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Aquaculture technology and community based mangrove rehabilitation in Indonesia

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In Indonesia, the vulnerability of coastal erosion is driving coastal villages to initiate community-driven efforts to rehabilitate mangrove forests that protect against erosion. Analyzing data from a survey of 75 coastal villages, this study identifies factors that are encouraging or constraining communities to initiate their own mangrove-planting programs. Results show that communities with higher levels of shrimp HYV adoption were more likely to plant mangroves, which implies that some technologies can increase the value of ecosystem services that mangroves provide. In addition, villages with aquaculture farmer cooperatives were 35% more likely to replant mangroves, and villages with the ability to impose sanctions were 36% more likely to plant mangroves. The capacity of local governing bodies to coordinate efforts through farmer cooperatives and enforce compliance with a credible threat of sanctions is critical in carrying out mangrove-planting programs at the village level.

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1. INTRODUCTION

Mangroves are an important natural resource found on tropical coastlines, and they serve as an important protective barrier against the threat of erosion and subsidence into the ocean (Barbier, 2007; Rönnbäck, 1999). Pressure from urbanization and expansion of farms has driven the loss of 86% of the world's mangrove forests in less than 25 years leaving many coastal communities in a "world without mangroves" (Duke et al., 2007; Ron & Padilla, 1999; Valiela, Bowen, & York, 2001).

In light of their perilous state, the rehabilitation of mangrove forests has become a critical issue for many coastal communities, which are now exposed to the threat of erosion and loss of valuable coastal land. Evidence from the Philippines demonstrates that while centrally planned mangrove rehabilitation had limited success; the decentralized community-driven initiatives were surprisingly more effective despite significantly smaller budgets and limited technical training (Primavera & Esteban, 2008). This has significantly shifted interest and discussion towards community-based approaches to mangrove rehabilitation (Datta, Chattopadhyay, & Guha, 2012).

Recently, community-driven mangrove planting initiatives have been observed in Indonesia (Babo & Froehlich, 1998; Brown, Fadillah, Nurdin, Soulsby, & Ahmad, 2014), however most villages remain unable or unwilling to follow suit. This demonstrates that there is a large degree of heterogeneity across villages in incentives and capacities to replant mangroves. What remains unknown is why some villages are initiating mangrove planting programs while others are not. The main objective of this study is to redress this gap in knowledge by identifying factors that encourage or constrain villages in initiating mangrove-planting programs. We focus our analysis around two main research questions:

RQ 1: What are the institutions and governing tools that are most effective in increasing the probability that a village rehabilitates mangroves?

Past research on community-based management has found that the ability of local institutions to devise policy, monitor behavior, and enforce compliance are important in determining natural resource outcomes in the community (Baland & Platteau, 1996; Ostrom, 1990; Wade, 1989). Using data on the diverse set of village institutions that exist in Indonesia, this study will compare the effect of various village-level institutions (farmer organizations, labor pooling cooperatives, and sanctions) to identify which are most effective in facilitating village mangrove-planting initiatives.

RQ 2: Does the diffusion of shrimp HYV increase or decrease the probability that a village rehabilitates mangrove forests?

Second, we examine the role of aquaculture farming intensification and its impact on mangrove planting. Evidence has overwhelmingly shown that the impact of extensive shrimp farms on mangroves has been negative (Barbier & Cox, 2004; Gunawardena & Rowan, 2005). However, shrimp farming systems are transforming and intensifying with the diffusion of *litopenaeus vannamei*, a shrimp HYV (High Yielding Variety) that significantly increases farm productivity (Briggs, Funge-Smith, Subasinghe, & Phillips, 2004). Previous research appears to put forth two competing hypotheses on the relationship between farming-system intensification and mangroves. On one hand, research on soil conservation has found that the more intensive and profitable farms were more likely to invest into erosion mitigation (Knowler & Bradshaw, 2007); On the other, deforestation studies find that intensifying farming systems and increasing returns per hectare can lead to negative forest outcomes (Angelsen & Kaimowitz, 2001). This study identifies if shrimp HYV diffusion has a positive or negative impact on the probability that a village rehabilitates mangrove forests.

Lastly, previous research on community level management of natural resources has primarily been conducted using case-studies and low-n statistics (Agrawal, 2003). We add to this literature by analyzing data from a survey of 75 coastal villages in Indonesia to identify which institutions are facilitating mangrove planting, and if shrimp HYV diffusion is encouraging or inhibiting mangrove forest rehabilitation.

The rest of the paper proceeds in the following sections: (2) Theoretical model; (3) Data; (4) Model Specification and Hypotheses; (5) Estimation; (6) Descriptive Statistics; (7) Regression Results; (7) Summary & Conclusions

2. THEORETICAL MODEL

Collective action is essentially a set of nested rules and institutions that govern behavior (Ostrom, 1990). This paper focuses on collective action as a group labor contribution to construct a collective infrastructure that enables the (1) design of program; (2) enforcement of group resolutions; (3) recruitment of volunteer labor, and; (4) management and coordination of labor to execute the program.

The village mangrove investment decision is modeled as a two-stage process that is solved through backward induction. In the first stage, the village collective decides whether or not to act collectively to plant mangroves. In the second stage, individual village members decide how much labor to contribute to the collective action.

In the rest of this section discusses (1) the villages decision rule to initiate collective action; (2) how the village forms it's belief on how much labor will be contributed to collective action, and; (3) the final Nash equilibrium that models village-level mangrove-planting behavior.

2.1. Simple village decision rule

The village will initiate mangrove-planting collective action if the village anticipates that there will be enough labor contributed by members of the village to successfully rehabilitate mangroves. To model this decision, we begin with a simple heuristic where villages choose to initiate ($Y = 1$), if the village believes its efforts will be sufficient to rehabilitate a minimum viable stock of mangroves.

$$Y = \begin{cases} 1, & if\ g(M, L) > \mu \\ 0, & otherwise \end{cases}$$

g(•) is the growth function of mangroves. It depends on (1) M, any pre-existing mangrove, and; (2) L, the amount of labor allocated to mangrove planting.

Mangrove forest stocks have a critical mass. The critical mass (μ) is the minimum stock of mangroves necessary to maintain a steady state of mangroves. Below this point, the forest cannot sustain itself and the forest stock will decline over time. Above this point, the forest sustains itself and grows over time. If the amount of labor to be allocated to mangroves planting, L, is not sufficient to reach the critical mass (μ), the village will not initiate a planting program.

When deciding to initiate a mangrove planting program, the village cannot observe L, the amount of labor that will be allocated at the future time of program execution. To make the mangrove-planting decision, the village forms its belief on future labor (L^*).

The village's belief on total labor allocation is as follows:

$$L^* = \begin{cases} \sum_i^n \ell_i^* \,, & if\ Y = 1 \\ 0\,, & if\ Y = 0 \end{cases}$$

Where ℓ_i^* represents the optimum mangrove-planting labor allocation for each individual in the village.

2.2. Household's optimization problem:

The village forms the belief on total contributed labor by solving each household's optimization problem. To model, we add to the de (Janvry & Sadoulet, 2006) dynamic household model to incorporate erosion mitigation and reactions to other households' behaviors.

In this model, households maximize utility by allocating labor to mangrove-planting, choosing a production technology (x), and the level of consumption (c). Utility in future periods is discounted at constant rate, β.

The household optimization problem is expressed as follows:

$$\underset{v_t\ \ell_t\ c_t\ s_t\ x_t}{Max}\ E\left[\sum_{t=0}^{\infty} \beta^t u(c_t)\right]$$

Where *t* indexes time, v indexes shrimp variety and, ℓ represents the household's labor allocation. S is the cash savings (or debt) of the household. x>0 represents a good (shrimp) produced, and x<0 represents factor inputs used such as PL, and feed. The household is subject to the following constraints:

(i) $\sum_i (p_i + t_i)(x_{it} - c_{it}) - S_t = 0$, budget constraint

(ii) $t = h(K)$, transaction costs

(iii) $\beta S_{t+1} = S_t$, interest on savings (or borrowing)

(iv) $S_i \geq S_{min}$, credit constraint

(v) $f\left(x_t, \ell_t^f, T_t, v_t\right) = 0$, production technology

(vi) $T_{t+1} = \varphi(T_t,\ M_t)$, land retained into next period

(vii) $M_{t+1} = g(M_t\,,\ \ell_t^m + L_v^*)$, mangrove stock update

(viii) $\bar{L} = \ell_t^m + \ell_t^f$, labor constraint

S_{min} is the household's credit limit. p_i is the market price that the household faces. t represents the transaction costs. K is the vector of institutional capital in the village. T is pond area operated by the household. ℓ_t^m represents labor allocated to mangrove planting, ℓ_t^f

represents the labor allocated to farm production, and L_v^* represents the household's belief on how much labor the rest of the village will allocate to mangrove planting.

2.2.1. Updating land endowment with erosion loss

The household's endowment of land is at risk of erosion and subsidence. The size of the household's land endowment is determined by constraint (vi), where $\varphi(\bullet)$ represents the amount of land that the household expects to retain in the next period. Mangroves stabilize shorelines and mitigate coastal erosion in two ways: (1) their subsurface roots bind soil together and help to retain sediment; (2) their aerial roots change water flows, which encourage sediment deposition. The amount of land that is retained into the next period is thus a function of the village's mangrove stock, $\mathrm{M}_{\mathrm{t+1}}$ and the amount of land at risk T_{t}. Mangroves increases the amount of land that is retained, so households have incentive to improve mangrove stocks.

2.2.2. Updating village mangrove stock

The village's mangrove stock updates in the manner specified in constraint (vii). g(•) is a function of the household's labor allocation ℓ^m plus the labor allocation of the remaining village members L_v^*. Households will incorporate their beliefs on how much labor others will allocate in their own decision to allocate labor.

In addition, g(•) is not a linear function with respect to labor. At low levels of labor, the marginal productivity of labor on mangroves is zero. This is because low levels of labor cannot plant enough mangroves to produce a viable minimum stock of mangroves on the coast. Mangrove planting is most productive when a large labor pool is assembled to: (i) collect seeds and saplings from nearby forests; (ii) plant saplings along the village's coastline all at once, and; (iii) monitor and manage mangrove growth in the early stages of development. This means that the benefit of allocating labor to planting mangroves will outweigh the opportunity cost only if many other members of the village will also be allocating labor to plant mangroves.

2.2.3. Shrimp varietal choice

The household will choose the optimal shrimp variety to produce given its relative tradeoffs. The traditional shrimp HYV is a land-intensive labor-saving technology, while HYV is a land-saving labor intensive technology. While the yield of the HYV are higher, they also make more use of farm-assets, and require transactions in unfamiliar input and output markets.

2.3. Solutions to the household problem

Following, the household's constrained optimization problem can be decomposed into a two period problem in which the household maximizes utility by allocating labor, choosing production technology, in addition to consumption and savings levels. The dynamic programming problem is expressed with the following value function that is subject to constraints (i) through (viii)

$$V(M_t, T_t, K_t, Y_t) = \underset{v_t\ \ell_t\ c_t\ s_t\ x_t}{MAX}\ u(C_t) + \beta V(M_{t+1}, T_{t+1}, K_{t+1}, Y_t)$$

2.3.1. Shrimp varietal choice

With manipulation of first order conditions, we can derive the equations for household *i*'s varietal choice. The following equation represents the varietal choice in the current period:

$$v^*(p_t, M_t, K_t, T_t)$$

The diffusion of shrimp HYV in the village is the sum of the individual adoption decisions of each household:

$$D_t^* = \sum_{i}^{Nv} v_{it}^* = v(p_t, M_t, K_t, T_t)$$

2.3.2. Mangrove labor allocation

With manipulation of first order conditions, we can derive the equations for household *i*'s allocation of labor to plant mangroves as follows:

$$\ell_{it}^m = \begin{cases} m(p_t, T_{it}, M_t, K_t, v_t, L_v^*), & if\ Y = 1 \\ 0, & if\ Y = 0 \end{cases}$$

where $L_v^* = \sum \ell_j^m$, the rest of the village's contribution of labor to planting mangroves. Household *i* will allocate zero labor to mangrove planting if there is no village program, and will allocate labor according to function m(•) when there is a program.

By symmetry, household j's supply of labor is expressed as follows:

$$\ell_{jt}^m = \begin{cases} m\left(p_t, T_{jt}, M_t, K_t, V_t, \sum \ell_i^{m*}\right), & if\ Y = 1 \\ 0, & if\ Y = 0 \end{cases}$$

Note that household i's allocation of labor to plant mangroves also depends on household j's allocation, and vice versa.

To solve for household i's optimal labor allocation, we can theoretically substitute in the optimal labor functions for all other households in the village into household i's expression and solve for household i. This is the Nash equilibrium labor allocation of household *i* that takes into consideration the reaction functions of all other members of the village. We express this final allocation decision as the following equation:

$$\ell_{it}^{m*} = m(p_t, M_t, K_t, D_t, T_t, Y_t)$$

2.3.3. Village institutions

Recall that village institutions, K, play an important role in determining the transaction costs that an individual household faces in the market. Producer organizations, labor cooperatives, and enforcement mechanisms used in the village help to reduce the transaction costs associates with making trades.

If village members deviate from their labor commitment, they face the risk of expulsion, or restricted benefits from these institutions. The reputation and social capital invested in these institutions help to ensure that individuals will follow through on the commitments they make to the community. Households will have incentive not to free-ride when there are institutions in place that are enforcing compliance.

2.4. Village's solution

The village sums up the individual commitments to form the aggregate belief on village labor allocated to mangrove planting L^*. The village makes the decision using this decision rule:

$$Y = \begin{cases} 1, & if\ g(M, L^*) > \mu \\ 0, & otherwise \end{cases}$$

Then it follows that the reduced form equation to model how a village will decide to initiate a program is expressed as follows:

$$Y_t^* \ (p_t, M_t, K_t, D_t, T_t)$$

3. DATA

To answer our research questions, we analyze data from a survey of 75 coastal villages in Indonesia conducted in July and August of 2010. The survey collected information on (1) village institution; (2) village characteristics; (3) aquaculture production technology, and; (4) collective action.

3.1. *Survey Geography*

Observations were purposely drawn from a set of villages from two provinces in Indonesia: (1) Central Java, located in the most densely populated and developed island of Indonesia where infrastructure is dense, rural economies are diversified, but suffer from poorer aquaculture production compared to; (2) South Sulawesi, a less developed region of Indonesia with less developed infrastructure, rural economies highly reliant on agriculture, but cleaner waters more suited for aquaculture production.

Within each selected province, two districts were chosen: one district near the main provincial port and one district that was distant from that port. The variation in geography in the sample allows the survey to capture a larger range of incentives, capacities, and resultant behaviors of coastal villages in Indonesia. The level of randomization in this survey is at the district level, thus interpretation and generalization of results should be confined within the bounds of these districts.

3.2. *Village level census*

In each of the selected districts, we conducted a census of all coastal aquaculture villages. Enumerators collected data by interviewing the head of each village and gathering population data from the village level administrative offices. Enumeration began in the eastern most village in each district and worked westward along the coasts until the administrative border of the next district was reached. The use of formal appointments with village offices allowed us to achieve a 100% response rate for the survey of villages.

4. Model Specification and hypotheses

In specifying the mangrove planting equation, recall that the village's mangrove-labor allocation L is a function of prices (p), village mangrove stock (M), village institutional capital (K), the diffusion of shrimp technology (D), and the endowment of land (T). In this section we describe how each of these variables are measured, and the hypotheses associated with the included variables.

4.1. *Dependent variable: village planted mangroves (Y_t)*

$\mathrm{Y_t}$ indicates if the village initiated a program to replant mangroves in 2009 to 2010. $\mathrm{Y_t}$ is observed as a binary dependent variable taking on the value of one if the village has conducted a mangrove replanting program and zero other wise.

$$Y_t = \begin{cases} 1, & mangrove\ planted \\ 0, & otherwise \end{cases}$$

4.2. Explanatory variables

4.2.1. Prices (p)

To control for the variation across villages in the returns to farming and wage labor, we include: (1) the output prices of one kilogram of HYV and traditional variety shrimp at the village measured at its most common grade; (2) village price of HYV and traditional post-larvae (seed); (3) the village price of one casual day of labor.

4.2.2. Mangrove (M)

The status of mangroves is measured with a binary variable that indicates the presence of mangroves along the village's coastline. This indicates the initial stock of mangroves and the level of erosion risk that is faced by the village. Villages that already have mangroves lining the coastline may have less incentive to plant mangroves than villages that do not have any at all. We control for variation in exposure to erosion risk by including this variable in analysis.

4.2.3. Village Institutional Characteristics (K)

This set of variables measures the institutional characteristics of the village: variables indicating presence of pre-existing village cooperative institutions, and governance mechanisms used by the village.

First, is a dummy variable indicating if the village has a shrimp producer organization. Producer organizations play an important part in the village in (1) the diffusion of market information and information regarding new technologies; (2) collective management of common-pool waterways like canals, rivers, and mangroves; (3) containing shrimp disease problems in production; (4) collectively marketing to access input and output markets. The existence of this institution indicates the increased interdependence of aquaculture farmers and a superior ability to manage common-pool resources.

Second, is a dummy variable indicating if the village has a general shared labor cooperative called '*Gotong Royong*' in the village. This institution is a remnant of the Suharto era that was used primarily for the construction and management of irrigation infrastructure and also in organizing collective labor to plant and harvest rice.

Third, we include a dummy variable that indicates if the village government has the power to impose sanctions (financial or otherwise) on village members that do not comply with village directives. Some villages use this institution to ensure participation in canal dredging or maintenance initiatives or imposing fines on members who violate a policy. While most villages rely only on the embedded cultural values and social relationships to enforce policy, those that employ sanctions may have a different ability to influence behavior of village members. Adding formal sanctioning institutions to the village's enforcement ability will help villages to coordinate individual agents to rehabilitating mangroves more effectively.

4.2.4. Village HYV technology diffusion (v)

In the village's mangrove-planting function, we summarize the technology employed by individual households in the individual by measuring the total population households in the village using each kind of technology, v. This is specifically measured with three village level population counts: (1) the population of all households in the village; (2) the population of shrimp farming households; (3) the population of HYV shrimp farming households.

$$v_t = \{Pop_{All}, Pop_{Shrimp}, Pop_{HYV}\}$$

These variables measure the level of heterogeneity in stakeholder group sizes and the aggregated preferences of each group.

The first variable is the population all households residing within the village's political boundaries. Larger populations have larger labor pools to recruit labor from, but also suffer from more difficulty in organizing collective action. We test to see the net effect of population size on the propensity to plant mangroves.

Second is a variable measuring the population of shrimp farm households in the village. In the era of extensive expansion, shrimp farmer significantly contributed to mangrove deforestation (Barbier & Cox, 2004; Ron & Padilla, 1999), which suggests that this population will decrease the propensity to plant mangroves; however, when coastlines are bereft of mangroves, aquaculture households are most at risk and have incentives to protect their ponds by planting mangroves.

Third is a variable measuring the population of households in the village that have adopted the HYV technology. The HYV adopting population is a subset of the shrimp farm population in the village, and with it we test the effect of HYV diffusion on the propensity to plant mangroves relative to conventional farms. HYV adopting farms may value mangrove resources higher than the normal population of aquaculture households for two reasons: (1) The profit per hectare on their aquaculture ponds are higher; so they may value erosion mitigating mangrove barriers higher than non-adopting farms; (2) HYV adopting farmers have made significant irreversible investments into their ponds that are specific to HYV farming practices: (1) increasing the pond depth; (2) reshaping the pond floor; (3) and installing monitoring points. Farms with these investments may have more incentive in preventing erosion and protecting these investments.

4.2.5. Village Land (T)

In the village's labor supply function, we summarize household endowments of land in the village $T_{it}, \dots, T_{Nv}$ by describing the distribution of land in the village with three variables: (1) the average area of ponds farmed in the village; (2) the Gini coefficient measuring the concentration of pond area in the village; (3) the total length of the village's coastline.

$$T_i, \dots, T_{Nv} \approx T = \{\overline{T_\iota}, GINI_V, Coast_V\}$$

The effect of the land endowment is uncertain. While villages with large areas of land and long coastlines are at the higher risk and thus have higher incentives to invest into erosion mitigating mangrove resources, it also means that the cost are higher to plant mangroves on the larger area. The result of these variables depend on how the marginal benefits of mangrove planting increase relative to the marginal cost with respect to area and coastline length.

5. Estimation Method

Estimation of the mangrove-planting equation requires the specification of a functional form and distribution of error terms. These specifications are as follows:

5.1. Functional Form & nonlinearity

To economize notation, we will express the variables p, M, K, D, T simply as X and leave our independent variable of interest (D), the population of HYV adopters, as a separate right-hand side variable. Following, we take a stochastic approximation of the investment equation, which leads to the following empirical specification:

$$Y_v^* = X_v\beta_1 + \beta_2 D_v + \varepsilon_v$$

Where v subscripts villages. We observe the dependent variable in the following binary way:

$$Y_v = \begin{cases} 1, & for\ Y_v^* > 0 \\ 0, & otherwise \end{cases}$$

5.2. *Estimation with Instrumental Variables*

In estimation we face a problem of endogeneity. HYV diffusion is endogenous with mangrove planting. When choosing to adopt HYV, shrimp farming households may take into consideration the future endowment of mangroves in their village's coastline; and choose to adopt after having observed Y_v.

To account for potential endogeneity, we draw from the exogenous variation of two instrumental variables (Z) in identifying the effect of HYV diffusion on investment into mangroves. The variables included in the HYV diffusion equation that are excluded from the mangrove planting function are $Z = \{Z_1, Z_2\}$:

(1) Z1: the first instrument is a dummy variable indicating if the village has a bank branch operating in the area. Bank branches can assist farm households in obtaining capital for shifting to the HYV variety, but will not affect if the village decides to coordinates a mangrove-planting program.
(2) Z2: the second instrument is a count of the total number of shrimp traders that operate in the village. The number of shrimp traders in the village will facilitate diffusion of HYV because these agents disseminate market information and information on shrimp production technology; but this population does not affect how the village decides to coordinates a mangrove-planting program.

The mangrove-planting equation is then estimated using the IV-probit estimator (Evans, Oates, & Schwab, 1992) to control for endogeneity in the variable D, the population of HYV adopters in the village, using the instruments discussed above. The equations we estimate are then:

$$H\begin{pmatrix} Y_v \\ D_v \end{pmatrix} = \begin{cases} 1[X_v\beta_1 + \beta_2 D_v >- \varepsilon_{1v}] \\ X_v\gamma_1 + \gamma_2 Z_v + \varepsilon_{2v} \end{cases}$$

Assuming the error term is distributed multivariate normal, the likelihood of observation *v* is:

$$\mathcal{L}_v(Y_v, D_v, X_v, Z_v; \beta, \gamma, \sigma, \rho) = \iint_{H^{-1}} \phi(\begin{bmatrix} \varepsilon_{1v} \\ \varepsilon_{2v} \end{bmatrix}, \begin{bmatrix} 1 & \rho\sigma \\ & \sigma \end{bmatrix})$$

We test to see if V_v is exogenous once the MLE has been obtained by testing if the ρ parameter is equal to zero using an asymptotic t-test (Wooldridge, 2010), and also conduct a test of over-identifying restrictions for the ivprobit estimator (Lee, 1991) using the stata routine written by (Baum, Wiggins, Stillman, & Schaffer, 2010).

6. Descriptive results

In this section, we present means, standard errors, and the t-tests on the variables used in analysis. Detailed results are presented in Table 1 in the appendix. The salient results are highlighted in this section.

First, we find that 33 out of 75 of the villages in our sample have executed mangrove-planting programs on their coastlines. This is a very high percentage and it demonstrates that coastal communities in Indonesia are actively engaged in planting mangrove forests and protecting valuable coastal land from the threat of erosion and subsidence. While mangroves have been severely degraded in Indonesia, rehabilitation of these forests appears to be underway in many villages.

Second, producer organizations and labor cooperatives appear to be facilitating mangrove planting. We find that (1) shrimp producer organizations were active in 94% of mangrove planting villages compared to 84% in non-planting villages; (2) 41% of mangrove planting villages have a labor pooling cooperative with only 16% among non-planting households. This suggests that these organizations may be an important factor in facilitating the planting of mangroves.

Third, the enforcement mechanisms wielded by the village appears to be a very important factor. While 31% of mangrove planting villages had the power to sanction village members for non-compliance, only 7% of village that were not planting mangroves had the same ability. The power to enforce may be an important factor in inducing village members to manage common-pool resources.

Fourth, we find that villages that planted mangroves also have 50% more HYV adopters than villages that did not plant mangroves. In contrast the total population of shrimp farmers is smaller (27) in mangrove planting villages when compared to non-planting villages (30). These results suggest that the farming technology employed by shrimp farming households is correlated to the planting of mangroves in the village.

Many factors can be correlated with HYV population and the village characteristics discussed in this section. In order to identify the independent effect of these variables holding all other things constant, we must turn to regression analysis to parse out each effect.

7. Regression Results

Complete regression results can be found in Table 2 through Table 4 in the appendix. In this section we discuss the salient results from IV probit estimation of the model parameters, of the mangrove labor equation, and also the reduced form HYV diffusion equation.

7.1. Mangrove planting equation

We find a number of interesting results in the mangrove planting equation (Table 4). First, we find that villages with higher populations of traditional shrimp aquaculture farmers were significantly less likely to invest into replanting mangrove resources. The marginal effect of one additional shrimp aquaculture farmer on the probability that the village allocates labor to plant mangroves is -1% (Table 5). This stakeholder group, on average, does not value the rehabilitation of mangrove resources and prefers not to expend labor resources to rehabilitate mangroves.

Second, we find a strong opposite result for the population of HYV adopters. Relative to traditional farmers, the HYV adopting population was found to have a positive and statistically significant impact on the probability that the village allocates labor to replanting mangroves. Converting one traditional farmer to a HYV farmer increases that propensity to plant mangroves by 4% (Table 5). HYV adopting farms may value mangrove resources higher than the rest of the population because: (1) they have higher profit per hectare on their aquaculture ponds, which they want to protect from the threat of erosion; (2) they may also have made significant irreversible investments into their ponds that they would lose to erosion.

These results already show that the diffusion of shrimp aquaculture technology is having a significant impact on mangrove forests along Indonesia’s coastline. If communities remain farming the traditional variety, the mangrove forests may remain in their current state of degradation; on the other hand, inducing adoption of the HYV could lead to a significant increase in efforts to rehabilitate mangrove forests. One HYV farmer offsets the negative effects of three to four traditional farms.

Third, the presence of producer organizations in the village has a marginally significant relationship with mangrove replanting behavior in the village. Compared to villages without a producer organization, those with a producer organization were 35% more likely to invest into mangroves. This institution provides organization structure for individual shrimp farmers to coordinate behavior and improve the overall welfare as a collective. An important role that this organization is playing is in the rehabilitation of mangroves on coastlines.

Finally, the village's ability to impose sanctions on non-compliant village members was a significant factor related to the village's mangrove investment behavior. Compared to villages without the ability to sanction members, villages with this power were 36% more likely to invest into mangrove resources. The ability of a village to enforce its regulations with sanctions (ability to create credible threats) is an effective tool for governance, and this power is critical to the management of mangrove resources in the village.

7.2. Identifying conditions

Model parameters are identified using exogenous variation from two instrumental variables. To examine the validity of our estimation strategy, we conduct the following tests:

First, we test exogeneity of the shrimp HYV population variable by testing the null hypothesis that the rho parameter, endogeneity parameter, is equal to zero. We reject the null hypothesis (Table 3), which means the shrimp HYV population variable is endogenous and requires the use of the IV probit estimator.

Second, villages with a bank branch, one of our instrumental variables, has a significant positive correlation with HYV adopting population in the village. This suggests that farm households may be facing credit constraints in the adoption of the HYV. Household without access to credit may not be able to make the necessary investments to intensify production practices by acquiring critical capital items like water-pumps and purchasing market inputs like HYV PL.

Third, the number of shrimp traders operating in the village, another instrumental variable, has a significant positive relationship with the HYV adopting population in the village. Having more shrimp traders operating in the village may be improving farmer access to information regarding how to market, where to procure inputs, and knowledge regarding production practices for the HYV.

Last, we test the over-identifying restrictions for the ivprobit estimator (Lee, 1991). The test yields a chi-square statistics of 0.07 (df=1), and we can conclude that the instruments are not correlated to the error term in the mangrove planting equation.

8. Summary and conclusions

Mangroves are an important natural resource and are especially important for coastal communities because they keep loose coastal soils in place and prevent erosion of land and subsidence into the sea. In Indonesia, the mangrove forests are in a severely degraded state, but many villages throughout the country have been observed planting mangroves and attempting to rehabilitate these forests. This study examined the factors driving mangrove forest rehabilitation efforts, focusing specifically on how the diffusion of a new shrimp HYV technology is affecting how farm households and communities are allocating labor to revive valuable erosion mitigating mangroves.

The diffusion of the HYV is driving villages to invest into erosion mitigating mangrove forests. This demonstrates that agricultural intensification and natural resource conservation are not necessarily mutually exclusive objectives. Some technologies, like shrimp HYV, actually increase the use-value of mangroves to a community. It appears that when productivity increases, communities are more willing to invest in mangroves to protect land from erosion. The diffusion of technologies that increase the demand for ecosystem services may be a more sustainable and cost-effective way to conserving and even rehabilitating natural resources in coastal communities.

In addition, we find that village institutions are very important in the management of mangrove resources. Villages with aquaculture farmer cooperatives were 35% more likely to implement mangrove-planting programs than those without. These cooperatives appear to provide a forum to express interest and facilitate the design of mangrove planting programs. Typically, the functions of these cooperatives are to collectively manage aquaculture diseases and manage shared waterways (canals, streams), and it appears that some of these cooperatives have extended their role into managing mangrove forests along their coastlines.

Finally, we find that villages with the ability to fine members were 36% more likely to plant mangroves than those that were not able. While most villages rely on embedded cultural values and social traditions to enforce group directives, a formal sanctioning ability that creates credible threats for non-compliance results in significantly higher likelihood of executing mangrove planting programs.

These results show that the valuation of mangroves can be increased with HYV diffusion, but this increased valuation must be supported by the right institutes in order to translate higher valuation into successful collective action. The capacity of local governing bodies to coordinate efforts through farmer cooperatives and enforce compliance with a credible threat of sanctions is critical in carrying out mangrove-planting programs at the village level.

REFERENCES

Agrawal, A. 2003. Sustainable Governance of Common-pool Resources: Context, Methods, and Politics. Annual Review of Anthropology, 32(1), 243–262.

Angelsen, A., & Kaimowitz, D. 2001. Agricultural Technologies and Tropical Deforestation. CABI.

Babo, N. R., & Froehlich, J. W. 1998. Community-Based Mangrove Rehabilitation: A Lesson Learned from East Sinjai, South Sulawesi, Indonesia. The World Bank/WBI's CBNRM Initiative.

Baland, J.-M., & Platteau, J.-P. 1996. Halting Degradation of Natural Resources: Is There a Role for Rural Communities?. Food & Agriculture Org.

Barbier, E. B. 2007. Valuing Ecosystem Services as Productive Inputs. Economic Policy, 22(49), 177–229.

Barbier, E. B., & Cox, M. 2004. An Economic Analysis of Shrimp Farm Expansion and Mangrove Conversion in Thailand. Land Economics, 80(3), 389–407.

Baum, C. F., Wiggins, V., Stillman, S., & Schaffer, M. E. 2010. OVERID: Stata module to calculate tests of overidentifying restrictions after ivreg, ivreg2, ivreg29, ivprobit, ivtobit, reg3. Boston College Department of Economics. Retrieved from http://ideas.repec.org/c/boc/bocode/s396802.html

Briggs, M., Funge-Smith, S., Subasinghe, R., & Phillips, M. 2004. Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific. RAP Publication, 10, 92.

Brown, B., Fadillah, R., Nurdin, Y., Soulsby, I., & Ahmad, R. 2014. CASE STUDY: Community Based Ecological Mangrove Rehabilitation (CBEMR) in Indonesia. S.A.P.I.EN.S. Surveys and Perspectives Integrating Environment and Society, (7.2). Retrieved from http://sapiens.revues.org/1589

Datta, D., Chattopadhyay, R. N., & Guha, P. 2012. Community based mangrove management: A review on status and sustainability. Journal of Environmental Management, 107, 84–95.

Duke, N. C., Meynecke, J.-O., Dittmann, S., Ellison, A. M., Anger, K., Berger, U., … Dahdouh-Guebas, F. 2007. A World Without Mangroves? Science, 317(5834), 41–42.

Evans, W. N., Oates, W. E., & Schwab, R. M. 1992. Measuring Peer Group Effects: A Study of Teenage Behavior. Journal of Political Economy, 100(5), 966–991.

Gunawardena, M., & Rowan, J. S. 2005. Economic Valuation of a Mangrove Ecosystem Threatened by Shrimp Aquaculture in Sri Lanka. Environmental Management, 36(4), 535–550.

Janvry, A. de, & Sadoulet, E. 2006. Progress in the Modeling of Rural Households' Behavior under Market Failures. In A. de Janvry & R. Kanbur (Eds.), Poverty, Inequality and Development (pp. 155–181). Springer US.

Knowler, D., & Bradshaw, B. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy, 32(1), 25–48.

Lee, L.-F. 1991. Amemiya's generalized least squares and tests of overidentification in simultaneous equation models with qualitative or limited dependent variables. Center for Economic Research, Department of Economics, University of Minnesota. Retrieved from http://www.econ.umn.edu/library/mnpapers/1991-262.pdf

Ostrom, E. 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.

Primavera, J. H., & Esteban, J. M. A. 2008. A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecology and Management, 16(5), 345–358.

Ron, J., & Padilla, J. E. 1999. Preservation or Conversion? Valuation and Evaluation of a Mangrove forest in the Philippines. Environmental and Resource Economics, 14(3), 297–331.
Rönnbäck, P. 1999. The ecological basis for economic value of seafood production supported by mangrove ecosystems. Ecological Economics, 29(2), 235–252.
Valiela, I., Bowen, J. L., & York, J. K. 2001. Mangrove Forests: One of the World's Threatened Major Tropical Environments. BioScience, 51(10), 807.
Wade, R. 1989. Village Republics: Economic Conditions for Collective Action in South India (1st ed.). Cambridge University Press.
Wooldridge, J. M. 2010. Econometric Analysis of Cross Section and Panel Data: Second Edition. Mit Press.

APPENDIX

Figure 1: Decision Tree

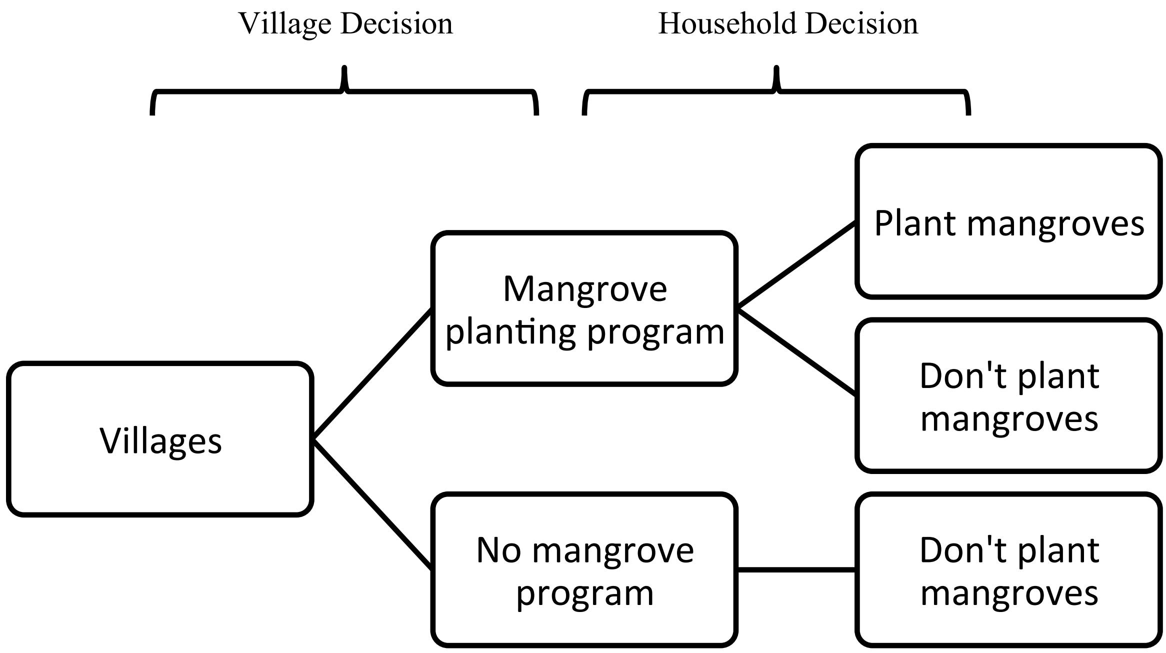

Table 1: Descriptive statistics by mangrove replanting status

VARIABLES	(1) Overall	(2) Non-planting	(3) Planting	(4) t-test
Population of HYV adopters (count)	4.37	3.58	5.44	
	(1.125)	(1.526)	(1.667)	
Village population of shrimp farms (count)	29.00	30.16	27.44	
	(3.354)	(4.894)	(4.380)	
Village population (10 count)	40.81	39.11	43.08	
	(3.725)	(4.858)	(5.865)	
Village has aquaculture producer organization (binary)	0.88	0.84	0.94	
	(0.038)	(0.057)	(0.043)	
Village has general labor cooperative (binary)	0.27	0.16	0.41	*
	(0.051)	(0.057)	(0.088)	
Pond area of village (ha)	1.99	1.87	2.14	
	(0.205)	(0.280)	(0.303)	
Concentration of pond area (Gini Coef.)	0.33	0.30	0.38	*
	(0.022)	(0.030)	(0.030)	
Village has mangroves on coastline (binary)	0.43	0.37	0.50	
	(0.057)	(0.075)	(0.090)	
Length of coastline (Km)	3.95	3.47	4.59	
	(0.376)	(0.419)	(0.669)	
Village shrimp output price (1000 IDR/Kg)	55.01	54.38	55.85	
	(0.915)	(1.192)	(1.435)	
Village price of HYV output (1000 IDR/Kg)	37.32	37.37	37.25	
	(0.708)	(0.927)	(1.112)	
Village shrimp input price (IDR/PL)	21.53	22.24	20.58	
	(0.435)	(0.511)	(0.728)	
Village shrimp HYV input price (IDR/PL)	24.69	25.43	23.71	
	(0.695)	(0.845)	(1.160)	
Village price of one labor day (1000 IDR/day)	31.23	30.78	31.84	
	(1.138)	(1.568)	(1.656)	
Village imposes sanctions for non-compliance (binary)	0.17	0.07	0.31	*
	(0.044)	(0.039)	(0.083)	
Village has bank branch (binary)	0.37	0.33	0.44	
	(0.056)	(0.072)	(0.089)	
Village population of shrimp traders (count)	1.83	1.47	2.31	
	(0.404)	(0.408)	(0.772)	

Standard errors in parentheses

* p<0.05

Table 2: HYV diffusion equation

VARIABLES	(1)
Village population of shrimp farms (count)	0.10**
	(0.039)
Village population (10 count)	-0.08**
	(0.038)
Village has aquaculture producer organization (binary)	-2.91
	(3.182)
Village has general labor cooperative (binary)	8.98***
	(2.410)
Pond area of village (ha)	-0.05
	(0.504)
Concentration of pond area (Gini Coef.)	8.74
	(5.499)
Village has mangroves on coastline (binary)	1.38
	(2.070)
Length of coastline (Km)	-0.46
	(0.332)
Village shrimp output price (1000 IDR/Kg)	0.08
	(0.147)
Village shrimp input price (IDR/PL)	0.40
	(0.289)
Village shrimp HYV input price (IDR/PL)	-0.07
	(0.271)
Village price of one labor day (1000 IDR/day)	0.11
	(0.133)
Village imposes sanctions for non-compliance (binary)	-2.37
	(2.817)
Brebes District (binary)	-2.33
	(2.955)
Bulukumba District (binary)	-1.82
	(3.734)
Barru District (binary)	-2.40
	(4.154)
Village has bank branch (binary)	4.17**
	(1.876)
Village population of shrimp traders (count)	0.51*
	(0.287)
Constant	-11.81
	(9.537)
N = 75	
Log-likelihood = 294.7	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Covariance parameters

Parameters	(1)
rho	-0.83**
	(0.178)
sigma	7.54***
	(0.617)

Table 4: Mangrove labor equation

VARIABLES	(1)
Population of HYV adopters (count)	0.09***
	(0.032)
Village population of shrimp farms (count)	-0.02***
	(0.007)
Village population (10 count)	0.01
	(0.006)
Village has aquaculture producer organization (binary)	0.86*
	(0.514)
Village has general labor cooperative (binary)	-0.45
	(0.598)
Pond area of village (ha)	0.15
	(0.111)
Concentration of pond area (Gini Coef.)	-0.03
	(1.055)
Village has mangroves on coastline (binary)	-0.15
	(0.339)
Length of coastline (Km)	0.09
	(0.062)
Village shrimp output price (1000 IDR/Kg)	0.03
	(0.027)
Village shrimp input price (IDR/PL)	-0.05
	(0.046)
Village shrimp HYV input price (IDR/PL)	-0.02
	(0.044)
Village price of one labor day (1000 IDR/day)	0.01
	(0.024)
Village imposes sanctions for non-compliance (binary)	1.04**
	(0.515)
Brebes District (binary)	0.21
	(0.474)
Bulukumba District (binary)	0.29
	(0.590)
Barru District (binary)	0.67
	(0.669)
Constant	-2.15
	(1.877)

N = 75
Log-likelihood = 294.7

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Marginal probabilities

VARIABLES	(1) Margins
Population of HYV adopters (count)	0.04
	(0.013)
Village population of non-adopting farms (count)	-0.01
	(0.003)
Village has aquaculture producer organization (binary)	0.35
	(0.169)
Village imposes sanctions for non-compliance (binary)	0.36
	(0.142)

Standard errors in parentheses