was more the exception than the rule; in most cases, the fisheries based on feeder canal networks were devoid of collective organizations. In such instances, the contribution towards embankment maintenance was the result of individual optimization. This was also the case with households that directly draw water from the river through single outlets into their own land.

In order to identify the factors that influence household contribution towards embankment maintenance, we therefore formulate in the next section a general model of the household choice of land use and their contribution towards embankment maintenance.

3. The Theoretical Model

A rational individual will commit resources for embankment conservation only if the commitment is not larger than the expected avoided loss if the embankment is breached. The expected avoided loss is in turn influenced by the nature of land use, i.e., the returns from the land that the embankment protects from tidal incursion. Hence, the household has to decide upon the most profitable use for the land in their possession and the effort that must be exerted towards embankment conservation in order to avoid loss from the tidal inundation of land. Let us consider a rural farm household that is endowed with an initial stock of land $\overline{L}$ that could be kept in agriculture or can be converted to aquaculture.[15]

$$\overline{L} = L_A + L_F \qquad (1)$$

where, L_A: total landholding under agriculture and L_F total landholding under aquaculture.

The Agricultural (A) and Aquaculture output (F) exhibit a production function that we characterise as having constant returns to scale,

$$A = A(L_A) \qquad (2)$$

$$F = F(L_F) \qquad (3)$$

However, the returns from the plots are uncertain since the river embankments that bound them often breach under tidal surges, causing saline water to either spoil the agricultural crop or sweep away fish carps resulting in the loss of outputs. Although the extent of loss depends on spatial factors such as proximity of the plot to the embankments, it would also depend on whether the embankments are well maintained since that would minimize the extent of the breach. The nature of the breach in turn depends on individual conservation efforts and public maintenance in the past.

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[14] Initially villagers leased out their land for aquaculture and the land lessees were outsiders. As a result events of tidal inundation were almost immediately followed by non-payment of lease rentals and in extreme case abandonment of aquaculture farms (Bhattacharyya, 2009). Thereafter village community decided to carry out aquaculture on their own.

[15] Conversion of cropland into modern aquaculture ponds involves a degree of irreversibility as the soil becomes loaded with acid sulphates and hinders further production of crops. This cost of land conversion is intertemporal in nature and the land allocation decision between alternative uses have been modeled from the perspective of a social planner in a dynamic set up elsewhere (see Bhat and Bhatta, 2004). However, this study attempts to model the private land allocation decisions of farm owners in a static partial equilibrium framework.

Suppose, L_{AE} and L_{FE} and denote the total agricultural and aquaculture land that adjoin the embankments respectively and k_C and G are the current private conservation efforts and past public maintenance efforts respectively. The extent of public maintenance in the past is likely to determine the resilience of the embankment in the face of a tidal surge. This in turn affects the intensity of the loss suffered by the household with a given land holding. While perceptibly the loss increases relative to the proximity of the land to the embankments, it decreases relative to the private and public conservation efforts. We also assume that conservation through private contribution alone in the absence of public investment would be inefficient and lead to irreparable loss.[16]

Thus, the loss function for agricultural and aquaculture activities from an embankment breach can be specified as[17]

$$S_A = S_A\,(L_{AE}, k_C, G) \tag{4}$$

$$S_F = S_F\,(L_{FE}, k_C, G) \tag{5}$$

$\frac{\partial Si}{\partial L_{iE}} > 0,\ \frac{\partial Si}{\partial kc} < 0,\ \frac{\partial Si}{\partial G} < 0$, where "$i$" = A, F

The cost incurred by the households for embankment maintenance can be represented as

$$C_E = C(k_C),\ C' > 0 \tag{6}$$

Further, note that the land facing embankments for each type of activity can be specified as a constant fraction of the total land devoted to each use such that:

$$L_{AE} = \alpha L_A \tag{7}$$

$$L_{FE} = \beta L_F \tag{8}$$

where $0 \leq \alpha,\beta \leq 1$

If the probability of embankment breach is p and the level of public assistance is G, then the expected profits (or loss) function of farm households is given by equation 9 below. Since it is rational for him to maximize his expected profit, we have[18],

$$\text{Max}E\,(\pi) = p[A(L_A) + rF(L_F) - S_A\,(L_{AE}, k_c, G) - S_F\,(L_{FE}, k_c, G) - C(k_c)] + (1-p)\,[A(L_A) + rF(L_F) - C(k_c)] \tag{9}$$

subject to the constraints (1), (7), (8) and $k_c >= 0$. Here r stands for the price of aquaculture output while the prices of the agriculture outputs are normalized to unity. Given the non-negativity constraint and assuming that (1), (6) and (7) are binding, the farm household chooses L_F and k_c to maximize the expected profit. The Kuhn-Tucker necessary conditions yield:

$$\pi_{iLF} := L_F\,[p(\alpha S'_{AL}(.) - \beta S'_{FL}(.)) - A(.) + rF'(.)] = 0 \tag{10}$$

Thus, $L_F > 0$ only if $rF'(.) - p\beta S'_{FL} = A'(.) - aS'_{AL}$, i.e., the expected net benefit from the aquaculture land is at least as large as that of agricultural land.

Further, $\pi_{kc} : k_c\,[p(-S'_{Ak}(.) - S'_{fk}(.)) + C'(.)] = 0$ (11)

Thus, positive conservation efforts would be observed if the avoided expected loss is no greater than the marginal cost of conservation, i.e., $k^*_c > 0$ only if $p\,(S'_{AK}(.) + S'_{FK}(.)) = C'(.)$. Observe that given the land use and the potential loss by (4) and (5), optimal conservation efforts might be zero if $P > \frac{C'(.)}{S'_{AK}(.) + S'_{FK}(.)}$. Thus, if the probability of embankment damage is greater than the conservation cost per unit loss of output at the margin, the agent may choose not to contribute to embankment maintenance.

[16] Thus, it amounts to assuming $S_i = S_{iE}\,(L_{iE}, k_c, 0) \rightarrow \overline{R}_i$, i = A, F where $\overline{R}_i$ the maximum return from ith land use . For instance one could conceive (4) and (5) as $S_i = L_{iE} / G\,(k_c + 1)$, i = A, F that satisfies the above condition.

[17] Another way of accounting the loss from inundation would be to incorporate the distance of the plots from the river embankments. However, we choose to model the land use decision and the associated maintenance effort of the households given the location of their plots and here distance of the plots is regarded as a parameter rather than a choice variable. The distance parameter, incorporated in this model, would thus represent the probability of damage p keeping the basic results unchanged.

[18] The model is formulated as a simple Cost Benefit Analysis (CBA) type decision process. However, since most decision agents are smallholder subsistence farmers with few alternative livelihood options there could be a 'safety first' or 'survival algorithm' dimension related to ensuring some minimum food production to meet family needs, regardless of a simple CBA rule. An alternative way of modeling this is to incorporate a form of inequality constraint where food production cannot go below some level with some probability.

From (9) we can solve for the optimum conservation efforts as

$$k^*_c = k_c\,(L_A, L_F, p, G) \tag{12}$$

4. Econometric Specification

Pursuant to expressions (9) and (10), it should be observed that estimation of private conservation expenditure on embankments in (11) requires data on the expected loss from tidal inundation. This in turn would depend on the probability of damage (p) as well as the return from the affected plots. The probability of damage can be expressed as a function of a) Plot Location: closer the plot is to the river, higher the risk from breach events; we use the total area of plots directly facing the embankments that are owned or leased as a measure of this risk; b) State of the Embankment: this is measured by the amount of past maintenance activities by the state agencies as well as the past damage events .

The former can be incorporated once we classify the alternative land uses viz., agriculture and aquaculture according to their distance from the embankment. Even within aquaculture, land use type determines the susceptibility of the embankment to breach events. For instance, owing to frequent withdrawal and release of tidal water, the pressure on the multiple source outlets is higher than on single-source outlets with a high probability of the outlets collapsing under high tide.[19] In the case of agricultural land, we can capture the variation in expected damage by replacing L_A as (L_{AE} + L_{AA}), which is the sum of land that adjoins the embankment (L_{AE}) and those at a distance (L_{AA}) . However, using the same decomposition for the aquaculture plots can mask the impact of multiple-plot fisheries on maintenance because, in such cases, while head-enders could reside in plots facing embankments, tail-enders may reside in plots at a distance from the embankment. At the same time, households with plots near embankments may also have single-source aquaculture farms. In order to circumvent the aggregative impact of including aquaculture plots adjoining the embankments, we define a dummy (D_S) for plots with canal-based aquaculture while including its interaction term with the aquaculture plots near embankments. The latter serves to distinguish the impact of canal-based and single-source-based plots on maintenance expenses in the case of plots near embankments. It should be noted, however, that all aquaculture farms in distant plots (F_A), are located within feeder-canal networks.

To account for the state of embankment we use both the frequency of embankment maintenance activities by public institutions (G) like DIW and the *Panchayats* in the last three years prior to Aila as well as the number of events of embankment breach during the same period (E). However, one needs to remain aware of possible endogeneity between the past level of maintenance and the current damage, i.e., the current state of embankment may well depend on past maintenance by public agencies and private plot owners. However, it can be argued that as past damages are observed, households contribution towards embankment maintenance is a 'current' decision based on 'past damages'. We include a square term for public expenditure (G^2) to account for any non-linearities (see equations 4 & 5) and to investigate whether there has been any crowding out of private expenditures.

The return from plots depends on the total operating land (total land owned by the household plus the net leased land). The classification of land into fishery and agricultural plots automatically controls for the differential returns of these two different land uses. We also control for yield difference by differentiating households on the basis of their major income source, which is aquaculture, relative to non-fishery sources like agriculture and other non-farm employment. Thus, we include a dummy for the major source of occupation (I), which also serves as a measure of the household's interest in conserving embankments. In order to account for household-specific effects, caste dummies (D_C) have been included in the model.[20]

[19] To date, aquaculture activities in the Sundarbans are traditional in nature so that the system depends on the tidal inflow of water carrying carps of different species of fish. After impounding the water, the general practice is to perform stocking for tiger prawn. But in general the tidal water is allowed to flow in through the outlets twice a month during the spring tides as then the tidal flow has the maximum potential of carrying in seeds for harvesting. On average, for 24 spring tides per annum, the process of water withdrawal and release in the tidal river continues more than 100 times through the embankment outlets (personal communication with aquaculture owners). Moreover, compared to single source inlets, those that supply to multiple plots are of bigger dimension and, hence, the probability of collapse in times of tidal surge is also likely to be higher in the case of the latter.

[20] Caste dummies have been incorporated as there were significant variations in land holdings across caste groups. Due to the preponderance of Muslim households in the sample, we have considered them as a separate social category just as we treat disadvantaged groups like Scheduled Caste, Scheduled Tribes and Other Backward Classes as a separate social category. We have merged the ST and OBC categories since they do not have significant variation in land and asset holdings in the study area while taking the Hindu general class as the reference category.

To control for unobserved village fixed effects, we introduce a village-level dummy (D_{CV}) that distinguishes between villages on the basis of dominant mode of land use: agriculture and aquaculture. However, as discussed earlier, where there are collaborative arrangements in aquaculture, it is possible that in addition to public maintenance there is community involvement in embankment conservation. Hence, we define three categories for the village dummy: agricultural village with no aquaculture, aquaculture villages with collaborative arrangements for embankment maintenance and aquaculture villages without such collective action. In addition, we also include block dummies (D_B) to capture the inter-regional variations.

The econometric specification for estimating (11) is thus given as

$$k_c = \beta_0 + \beta_1 L_{FE} + \beta_2 L_{AE} + \beta_3 D_S + \beta_4 D_S L_{FE} + \beta_5 L_{FA} + \beta_6 L_{AA} + \beta_7 E + \beta_8 G + \beta_9 G^2 + \beta_{10} I + \beta_{11} D_C + \beta_{12} D_{CV} + \beta_{13} D_B \qquad (13)$$

The variables used in the empirical estimation are described in Table 9.

5. Study Area and Sampling Strategy

The impact of land use on embankment maintenance is best captured in areas where such land transformations have been in vogue. To this end, we chose two blocks in the Sundarbans: Sandeshkhali II in North 24 Parganas and Basanti from South 24 Parganas. We selected 11 villages from the two blocks: 7 from Sandeshkhali II and 4 from Basanti.[21] The reason for selecting these blocks is that they fall under the high salinity zones (10-20 ppt[22]) and are spatially close (below 22 degrees 20 minutes North) (Saha et al., 1986) and thus are expected to account explicitly for the district-specific characteristics of the - sample units, i.e., the households. As mentioned earlier, aquaculture activities have a greater spread in North 24 Parganas as compared to South 24 Parganas. Four of the seven villages chosen in Sandeshkhali-II (North 24 Parganas block) show extensive aquaculture activities while two others have moderate aquaculture practices along with agriculture; only one village in the selection was exclusively engaged in agriculture. Of the four villages chosen from Basanti block (South 24 Parganas), two had a dominance of aquaculture activities while the other two were engaged exclusively in agriculture.

In our study, we surveyed 534 households from the chosen villages in the two blocks. Of these, 400 households were from the seven villages in Sandeshkhali II while 134 households were from the 4 villages in Basanti. The households were randomly selected from the village household listing.

5.1 Data Description

We conducted the household survey during the period between November and February of 2009-2010. We designed the questionnaire to collect data on the land holdings of households and land use both in terms of the number of plots owned as well as the maintenance expenditure on embankments that the respective households had incurred in the year just prior to the survey.[23] We measured the private contribution towards embankment maintenance as the sum of the household's own labor contributions or his/her monetary contributions towards hired labor. Since the labor market in the villages is active, family labor time for maintenance can be computed in monetary terms by imputing the daily wage for hired labor locally. The MGNREGA scheme, for example, paid INR 100 per day for 8 hours of casual unskilled labor. On occasion, there would be costs incurred for material too in the form of bamboo shacks and bricks for paving the slope and base of the embankments. Thus, household private expenditure can be expressed as a sum of expenditures on labor (one's own and hired) and the expenses on raw materials. We exclude lobbying efforts such as meetings with the *panchayat* or attempts at persuading public agencies such as the Irrigation Department to undertake repairs as these practices are uncommon except during extreme events.

The sample consists of two major occupational classes in terms of the land use practices of households: households with agriculture as the major source of income and households whose principal income comes from

[21] Among the 8 *gram panchyats* in Sandeshkhali II block, the study villages were purposively selected from 4 *gram panchayats*. The 3 villages in Basanti were chosen from the 13 *gram panchayats* in the block.

[22] Ppt stands for particles per thousand.

[23] It is to be noted that the area under study was ravaged by Cyclone Aila a few months before the survey. Hence, the maintenance expenditure for this period would have been quite different from what a household incurs during a normal year.

aquaculture. Of the sampled households, 61 percent owned aquaculture land with or without agricultural land. Among the aquaculture households, while 65 percent had canal-based aquaculture, 6 percent had plots drawing water from a single source in addition to plots connected to the feeder canal network. Among the aquaculture households, 29 percent were under the collective maintenance system for embankments. The maintenance expenditures in case of these households were decided at the community level. Here, aquaculture committees realize the payments either in the form of fixed fees or amount that is proportional to the landholding in the canal aquaculture. However, such collective endeavors are not a widespread practice[24] and we exclude these households from the estimation sample to isolate individual contribution motives from community level maintenance efforts[25]. Thus, we analyze private maintenance expenditure in a truncated sample of 438 households.

5.2 Land Use, Private Contribution and Public Maintenance: Survey Results

The distance of the plots from the embankments in relation to their use is reported in Table 2. In villages with extensive aquaculture activities, the mean distance of the agricultural plots from the embankments is higher than that of the aquaculture plots. This describes to some extent the dynamics of the conversion of paddy fields near embankments to aquaculture plots. On the other hand, the distance from the embankment of aquaculture plots drawing water from multiple sources is significantly higher than those drawing water from a single source, demonstrating the fact that the average distance from the embankments in the case of multiple-source distant plots is likely to be higher because they are connected by feeder channels. The sampled households can be catergorized in accordance with their land use patterns : households with only agricultural land (36 percent), those with only aquaculture (40 percent) and finally households using land for agriculture and aquaculture (24 percent). Table 3 reports the land holding patterns as well as extent of household expenditure on embankment maintenance across these groups of households. The average maintenance expenditure is least for households with only agricultural plots compared to households that practices aquaculture. When we compare between households that have both aquaculture and agriculture and households with only aquaculture the former appears to make higher average contribution for embankments. This may be related to the observed greater average aquacultural landholding adjoining the embankments for such households. Higher endowment of risky plots may initiate greater conservation efforts.

The descriptive statistics suggests that aquaculture households spend more on average than non-aquaculture households on embankment maintenance, with only 7 percent of households which own agricultural plots contributing towards maintenance activities. However, the impact of different aquaculture landholdings, viz., single source versus multiple source outlets, on expenditure is yet to be seen. One of the risks facing aquaculture plots drawing water from multiple source outlets is that, in the absence of community surveillance of embankment maintenance, non-compliance from smaller plot holders and those at the tail could result in under provision of the public good. Of course given the non-convexities in the collective good, it is always possible that big landholders would undertake the investment on their own irrespective of others' contribution in order to avoid loss, which in the literature is called the 'Olson Effect'. Similarly, while it is perfectly possible that small landholders relying on their subsistence land would contribute even without big landholders to pick up the slack, it would depend on their belief regarding the effectiveness of their contribution in arresting the damage (Yoder, 1986; Baland and Platteau, 1996). In case of multiple source aquaculture,as mentioned earlier, the inlets are of larger dimension and is likely to require higher maintenance expenditure. Given the returns from land, the small landholders may find it relatively more expensive to manage the embankments privately in an uncoordinated setting. Thus, the observed variation in the contribution level of households across villages can be explained in greater details if we control for the different interest groups in our sample, namely, aquaculture and non-aquaculture households and for aquaculture households by the source of brackish water.

We report the summary statistics of the explanatory variables of our econometric model in Table 4. The average private expenditure on embankment maintenance for aquaculture households is nearly six fold more than that

[24] In the study area we find ample evidences that barring very few exceptions these collective arrangements almost never sustained in the long run. In their survey of shrimp farmers in Indian Sundarbans, Philcox et. al (2009) noted that the idea of collective shrimp farming doesn't have strong acceptance among stakeholder groups.

[25] However, we retain households within the same village that resorts to individual embankment maintenance. As is evident we also control for the presence of community institutions on private expenditure through village dummies.

for non-aquaculture households. Expenditure on hired labor constitutes the major expenditure share for both the groups though for non-aquaculture households the share of family labor in total conservation expenditure (at 21 percent) is higher than that for aquaculture households (at 6 percent). This substitution of family labor for hired labor, together with the lower land-holdings on average, indicates that non-aquaculture households are less wealthy than other occupation groups and that lower contributions towards embankment maintenance could be a reflection of this wealth effect. Furthermore, since public maintenance has been relatively high for this class of households, this too might crowd out private efforts. In order to understand the causal relation in greater detail, it is necessary to undertake an econometric estimation of voluntary contributions towards embankment maintenance.

6. Determinants of Voluntary Contribution

6.1 Results

In this section, we present the OLS estimates of (12). However, we also estimate a Tobit model since the expenditure on embankment maintenance contains many zero values. In addition, we present Probit estimates when the dependent variable is a binary outcome (1 if private contribution is positive and zero otherwise). The Probit estimates serve to check for specification errors in the Tobit model.[26] Table 5 and 6 report the regression results.

The Probit estimates show that greater the aquaculture plot size that adjoins embankments, greater would be the private expenditure on maintenance. As the marginal effects reported in Table 5 show, for every *bigha* increase in aquaculture plots near embankments the likelihood of private contribution increases by 4 percent. On the other hand, given plot size and location, the number of past breach events also leads to a significantly higher private contribution to embankment maintenance. Interestingly, the marginal effect on the interaction term for canal-based aquaculture farms is negative and significant. Thus, for every unit increase in plots near embankments which belong to multiple-user aquaculture farms, the probit estimates shows that the likelihood of contribution falls by 4 percentage points. On the other hand, an increase in agricultural land in inundation-prone areas does not have a significant impact on the contribution level to maintenance.

The OLS co-efficients have similar signs when we control for village-specific effects. The Tobit model and its two functional variants, linear (Model I) and log-linear (Model II) models, also show similar effects. The Tobit models have been estimated for the full sample for all the households owning both aquaculture plots and agricultural plots. The linear model predicts the change in the dependent variable for a unit change in the explanatory variable while the log-linear model (Model II) predicts the percentage change in the dependent variable for a unit change in the independent variable (Table 5).

The marginal effects of the Tobit regression results suggest that private contribution increases for aquaculture plots that adjoin the embankments, the frequency of past embankment breaches, and the amount of land-holdings other than the “risky” plots near embankments. Thus for a one *bigha* increase in aquaculture land near river embankments, private conservation expenditure increases by INR 121 (or 2.3 percent). The conservation expenditure of aquaculture land owners other than those facing embankments increases by INR 43.07 (or 1.6 percent) per *bigha*. But the contributions of households owning agricultural land located at a distance from the embankments are significant and negative (see Model I). This implies that private contributions decline by INR 261 for a unit increase in agricultural landholdings located at a distance from the embankments.

These findings are reinforced by the positive marginal effects of the occupation dummy implying that households whose major occupation is aquaculture spend INR 1300 compared to non-aquaculture households on embankment maintenance. Households owning agricultural plots adjoining the embankments make a significant contribution towards embankment maintenance in Model I but it becomes insignificant and even negative in Model II. An additional past event of embankment damage increase private contribution by INR 451.75 (or 29 percent).

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[26] See Woolridge (2009), pp 446-448.

A consideration of the impact of government intervention on private efforts shows that, taken together with the extent of past damage and plot characteristics, the frequency of public maintenance seems to have an inverted U (concave) relation with private contribution efforts. Thus the marginal effect of the frequency of intervention by the irrigation department in the last three years is negative and significant while that on its square term is statistically significant and positive. For the pooled sample, the turning point is at around 1.21, which implies that if public intervention takes place only once in the three year period, there would be less private involvement whereas for higher levels of public intervention, there may be a crowding in of individual contributions. We estimate the turning point by using $\frac{\text{coefficient on public maintenance}}{\text{2 x coefficient on the square term on public maintenance}}$ (see Woolridge, 2009, p. 161).

One consistent finding in all the models is that the area of aquaculture plots drawing water from multiple-source outlets near embankments has a significant negative impact on private contribution. For every *bigha* of land using multiple-source outlets near embankments, private conservation expenditure falls by almost 1.5 percentage points (or INR 73). The exclusion of agricultural households brings the decline in expenditure to INR 96 (or 1.3 percent) (see Table 6). This suggests that conservation activities in these canal-fed aquaculture farms are lower in a decentralized set up. In the case of households having both aquaculture and agricultural land, the area of agricultural plots near the embankments shows ambiguous results with the marginal effect positive and showing a significant relation in Model 1 but statistically insignificant in Model II.

6.2 Discussion

Three major results stand out from the estimated models: firstly, faced with a given level of risk, households owning aquaculture plots are more likely to contribute to embankment maintenance compared to households with only agricultural plots. This contribution, as expected, is positively impacted by the size of both agriculture and aquaculture plots near embankments. However, in case of agricultural plots that adjoin the embankments this relationship is not consistent. In terms of our theoretical model this phenomenon could be explained as follows: given the per unit maintenance cost $C'(k_c)$ and damage probability (p), maintenance effort (k_c) would be lower in land with relatively lower returns and thus with lower expected avoided loss. In fact it may also happen that $C'(k_c)$ is higher than the expected avoided loss (S'_i) at all levels of k_c such that equilibrium level of maintenance effort is zero (Figure 3).

Our survey reveals that the mean per-*bigha* net revenue from paddy cultivation is INR 2,387 (excluding the benefit of self-consumption), which is almost eight times less than the average returns from aquaculture practices which stands at INR 17, 285.[27] At the same time, for the sample as a whole the average embankment maintenance cost stands at INR 2,753. Considering the group of households whose major occupation is agriculture, we further observe that average agricultural land size adjoining the embankments is 1.78 *bigha* and here the average maintenance expenditure would constitute almost 64 percent of the yield valued at the above mentioned rate. But the median land size is little more than half-*bigha* and in this case the returns would be rather insignificant relative to the cost of maintenance. For households with aquaculture as the major source of income, the median aquaculture land facing the embankment is 1.5 *bigha* implying that the returns are in far excess of the average maintenance expenditure.

Next, we see that the size of the aquaculture plots significantly influences private conservation expenditures even when they are away from the embankment but a similar effect is not seen in the case of agricultural plots located at a distance from the embankments. In aquaculture-dominant areas, the distant agricultural plots are inevitably bordered by aquaculture plots so that the owners of agricultural plots appear to be free-riding on the efforts of aquaculture-plot owners located closer to the embankment.

But the question is why aquaculture plots do not similarly free ride. Our analysis does not lead to an unambiguous answer but number of possibilities can be scrutinized. Only 6 percent of the sampled households own plots at both the head water as well as in the interior. This mutually exclusive land holding pattern could create perverse incentive

[27] This finding tallies with responses yielded in focus group discussions. The average yield from a per-*bigha* paddy field is about 7 sacks (where 1 sack = 60 kg). Since one sack is sold at INR 500 per bag, the per-*bigha* revenue is INR 3,500. With operational costs amounting to INR 1,500-2,000 on average, the surplus is INR 1,500-2,000. In contrast, a 15 *bigha* land of aquaculture leads to yearly sales of INR 2,00,000. With operational costs amounting to INR 50,000, the per-*bigha* profit is INR 10,000. The difference in per-*bigha* profit thus is almost identical to the sample estimates.

for joint regulation.[28] Thus, we can conceive of two independent groups: households with aquaculture plots near the river and those with plots in the interior. The average size of plots near embankments (at 11.21 *bigha*) is significantly larger than the size of plots at a distance (at 4.64 *bigha*). It could be inferred then that wealthier households have plots near the embankment while the less wealthy have the interior plots.[29] Thus, it is plausible that the owners of interior plots participate in maintenance as they might depend for their livelihood on the success of their enterprise and therefore face a much stronger subsistence constraint. Although it is logical for head-water households to participate in maintenance, those at the tails are probably more risk-averse and hence wish to minimise the risk of inundation. Households with more land near the head waters are also better connected socially, able to claim kinship with the *panchayat* leaders and well-connected in terms of memberships in other local networks such as religious groups and neighborhood clubs (see Table 7). Thus, it is also possible that these households can impose sanctions on the interior land owners. However, further analysis regarding the strategic interdependence (economic as well as social) between head-enders and tail-enders are required to validate these claims.

We also found evidence of 'free-riding' with regard to canal-based aquaculture for all the model specifications. Free riding can be described as the inclination of individual agents to gain from collective activities without making a fair contribution of their own (Schneider and Pommerehne, 1981). As canal-based systems involve multiple users, its maintenance requires institutional surveillance. Without such institutions, it is to be expected that at least some households will shirk their responsibility toward maintenance.[30]

Moreover, when we analyze aquaculture and agricultural plots together, private and public contributions seem to be substitutes. The 'crowding in' of private efforts might occur beyond the threshold of 1.21, i.e., at least one public maintenance per year. For the sample as a whole, the mean public intervention lies in the range of .25 to .61. This suggests that individual conservation efforts are dependent on the initial state of the resource; unless public maintenance crosses a critical threshold, private contributions may be less likely (Pagiola, 1993).

However, this leads to another question regarding the perceived behaviour of aquaculture plot owners versus agricultural plot owners: if conservation activities in the case of distant aquaculture plot owners might be influenced by a subsistence constraint, why does not the same apply to agricultural households who are likely to be even poorer? We also need to investigate why these households do not convert their land to aquaculture ponds, choosing to keep their lands instead as agricultural lands.

These questions become all the more pertinent when we consider the fact that aquaculture is relatively more profitable than agriculture. It is possible to attribute the choice of land use to risk-aversion or the ability to sustain shocks. Not only are households whose aquaculture plots are located near embankments more prone to breach event exposure but, from 1994 onwards, they have also been exposed to another production shock in the form of the 'white spot disease' which has led to high mortality rates in fish species.[31]

The ability to cope with such shocks depends upon the wealth of the household. As Table 8 shows, aquaculture households, have significantly more land assets. Moreover, since aquaculture households possess higher amounts of less risky lands, in the form of land located at a distance from embankments, they may have a buffer to fall back upon in case of normal breach events. While, the availability of labor (proxied by the proportion of adult members to total members of the household) is significantly higher for non-aquaculture households, the ratio of total operational land holding to the number of adult members is significantly higher for aquaculture households.[32]

[28] As Wade (1987) notes that in case of irrigation canal maintenance if households have plots both near the outlet as well as at the tail end of another outlet it could facilitate consensus on the need for rules and joint regulation.

[29] However, this argument may not hold if the interior plots are more expensive than plots near embankments. Our plot-level data however suggests the opposite: the average price of a plot near the embankments is INR 72,440 per *bigha* in comparison with INR 62,387.10 per *bigha* for interior plots. The difference is significant at less than 1 percent.

[30] In fact, the households that were under community organizations (95 in number) detailed the prevalence of explicit sanctions for failure to contribute to embankment maintenance. In most cases, this took the form of cutting the supply of tidal water off from the canals until the realization of the fee.

[31] 53 percent of the sampled households reportedly suffered from one such incidence of fish disease over a recall period of three years with 2009 as the reference year.

[32] The average proportion of total land to the number of adult members in the case of aquaculture households is 4.22 whereas it is 2.55 for non-aquaculture households. The mean difference is significant at less than 5 percent level. Thus, there seems to be a positive association between the land-labor ration and contributions to embankment maintenance. This is in accordance with the findings of Gaspart et al. (1998), where the ratio of draught animals adjusted by the family labor force has a significant positive relation with private contributions to check dam maintenance. We also tested for the mean difference of the livestock adjusted by the adult member of the household and obtained similar results. Thus, for households with aquaculture as the major occupation, the mean value of adjusted livestock is higher than for non-aquaculture households with the difference significant at less than 5 percent.

Thus, for households with absolute and relative abundance of land, choosing alternative forms of land use in the form of brackish water aquaculture would be the most efficient option if the status–quo land use is less productive. The mean proportion of members working in off-farm employment is significantly higher among non-aquaculture households in comparison with aquaculture households.[33] Thus, for primarily agricultural households with less land and livestock endowments but relatively more labor endowments, non-farm employment seems to be the preferred option.[34] Our results find support in Philcox et. al. (2009) who find significantly higher wealth endowments for shrimp farmers relative to agricultural households.

The present study was conducted in the northern areas of the Sundarbans where land conversion from paddy to aquaculture is a widespread phenomenon. Thus, it begs the question whether the findings are applicable, for instance, to the sea-facing island areas in the Western Sundarbans. While the issue needs empirical verification, we could offer certain insights drawing on our theoretical model. Assuming that the marginal effects of private conservation efforts on private land related losses are the same across the Sundarbans, the outcome will depend on the probability of damage. Using (10), it could be argued that if we characterize the western Sundarbans as prone to a higher probability of damage, the bracketed expression would be negative and, hence, will indicate a dearth of private efforts in embankment protection. Here, then, a relatively larger public investment may be required in order to maintain the stability of the embankments and, thus, minimize, if not prevent, the damage loss from breach events.

7. Conclusions

Our study finds complementarities between returns from land and private conservation expenditures on river embankments in the case of the Indian Sundarbans. Households whose principal occupation is aquaculture commit more resources to embankment conservation than those in non-aquaculture occupations. We also found conservation efforts to increase in all types of aquaculture plots irrespective of the distance from embankments, but such efforts unambiguously decrease for agricultural plots that are located at a distance from the embankments. However, when we factor in the heterogeneity of resource users within aquaculture households (in terms of land-holding), free-riding becomes a possibility in the case of canal-based aquaculture, which involves multiple users drawing water from a single source. In such cases, we find tail-enders with lower land-holdings contribute more towards embankment maintenance while those at the head-water with greater wealth as well as intense social networks free-ride. There is an ambiguity, however, regarding the extent of strategic interdependence between the head-enders and tail-enders and the causal mechanism of free riding. Furthermore, when agricultural and aquaculture households are taken together, there is some evidence that public intervention in embankment maintenance crowds out private efforts.

Our study has implications for public policy with regard to embankment maintenance in the Indian Sundarbans. The state has to make a choice between direct expenditures on embankment maintenance or investing in productivity enhancement. While an increase in productivity would encourage individual conservation efforts, direct subsidization might lead to a crowding out of private contributions in general as well as perpetual inaction on the part of agricultural plot holders in particular. Coastal zone regulations that restrict conversion of land use from agriculture to shrimp cultivation in the coastal and tidal areas would further discourage private conservation efforts.

The relation between land productivity and conservation expenditure is modeled in this paper as a static problem. In reality this is a dynamic problem as land conversion occurs over time and embankment condition also changes over time depending on the extent of public maintenance. Further, since Sundarbans is the largest mangrove ecosystem and mangroves are shown to provide crucial storm protection in terms of avoided deaths (Das and Vincent, 2009) the interplay between mangrove and embankments needs to be taken into account. Since land use change can also cause changes in mangrove vegetation this must also be analyzed in a dynamic setup. This remains an important area of future research.

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33 The pair-wise correlation coefficient between proportions of agricultural land owned and proportion of household members engaged in non-farm employment is positive and significant.

34 Of course, we recognize that land and labor markets are fairly active in the study area and that households always have the option of pooling both resources by hiring labor and leasing land. But there exists the possibility that asset-poor households may also be credit-constrained to make the necessary investments. In keeping with this, the mean area of land taken on lease and the expenses for hired labor are significantly higher for the sampled aquaculture households than for households in other occupations.

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Tables

Table 1: Expenditure on Public Embankments (Rs) (1857-58 to 1866-67)

District	No. of Miles of Embankment	Expenditure on Original Works (Rs)	Expenditure on Repairs (Rs)	Total (Rs)	Average Expenditure (Rs/mile)	Average Repair Expenditure (Rs/mile)*
Burdwan and Hooghly (Damoodur Division)	238	130,188	4,44,225	5,74,413	2413.5	1866.492
Midnapore including Tamluk and Hidgelee Divisions	791	7,63,408	10,71,000	18,34,408	2319.1	1353.982
24- Pgs	220	51,017	4,34,685	4,85,702	2207.74	1975.841
Behrampore	80	11,009	65,703	76,714	958.925	821.2875
Rajshahye	05		902	902	180.4	180.4
Maintained by Public Officers at the Expense of the *Zamindars*						
Midnapore	289.05		4,32,603	4,32,603	43,230	1,497
Sarun	139		59,566	59,566	5,956	647.05
Tirchoot			30,375	30,375	3,937	
Behar	1.05		10,937	10,937	1,093	10416.0

Source: Harrison (1875) *own calculation

Note:1 mile=1.61 km

Table 2: Average Distance of the Plots from the River Embankments according to Land Use

Land Use /Village	Distance from the Embankment (in meters)										
	Aatapur	Bermajur	Rampur	Dhamakhali	Dwarirjungal	Jhupkhali	Sitalia	Ramchandra-khali	Masjidbati	Chunakhali	Sachiakhali
Aquaculture Plots	409.84 (302.29)	313.65 (353.15)	393.4 (411.54)	236.12 (356.61)	180.11 (207.20)	287.09 (401.83)	0	141.88 (226.39)	0	0	62.81 (118.07)
Agriculture Plots	411.35 (315.76)	654.33 (1275.08)	854.33 (900.70)	931.81 (537.24)	425.79 (1355.05)	588.93 (297.84)	228.56 (290.02)	585.58 (498.93)	150.73 (133.12)	452.94 (1356.24)	356.17 (349.31)
Aquaculture Plots using Multiple Source Outlets	470.70 (290.60)	388.58 (330.40)	470.26 (406.77)	312.73 (395.88)	196.96 (212.31)	354.84 (474.23)	0	110.11 (161.23)	0	0	130.8 (155.69)
Aquaculture Plots using Single Source Outlets	202.9 (255.71)	96.35 (333.24)	162.5 (331.64)	142.86 (278.72)	168.76 (179.65)	107.5 (189.00)	0	170.31 (273.65)	0	0	6.16 (4.44)

Table 3: Household Characteristics according to land use and land holding pattern in the Sampled Villages

Land Holding Catergory of Households	Aquaculture Area (*Bigha*)			Aquaculture area adjoining Embankments (*bigha*)			Aquaculture Area using Multiple Source (*bigha*)			Agriculture Area (*bigha*)			Agriculture Area adjoining Embankments (*bigha*)			Incidence of Breach (no.s/year)			Government Intervention (no.s/ year)			Private Expenditure (Family Labor Hired Labor +Raw Materials)(Rs/yr)		
	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min	Mean (S.D)	Max	Min
Agricultural Plots	0	0	0	0	0	0	0	0	0	3.74 (3.35)	28	.24	2.01 (3.13)	28	0	.68 (1.06)	6	0	.65 (.72)	3	0	90.72 (446.55)	4700	0
Aquaculture	6.64 (21.43)	180	0	10.61 (25.42)	180	.06	6.27 (22.92)	180	0	0	0	0	0	0	0	.99 (1.17)	5	0	.25 (.59)	3	0	4048.57	60000	0
Agriculture and Aquaculture	18.08 (55.09)	400	0	23.74 (58.57)	400	0	14.65 (51.67)	400	0	3.58 (4.20)	26	.025	1.26 (3.93)	26	0	1.33 (1.47)	6	0	.31 (.63)	3	0	6298.50 (18462.04)	120000	0

Note: Figures in Parentheses Shows Standard Deviation. 1 *bigha*=.1338 hectare

Table 4: Summary Statistics of the Dependent and Independent Variable

Variables	Households with Aquaculture as the Major Source of Income (N=198)			Households with Agriculture and Non-aquaculture Activities as the Major Source of Income (N=241)		
	Mean (S.D.)	Max	Min	Mean (S.D.)	Max	Min
Area of Aquaculture Plots That adjoin Embankments (*bigha*)	10.79 (37.70)	400	0	2.39 (18.68)	26	0
Area of Agricultural Plots That adjoin Embankments (*bigha*)	.51 (2.23)	26	0	1.64 (2.930	28	0
Frequency of Exposure to Embankment Breaches in the Last Three Years	1.15 (1.41)	6	0	.73 (1.11)	6	0
Frequency of Public Intervention in Last Three Years	.27 (.61)	3	0	.61 (.72)	3	0
Area of Aquaculture Plots with Multiple Source Outlets (*bigha*)	11.78 (38.78)	400	0	.62 (3.44)	40	0
Dummy Variable Taking the Value 1 if the Household Belongs to Scheduled Caste 0 Otherwise	.17 (.37)	1	0	.39 (.48)	1	0
Dummy Variable Taking the Value 1 if the Household Belongs to Scheduled Tribes and Other Backward Classes 0 Otherwise	.30 (.46)	1	0	.16 (.36)	1	0
Dummy Variable Taking the Value 1 if the Household Belongs to General Caste and 0 Otherwise	.05 (.23)	1	0	.11 (.31)	1	0
Dummy Variable Taking the Value 1 if the Household Belongs to Muslim Population and 0 Otherwise	.46 (.50)	1	0	.33 (.47)	1	0
Aquaculture Area Operated by Households Other Than Those Facing Embankments (*bigha*)	3.58 (15.41)	162	0	1.40 (11.77)	150	0
Agriculture Area Operated by Households Other Than Those Facing Embankments (*bigha*)	.88 (2.10)	16	0	1.55 (2.11)	12	0
Imputed Wage Bill of Family Labor Employed for Embankment Conservation Activities Last Year (INR/year)	221.25 (635.02)	5,000	0	171.27 (804.65)	6,000	0
Wage Bill of the Hired Labor for Embankment Conservation Last Year(INR/year)	3,372.70 (1,1591.71)	100,000	0	378.21 (2787.56)	30,000	0
Expenditure on Raw Materials Like Brick, Bamboo, etc., for Conservation of Embankments Last Year (INR/year)	1,432.15 (5,032.58)	50,000	0	285.71 (2167.84)	30,000	0
Total Private Expenditure (Sum of Wage Bill for Hired Labor, Family Labor and Expenditure on Raw Materials) (INR/year)	5,284.90 (14,647.00)	120,000	0	859.88 (4325.49)	40,000	0

Table 5: OLS Probit and Tobit Model for the Full Sample

Variables	OLS Regression Dependent Variable: Private Expenditure on Embankment Conservation (Rs/year)	Probit Regression Dependent Variable: (Expenditure=1,0 otherwise)	Tobit Marginal effects	
			Model I	Model II
	Coefficients	Marginal effects	Conditional on being Uncensored	Conditional on being Uncensored
Aquaculture Area Facing Embankments	402.42*** (20)	.04*** (.01)	121.32***	.023***
Aquaculture Area Adjoining Embankment x Dummy for Multiple Source	-215.84*** (24.23)	-.04*** (.01)	-72.24***	-.015**
Dummy for Multiple Source	503.04 (806.11)	.13* (.08)	364.34	-.085
Aquaculture Area Other than Facing Embankment	112.85*** (22.82)	.013** (.007)	43.07***	.016**
Agricultural Area Facing Embankment	397.53*** (116.67)	.002 (.011)	160.53*	-.02
Agriculture Area Other Than Those Facing Embankment	-124.77 (146.65)	-.027* (.015)	-261.57**	-.13**
Embankment Breach	415.18* (250.73)	.05** (.02)	451.75***	.29**
Public Maintenance	-1147.94 (1150.01)	-.22** (.11)	-1596.74*	-.98**
Public Maintenance Square	541.99 (529.17)	.08* (.04)	657.14*	.33*
Occupation Dummy	509.17 (798.92)	.09 (.07)	1300.75***	1.14***
Scheduled Caste Dummy	156.37 (1198.22)	.52*** (.14)	3246.08**	2.60***
Scheduled Tribe and OBC Dummy	-.891 (1226.27)	.32 ** (.18)	1108.40	.87*
Muslim Dummy	1709.21 (1150.73)	.36** (.15)	2863.21**	1.80***
Village Dummy1 (1=aquaculture and Agriculture, 0=otherwise)	193.43 (931.32)	.12 (.08)	1713.16**	1.15**
Village Dummy2 (1= Community aquaculture and Agriculture, 0=otherwise)	1315.01 (1181.52)	.59*** (.10)	4611.53***	3.35***
Block Dummy	-422.56 (809.24)	-.46*** (.08)	-3135.69***	-2.46***
Constant	-1048.82 (1336.84)			
	N=438,F (16,421)= 51.18*** R^2=.64, adj-R^2=.66	N=438, LRChi2 (16)= 217.28*** Pseudo R^2= .42,Log-likelihood= -148.96 Obs P:.271 Pred P:.25 (at mean)	N=438, LRChi2 (16)= 266.01***, Pseudo R^2=.09,326 left censored observations at 0,112 uncensored observations, Log-likelihood=- 1294.27	N=438, LRChi2(16)= 205.64***, Pseudo R^2=.17,319 left censored observations at 0,119 uncensored observations, Log-likelihood=- 477.56

Note:***less than 1 percent level of significance, **less than 5 percent, *less than 10 percent. Figures in Parentheses Show Standard Error

Table 6: OLS estimates, Marginal Effects of Probit and Logit Models for the Households with aquaculture (excluding Households with only agricultural land)

Variables	OLS Regression with Village Dummies Dependent Variable: Private Expenditure on Embankment Conservation (Rs/year)	Probit Regression Dependent Variable: Binary Variable (Expenditure=1,0 otherwise)	Tobit Estimates	
			Model I	Model II
	Coefficients	Coefficients	Conditional on being Uncensored	Conditional on being Uncensored
Aquaculture Area Adjoining Embankments	409.62*** (28.92)	.03** (.04)	147.11***	.017***
Aquaculture Area Adjoining Embankment x Dummy for Multiple Source	-250.94*** (34.08)	-.03* (.04)	-96.27***	-.013
Dummy for Multiple Source	788.84 (1190.01)	-.06 (.13)	-581.88	-.89***
Aquaculture Area Other Than Facing Embankment	111.71*** (31.83)	.009 (.013)	44.89***	.011
Agricultural Area Facing Embankment	1048.89*** (253.10)	.008 (.02)	432.59***	.034
Agriculture Area Other Than Those Facing Embankment	-273.44 (286.87)	.008 (.02)	-96.92	.04
Embankment Breach	670.63 (438.50)	.06* (.08)	574.41**	.28**
Public Maintenance	-2120.46 (2265.50)	-.32* (.44)	-2346.28	-1.06
Public Maintenance Square	731.92 (1004.30)	.08 (.13)	706.99	.19
Occupation Dummy	278.07 (1528.91)	-.13 (.13)	-903.46	-.39
Scheduled Caste Dummy	-947.42 (2899.55)	.90 (4.74)	4026.50	3.16***
Scheduled Tribe and OBC Dummy	111.43 (1281.47)	.96 (3.35)	488.88	.56
Muslim Dummy	2781.41 (2774.71)	.99** (.60)	4597.48*	2.57**
Village Dummy (1=aquaculture and Agriculture,0=Collective aquaculture and agriculture)	989.77 (1433.98)	-.52*** (.10)	3655.69***	-2.51***
Block Dummy	-473.14 (1911.47)	-.52*** (.74)	-3561.21***	-2.56***
Constant	-1272.76 (3289.11)			
	N=232, F (15,216)= 28.62*** R^2=.66, adj-R^2=.64	N=232, LRChi2 (15)= 135.99*** Pseudo R^2=.43, Log-likelihood=-91.35 Obs P:.44 Pred P:.41 (at mean)	N=232, LRChi2 (15)= 182.91***, Pseudo R^2 =.07,136 left censored observations at 0,96 uncensored observations, Log-likelihood=- 1092.08	N=232, LRChi2 (15)= 147.94***, Pseudo R^2 =.17,136 left censored observations at 0,96 uncensored observations, Log-likelihood=- 363.53

Note:***less than 1 percent level of significance, **less than 5 percent, *less than 10 percent. Figures in Parentheses Show Standard Error.

Table 7: Comparison of Social Connectivity of the Sampled Households

	Relation with *Panchayat*		Association with Political Party		Association in Local Networks (Religious Groups, Clubs, etc.)	
	Yes	No	Yes	No	Yes	No
Aquaculture Area Adjoining Embankments (*bigha*)	15.37 (5.72)	4.54 (1.32)	5.64 (2.37)	6.18 (1.60)	7.39 (3.21)	5.25 (1.33)
Aquaculture Area Other Than Those Facing Embankment (*bigha*)	1.03 (.40)	2.67 (.74)	2.32 (1.15)	2.57 (.72)	3.97 (1.46)	1.74 (.65)

Note: Figures in Parentheses Show Standard Deviation. Relationship with *Panchayat* is indicated by a binary variable: 1 if the household has any kinship with members or officials of *Panchayat*, 0 otherwise. Association with political party and social network measured as binary variable (1=if the any household member actively participates in rallies meeting, and other party programs and similar activities in local networks, 0=otherwise) 1 *bigha*=.1338 hectare

Table 8: Asset Endowment of Aquaculture and Non-aquaculture Households

Variables /Controls	Aquaculture as the Major Source of Income (N=198)	Agriculture as the Major Source of Income (N=241)	Mean Difference
Total Operational Land holdings (*bigha*)	15.36 (3.00)	7.03 (1.41)	(+) and significant at less than 1 percent.
Land Other Than Those Facing Embankments (*bigha*)	4.47 (1.14)	2.95 (.76)	(+)Not Significant
Livestock (number of cattle, dairy animals and poultry) Owned Year before Cyclone Aila Expressed in Standard Livestock Unit (SLU) SLU: Bull=buffalo=1, cow=0.7, duck=poultry=0.02, goat=sheep=0.1	35.13 (7.10)	23.69 (1.75)	(+) and significant at less than 5 percent.
Proportion of Household Members in Non-Farm Employment	.15 (.13)	.23 (.16)	(-) and significant at less than 1 percent.
Proportion of Adult Member to Total Member	.58 (.18)	.69 (.21)	(-) and significant at less than 1 percent.

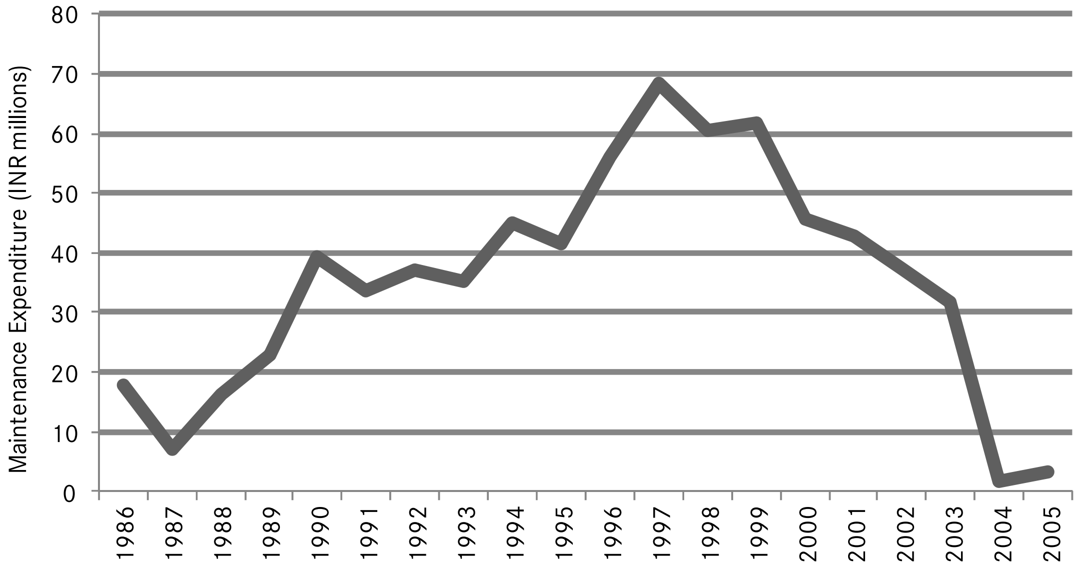
Note: Figures in Parentheses Show Standard Deviation. 1 *bigha* = .1338 hectare

Table 9: Variable Definitions

Variables	Symbols	Definition
Aquaculture Area Adjoining Embankments	L_{FE}	Aquaculture ponds that adjoin the embankment, so that one border of the bond is part of the embankment
Aquaculture area using Multiple Source/ Canal based aquaculture	L_{FA}	Aquaculture ponds that draws tidal water from sources that supplies to multiple plots
Aquaculture Area Other than Embankment	L_{FA}	Aquaculture ponds except those that adjoins the embankment.
Agricultural Area Adjoining Embankment	L_{AE}	Agricultural plots that adjoins the embankment, so that one border of the plot is part of the embankment
Agriculture Area Other Than Those Facing Embankment	L_{AA}	Agricultural plots except those that adjoins the embankment.
Embankment Breach	E	Incidence of breach in embankments that affected households crop/output in the last three years prior to Aila
Public Maintenance	G	Frequency of Government maintenance of embankments in the last three years prior to Aila.

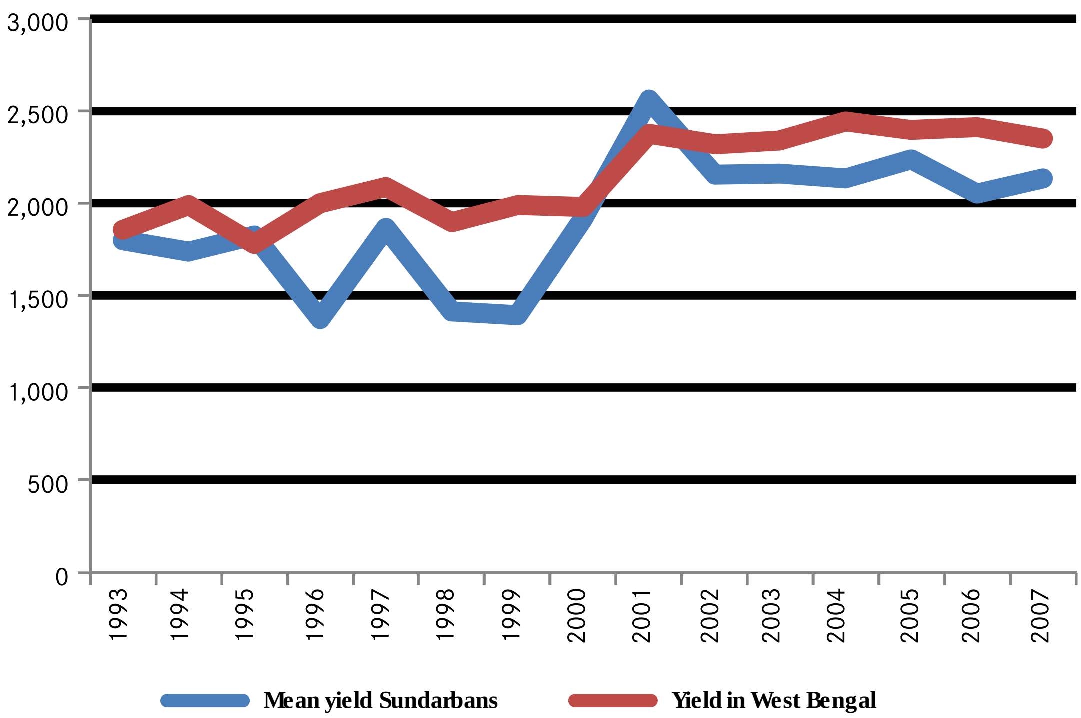
Figures

Figure 1: Trend of Public Expenditure Embankment Maintenance in Indian Sundarbans



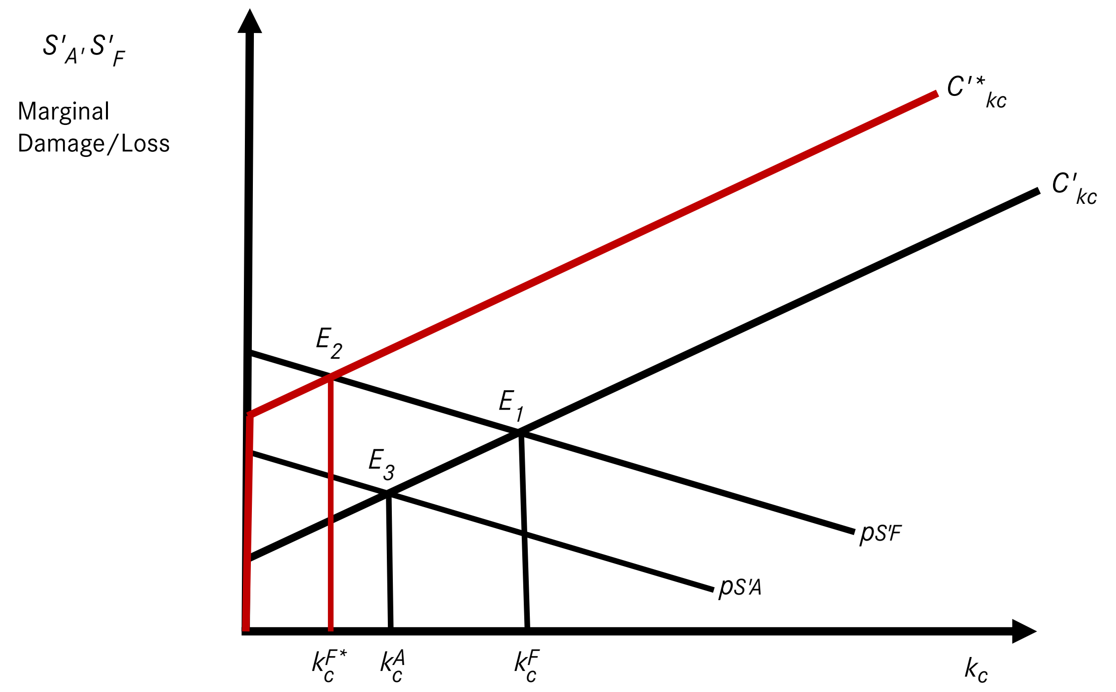
Source: Department of Irrigation and Waterways, Government of West Bengal

Figure 2: Mean Yield Rate of *Aman Paddy* (kg/ha) in the Sundarbans vis-à-vis West Bengal (1993-2007)



Source: District Statistical Handbook, GOWB (Various Issues)

Figure 3: Determination of Maintenance Efforts for Embankment Maintenance



Note: Assumed that $S''_A = S''_F = C''_{kc} = 0$

Map 1: Administrative Map of the Indian Sundarbans

Source: Centre for Science and Environment (2012)

Annexes

Public and Private Efforts for Conservation of River Embankments in Sundarbans

Principal Investigator: Dr. Prasenjit Sarkhel

Department of Economics, University of Kalyani

Name of the Interviewer...

Date of interview..

Block : Basanti		Block : Sandeshkhali-II	
Sampled Villages	Census Code	Sampled Villages	Census Code
Sachiakhali	04042700	Atapur	01761500
Ramchandrakhali	04045000	Dhamakhali	01760500
Masjidbati	04045500	Dwarirjangal	01761000
Chunakhali	04042300	Bermajur	01760700
		Jhupkhali	01760600
		Sitalia	01761400

0. Household Identification

1. Block..

2. Thana...

3. Village...

4. Hamlet..

5. Names of Household Head...

6. Name of the respondent...

7. Relationship with Household Head..

8. Househopld Religion (code)...

9. Household Caste (code)................

Code List	
7	**8**
Hindu...1 Muslim.....2 Christian....3 Others....4	SC......1 ST.....2 OBC...3 GEN....4

1. Household Member Information

1.1	1.2.	1.3.	1.4.	1.5.	1.6.	1.7.	1.8.		1.9	2.0	
HH Member Id.	Name	Sex (Code)	Age	Relationship with *Panchayat* (Code)	Education (Highest level of Education) (Code)	General Education (Code)	Occupation		Remittances/ Transfers None....0 Money sent....1 Money received....2	Participation of the HH members in groups and Networks	
							Main Source of Income	Others		1. Groups where members participate actively (Code) 2. Duration of memebership in each group	
										1	2

1.3	1.5	1.6	1.7	1.8	2.0
Male....1 Female...2	*Panchayat Pradhan*....1 *Panchayat* Samiti....2 *Panchayat* memeber....3 Husban/Wif...4 Son/Daughter5 Brother /Sister...6 Son inlaw/Daughter in Law...7 Other Relatives....11 Close Neighbour....12 Same political party...13 Others....14	Illiterate..1 Less than Primary....2 Less than Class 103 School Leaving ....4 Less than Higher Secondary...5 Higher Secondary 6 Less than Graduation....7 Graduate...8 Post graduate...9 Adult Education...10 Vocational training...11	Cannot read or Write1 Can sign....2 Can only read....3 Can read or Write....4	Own fishery...1, Own Agricultural land....2, Agricultural labour....3, Fishery labour....4, Business...5 Daily labour....8 Others...9	Club....1 Puja Committee2 Masjid Committee3 Political party....4 NG....5 Farmers Cooperative....6 Fishery Committeee....7 Business Association....8 Bazaar Committeee...9 School Committee...10 SHG...11 Others...12

Enumerators Fill up

	HH Member	No		
1	<12 years			
2	Adult Male			
3	Adult Female			
4	Old Male/Female			
5	Total earning member			
6	Total Household member			

2. Employment Information of Household members for the past one year (For members above 12 years)

2.1	2.2								2.3															
HH Id.	Own farm Work/Own Business Past 1 year Before Aila....1 After Aila to the Time of Survey...2								Off farm work/ Contractual work Past 1 year Before Aila 1 After Aila to the Time of Survey 2															
	2.2.1		2.2.2		2.2.3		2.2.4		2.3.1		2.3.2		2.3.3		2.3.4		2.3.5				2.3.6			
	Work (Code)		Average Daily Labour Hour (Hrs)		Workdays per week		No. of Months		Work (Code) Rs.		Average Daily Labour Hour Day...1 Week...2 Month...3 Year...4 Others....5		Workdays per week Monetary Value(Rs.)		No. of Months Day 1 Wek 2 Month...3 Year 4 Others....5		Salary/Wage received (Rs.)				Non-monetary thinga recived in Kind			
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2

2.2 and 2.3			
Cultivator...1 Agricultural Labour...2 Fishery Owner...3 Fishery Labour...4 Brick Kiln Owner....5 Brick Kiln Labour...6	Fruit Production...7 Tailor...8 Jweller...9 Blacksmith....10 Mechanic...11 Small Business (Small shop)....12	Medium Busineess (Wholesale trader)...13 Reatiler/Stockist...14 Car/Bus/Truck Driver...15 Other Vehicle Driver....16 Construction worker»....17 Daily Labour...18	NREGA Work...20 Government Job...21 Private Sector Job22 Pensioner...23 Maid/Household Help....24 Others...26

Enumerators Fill up			
Work	Total Of Farm Income (Rs.)	Total labour days in NREGA	Total Income from NREGA (Rs.)
Past 1 year Before Aila			
After Aila to the Time of Survey			

3. Operational Holdings of the HH

3.1	3.2						3.3		3.4		3.5		3.6	
Plot No.	Location of the Plot						Plot Area *Bigha*....1 Kottah....2		Ownership Land (Code) Past One year till Aila...1 After Aila Till Survey...2		Market Rate Of the plot (Code) Past One year till Aila...1 After Aila Till Survey...2		Land Use (Code) Past One year till Aila...1 After Aila Till Survey...2	
	1	2												
	Hamlet	Location with respect to nearest dyke												
		2.1	2.2	2.3	2.4	2.5								
		Direction of the Plot (Code)	Distance From nearest dyke (m/km)	Time taken by an adult male of general health to reach the nearest dyke (min)	Whether Boundary of the Plot faces dyke on any side Yes....1 No....0	Dyke type (Code)								
							Area	Unit	1	2	1	2	1	2

2.1	2.5	3.5	3.6
East1 West...2 North...3 South.....4 North-east5 South-east6 North-west7 South-west....8	Mud embankment....1 Mud embankment with brick pitching....2	Purchased Land...1 Inherited Land...2 Leased in...4 Leased out...5 Barga....5 Ryoti...6	Agriculture....1 Salt water fishery...2 Sweet water fishery....3 Brick Kiln....5 Fallow....6 Horticulture....7 Orchard.....8

Enumerators Fill Up

No.	Land Use	*Bigha*	Satak							
1	Total Agricultural Plot									
2	Total Fishery Plot									
3	Total Leased in Land									
4	Operational Holding (1+2+3)									
5	Area of the plot directly facing river embankments									
6	Contiguous plot									

4. Information about Agricultural Land for the past 12 months

4.1	4.2	4.3	4.4										4.5	
Plot No.	Crop (code)	Cropped Land (%)	Total Labour Hour used in the plot Past One year till Aila...1 After Aila Till Survey...2										Expenditure for seed,fertilizer and equipments (Rs.) Past One year till Aila...1 After Aila Till Survey...2	
			1				2		3		4			
			Family Labour				Hired labour (local)		Hired (Outsider)		Total expenditure for hired labbour (kind+cash) (Rs.)			
			No. of labour hrs		HH Id.									
			1	2	1	2	1	2	1	2	1	1	1	2

4.2
Aus...1 Aman...2 Boro...3 Cotton...4 Potato 5 Mustard....6 Vegetables...7
If there is multiple cropping in a single plot mention in different rows 1 mon=40 Kg

5. Information about Agricultural production

5.1	5.2	5.3				5.4						5.5
Plot no.	Crops (code from 4)	Amount of crop harvested Past One year till Aila...1 After Aila Till Survey...2				Amount of marketed Crops Past One year till Aila...1 After Aila Till Survey...2						The monetary value of harvest missed due to Aila (Rs.)
		Amount		Unit Mon..1 Basta2 Kg....3		Amount		Unit Mon..1 Basta2 Kg....3		Income from marketed crops		
		1	2	1	2	1	2	1	2	1	2	
Convert basta /mon into kg												
5.2												
Aus...1 Aman...2 Boro...3 Cotton...4 Potato 5 Mustard....6 Vegetables...7												
Enumerators fill up												
Income from marketed crops before Aila (Rs.)												
Value of Harvest lost due to Aila (Rs.)												
No. of multicropped plots												
Amount of multicropped plots (*bigha*)												

6. Information about leased out land

6.1	6.2	6.3		6.4		6.5	6.6					6.7	
Plot no.	Present Land Use	Lease rate		Time since leased out year1 Month...2		Use of land before lease	Location of the plot					Information about the lesse	
		1	2	3	4		1	2	3	4	5	1	2
		Annual lease (Rs./*bigha*)	tenure (yrs)	Unit	No. of yrs/ month		Hamlet	Distance from the Nearest embankment (m/km)	Time Taken by an adult male of general health to reach the nearest dyke (min)	Whether Boundary of the Plot faces dyke on any side Yes....1 No....0	Dyke type (Code	Place of origin (code)	Socio-economic condition (code)

6.2	6.5	6.6/5	6.7/1	6.7/2
Agriculture....1 Salt water fishery...2 Sweet water fishery....3 Brick Kiln....5 Fallow....6 Horticulture....7 Orchard.....8	Agriculture....1 Salt water fishery...2 Sweet water fishery....3 Brick Kiln....5 Fallow....6 Horticulture....7 Orchard.....8	Mud embankment....1 Mud embankment with brick pitching....2	Same Village....1 Same district other village...2 Other districts...3 Town4	Rich...1 Same staus....2 poor....3

Enumerators fill up

Leased out land before Aila (*bigha*)		
Leased out land after Aila (*bigha*)		
Land use before Aila (code)		
Land Use after Aila (code)		

7. Information about leased in Land

7.1	7.2		7.3		7.4	7.5		7.6	7.7
Plot no.	Lease Tenure/rate		How many years since taken lease		Land use before leased in (code)	Information about the owner who leased out the land		Whether interested in renewing lease yes....1 no..2 If no then next column	¢Reason for non-renewal Present is not profitable.....1 Loss due to Aila.....2 Others....3
	1	2	3	4		1	2		
	Annual Lease rate (Rs./ *bigha*)	Lease tenure (yrs)	Unit Yr..1 month...2	Amount		Place of Orgin (code)	Socio-economic condition (code)		

7.4	7.5/1	7.5/2
Agriculture....1 Salt water fishery...2 Sweet water fishery....3 Brick Kiln....5 Fallow....6 Horticulture....7 Orchard.....8	Same Village....1 Same district other village...2 Other districts...3 Town4	Rich...1 Same staus....2 poor....3

Enumerators fill up

Leased in land before Aila (*bigha*)	
Leased in land after Aila (*bigha*)	
Land use before Aila (code)	
Land Use after Aila (code)	

8. Information about livestock in HH

8.1	8.2		8.3	
Livestock	Number of Livestock		Present value of the livestock (Rs.) If purchased less than 1 year the actual value....1 If purchased more than 1 year the present value 2	
	Before Aila in the past one year	Livestock before Aila (Rs.) Present	Livestock after Aila (Rs.)	
Ox/buffalo				
Cow				
Goat				
Sheep				
Hen				
Cock				
Duck				
Pig				

Enumertators fill up		
Value of livestock lost due to Aila (Rs.)		

9. Information about assets and wealth of HH

9.1 Amount of Total land owned before Aila (*bigha*)..

9.2 Amount of land after Aila that is lost in river (*bigha*)..

9.3 Amount of land not usable any more due to salinity and /or siltatition..

9.4 Information about dwelling

No. of Dwelling	Type of Dwelling Mud house with thatched roof...1 Mu dHouse with Tiled roof/asbestos/tin roof....2 Pucca House......3	Impact due to Aila Fully damaged....1 Partially Damage...2	Present Value of the Dwelling

9.5 Information about other assets

Assets	No. of assets before Aila	No. of Assets after Aila	Estimated Market Value of assets lost in Aila(Rs.)
Desi boat			
Engine driven boat			
Motor cycle			
Bi-cycle			
Engine driven van			
radio			
Mobile/landline			
watch			
Sewing machine			
Other Assets a)..................................... b).. c)...			

10. Information about fishery plots

10.1	10.2	10.3		10.4
Plot No.	Source of brackish ater (code)	Year since in fishery business Yr...1 Month...2		Whether the Bheri is licensed to any government agency yes....1 No...2
		Unit	amount	

10.2	
Sluice Gate....1 Pipe....2 Riverine canals....3 From other fishery owners....4	

11. Production and cost details of Fishery

11.1	11.2	11.3				11.4								11.5				11.6
Plot no.	Fish (code)	Information about marketed fish Past One year till Aila...1 After Aila Till Survey...2				Labour days in Fishery in the past year Past One year till Aila...1 After Aila Till Survey...2								Other expenses				Production Technology (code)
			1	2	3													
			seed	Lime/ fertilizer/ inseticides	Alaghar (code)													
					unit	Value (Rs.)												
		Amount of harvest(kg)		Income frommarketed fish (Rs.)		Family labour		Hired (local)		hired (outsider)		Total expenditure for hired labour (cash+kind) (Rs.)						
		1	2	1	2	1	2	1	2	1	2	1	2					

11.2	11.5/3	11.6
Bagda...1 Galda...2 Bhetki....3 Parse.....4 Bhangar.....5 Other small fish....6 Other big fish.....7	If constructed within 1 year the actual value....1 If constructed less more than 1 year the present value....2	Traditional...1 Advice from FEO...2 NGO advice...4 Others....5
Enumerators fill up		
Total income from fishery in the past 1 year before Aila(Rs.)		
Total Income from fishery after Aila till survey(Rs.)		
Total expenditure on hired labour before Aila(Rs.)		
Total expenditure on hired labour after Aila till survey(Rs.)		
No. of days after Aila the first harvest obtained		

12. Problems of Virus Infection

121	12.2	
Plot no.	No. of times the harvest got affected by virus infection in the past 1 year	
	Frequency of virus infection	Estimated Loss (Rs.)

13. Information about embankment brecahes

13.1	13.2	13.3			13.4		
Plot No.	Number of times in the last three years the plot was affected from Embankment Damage	Nature and Extent of Damage mostly seen in the last three years			Nature and Extent of Damage due to Aila		
		1	2	3	1	2	3
		Type of Damage in the nearest Dyke (code)	Maximum height of water logging(ft)	Days inundated	Type of Damage in the nearest Dyke	Maximum height of water logging(ft)	Days inundated
13.3/1 & 13.4/1							
Subsidence of Embankment.....1 Embankment Breach....2 Tidal water spillover embankments.....3							

For enumerators: Consider both agriculture and fishery plots along with leased in plots

14. Public and Private Action for embankment conservation

14..1.	14.2.		14.3.			14.4.			
Plot No.	How many times in the last 3 years the following public agencies maintained the nearest embankment to your plot.		1.HH effort for dyke conservation (code) 2.Portion of embankment conserved (code)			Repair of Embankments nearest to your plot after Aila			
	Frequency of maintenance	Government Agency Irrigation....1 *Panchayat* throughNREGA...2 *Panchayat* through other fund.....3	Private effort	Frequency In last 3 years	Portion conserved	1. No.of days after Aila the repair work started	2 First Repair works done by whom. (code) .	3.Did you personally participated in the repair works	4. HH participation (code)
14.3/1			14.3/2		14.4/2		14..4/4		
Personal application to *Panchayat*.....1 Petition in Group.....2 Mud patching by own expenses...3 Subscribing to the committee for embankment maintenance...4 Voluntary labour......5 nothing.....6			Boundary of the plot....1 Entrance point of brackishwater......2 Others...3		Irrigation...1 *Panchayat*....2 Big Fishery owner/Fishery Committee.....3 Village people...4		Labour days...1 (mention labour hours) Monetary contribution....2 (Rs.) Supply of mtaterials..3 (Rs.) Others.....4 Nothing...5		

For enumerators: Consider both agriculture and fishery plots along with leased in plots

15. Expenditure on Embankment Maintenance in the last 1 year prior to Aila

15.1	15.2					15.3	15.4		
Plot no.	Labour days spent in last 1 year					Other costs Banboo,brick etc. (Rs.)	Expenditure through committee/Group		
	1 Family labour		2 Hired Labour days (local)	3 Hired Labour days (outsider)	4 Total expenditure for hired laboue (kind+cash) (Rs.)				
	HHmem ID.	Labour days					Type of expenditure One time..1 Annual.....2	Type of Expenditure Monetary contribution......1 Labour days...2 Land contribution...3	Monetary value (Rs.)
Enumerators fill up									
Own expenditure (Rs.)									
Amoount of money submitted to committee(Rs.)									
Amount of land contributed to committee(Rs.)									
Amount of labour days contributed									

For enumerators: Consider both agriculture and fishery plots along with leased in plots. If more than one household member worked in the same plot mention in separate rows.

16. Information about fishery committee/group

16.1	16.2				16.3			16.4					16.5	16.6			16.7	
Plot no.	Whether included in the committe				Composition of the Committtee/group			How many committee members are (a) same religion (b)member of the same political party (c)Supporter/worker of the same party (d) same HH wealth lvel (e) almost identical land parceels					Source of Committee revenue Lease money from donate land...1 Per *bigha* money¡....2 others3	1.Whether committee takes action for member not assistiing in dyke maintenace Yes...1 No..2 2. nature of penalty (code) 3. How many times have you observed such penalization in last 3 years			1.How many days after Aila did the committee convene a meeting 2.Was there any assistance on the part of committee to start harvesting after Aila yes....1 no....2 if the answer is yes state the type of effort undertaken	
	Yes....1 No..2 Previuosly it was...3*	Time since committee inclusion Yr...1 month....2		Amount of land under the committee (*bigha*)	1 No. of committee members	2 No. ofcommitee members directly linked with Panchayts/Political party	3 Nature of relation with *Panchayats* (code)											
		Time unit	Time amount					a	b	c	d	e		1	2	3	1	2

16.3	16.6/1
Sabhapati....1 Sahasabhapati....2 Pradhan....3 Upapradhan.....5 Samiti memebber....6 Member....4 Others....5	Threat of stopping water....1 Monetary penalty...2 Criticize in open forum3 others....4
Post Aila efforts of the Committe : 1... .... 2...	

For enumerators: Consider only own fishery plots along with leased in plots.

SANDEE
P.O. Box 8975, E.P.C 1056, Lalitpur, Nepal
Street address: c/o ICIMOD, Khumaltar, Lalitpur, Nepal
Tel: 977 1 5003222, **Fax:** 977 1 5003299, **Email:** info@sandeeonline.org **Web:** www.sandeeonline.org

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