Population, Consumption and Environmental Degradation in a Mangrove Ecosystem in El Salvador

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Introduction

Models that relate population and consumption to environmental outcomes typically fall into one of two camps. They are either Malthusian in nature, emphasizing that population pressure on the resource base is deleterious to the environment, and that if it remains unchecked can only result in the cumulative loss of natural capital and the consequent deterioration of livelihoods (Erlich et al 1993; Appleman 1976; Erlich 1968; Hardin 1968; Malthus 1798). The opposing view is that it is not population pressure *per se* that precipitates the loss of natural capital but the economic, social and institutional framework that allocates access rights, enshrines private property and fails to internalize externalities by ensuring that the true opportunity cost of degradation is signaled through prevailing market prices and economic incentives (Templeton and Scherr 1999; Ross 1998a,b; Kaimowitz and Angelsen 1998; Turner et al 1993; Boserup 1965).

This paper summarizes those factors that have precipitated the loss of environmental capital and contributed to the degradation of the mangroves in El Salvador. Current patterns of extraction and conversion in the mangrove ecosystem in El Salvador can be viewed through an entitlement lens that confers property rights upon some actors and denies them to others. A hierarchy of activities contribute to environmental degradation in the mangroves reflecting the different demands upon and entitlements to that ecosystem. Ecosystem goods and services are undermined by direct conversion to aquaculture and salt ponds; post-larvae collection that reduces the stock of juveniles in the estuary; pollution and runoff from the discharge of solid waste and agricultural chemicals; siltation and sedimentation from upstream deforestation; and the loss of mangrove stands to logging and fuelwood gathering. Exploring the multiplicity of these demands upon the ecosystem and those factors that accentuate or ameliorate the degradation of the mangroves provides information about how this degradation can be redressed.

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The rational and sustainable management of the mangrove ecosystem in El Salvador cannot be secured without a redefinition of entitlement rights and an examination of the mutual and overlapping concerns of those whose livelihoods are intimately connected to the health of the ecosystem. The failure to ensure that production and consumption activities are undertaken without internalizing the costs of degradation or redressing them has compromised the health of the mangrove ecosystem and undermined its productivity. In the absence of measures to harmonize resource use and modify entitlements the activities of competing users are likely to result in irreversible damage to the ecosystem contributing to the further loss of biodiversity and undermining habitats and livelihoods.

The research presented in this article uses a variety of national and local household survey data, indicators of pollution, contamination and runoff, and land conversion to aquaculture and salt ponds, to describe the multiple demands upon the mangrove ecosystem in El Salvador.[2] The article begins with an analysis of the principal causes of deforestation and degradation in El Salvador. Section II provides a historical overview of the mangrove ecosystem in El Salvador between 1950 and 1990. Section III discusses the population-consumption-environment linkages that affect the mangrove ecosystem and provides a profile of the principal stakeholders in the mangroves in El Salvador. This section explores how key stakeholders use and transform ecosystem resources. Section IV discusses the property rights framework that allocates concessions and permits to the mangrove ecosystem and provides the basis for the allocation of both *de jure* and *de facto* access rights to the mangroves. Finally, Section V summarizes the conclusions about how this system of property rights may be modified to foster sustainable common property management of the mangroves.

Section I: A Brief History of Deforestation and Environmental Degradation in El Salvador

Although population densities are high compared to the surrounding countries, deforestation in El Salvador has been driven primarily by the impact of colonization and the expansion of export agriculture. The loss of forests and natural capital throughout El Salvador

[2] Data are drawn from the Encuesta Nacional de Hogares de Propósitos Múltiples, the Anuario de Estadística Agropecuaria, the Informe Trimestral del Banco Central de Reserva and surveys and reports conducted or financed by non-governmental, governmental and bilateral organizations. We owe a great debt to colleagues in the ministries that provided essential data on biological and ecological functions, the granting of concessions, and the extent pollution and runoff, among these the Ministerio de Agricultura y Ganadería, the Servicio Forestal, the Secretaria

has its roots in the conquest and colonization of its territories and in the exercise of partiality in the assignation of access rights and the determination of land-ownership in the post-colonial era. Deforestation in El Salvador has been closely associated with the expansion of export-agriculture and cattle-ranching since the beginning of the colonial period. The cultivation of indigo contributed to deforesting the lowland forests in the 17th and 18th centuries and the annexation of large parcels of land for coffee plantations deforested much of the humid sub-tropical forest (Zambrana 1992; Arias Peñate 1988; Browning 1975). Lindarte and Benito (1993) estimate that 70 percent of all cultivated land was obtained through forest conversion prior to 1950.

Although rates of deforestation decreased after 1950 they have remained high. Estimates from the Ministry of Agriculture place the forest loss in the order of 50 percent of the remaining total forest cover between 1960 and 1980 (Ministerio de Agricultura 1991). Land conversion to coffee production alone increased by over 60,000 hectares between 1970 and 1975 (Ministerio de Agricultura 1997; Browning 1975).[3] Cotton cultivation also contributed to deforesting the lowlands and coastal plains in the latter part of the 1950s and 1960s, although its production decreased significantly with the onset of the war in 1979 and in response to the precipitous decline in world cotton prices in the 1980s. By 1964, the area dedicated to cotton cultivation had increased to a little over 114,000 hectares from approximately 18,000 hectares in 1950.[4] Although cotton production currently takes up 1,745 hectares of land, much of the land formerly cultivated for cotton has been converted to melon, canteloupe and other non-traditional agricultural exports (Ministerio de Agricultura 1996; Arias Peñate 1988).

Civil conflict, the collapse of coffee and cotton prices and the application of adjustment and stabilization reforms have greatly affected the macroeconomy in El Salvador and the rural economy in particular (Boyce and Pastor 1997; Segovia 1997; Boyce 1995a,b; Paus 1995; Wood 1995). In El Salvador's more recent history, civil war and the decline of agriculture has promoted an exodus of more than 35 percent of its population from their communities of origin. Currently,

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[3] Although coffee plantations displaced primary forest, the net impact is somewhat ambiguous. Coffee provides continual cover and has a cohesive root system that retards soil degradation. Additionally, coffee provides an important source of domestic fuelwood as other forests have been depleted (Heckadon Moreno 1990).

[4] The number of rented agricultural properties increased from 32,945 in 1950 to 81,408 in 1961. The majority of these plots were dedicated to cotton production in the lowlands of Usulután, La Paz and San Miguel. While some of these properties were drawn into cotton production from other uses, or subdivided by absentee landlords into smaller plots, others represent a net conversion of intermittently forested lowlands to agriculture (Cueva 1962).

over 20 percent of the population reside outside of El Salvador with an additional 15 percent reporting that they have relocated within the national boundaries to evade conflict, violence and repression in order to seek out new economic opportunities (IOM 1999; INS 1998; Murray et al 1994; Montes 1985, 1989a,b).

The prolonged civil war, border prices and the application of adjustment and stabilization reforms have also impacted upon the health, extent and density of the mangrove ecosystem in El Salvador. Some of these effects are direct and others are indirect. Direct effects occur where anthropogenic activities reduce the coverage and density of the mangrove ecosystem.[5] Indirect effects have taken place where anthropogenic activities generate byproducts or externalities that impact upon the health of the mangrove ecosystem. This may occur at source or at some distance from the activity itself. The *extensification* of farming, logging and salt-production which has consumed land adjacent to the mangroves, interrupted existing drainage patterns and cleared the mangroves for alternative uses. The expansion of subsistence farming onto marginal lands in upland areas has also contributed to deforestation, erosion and siltation that has affected the health of the mangrove ecosystem[6]. The *intensification* of existing agricultural practices in response to declining soil fertility and the adoption of input-intensive non traditional agricultural exports (NTAEs) and has increased the use of chemical inputs and agricultural runoff, raising the level of contaminants found in estuarine flora and fauna (Codas Friedman 1991; Chapin 1990). The intensification of aquaculture and the conversion of rustic shrimp and salt production to semi-intensive and intensive aquaculture has led to a greater quantity of nitrates, phosphates and potassium entering the estuary system and contributed to the loss of biodiversity in the estuaries as wild larvae are used to supplement or substitute for hatchery larvae.

These activities respond to economic, social and institutional factors that influence the range of actors and stakeholders whose interests lie in the use and transformation of the mangrove ecosystem in El Salvador. The prevailing macroeconomic and external conditions, as well as current and future prices affect this human ecosystem. The opportunity cost of capital, availability of credit, current and future interest rates as well as the terms of trade, all affect decisions to invest in activities that impact upon the health and extent of the mangrove

[5] There is evidence that anthropogenic activity in the mangroves is not all harmful. Selective felling for timber and fuelwood can contribute to the formation of 'optimal gaps' in the ecosystem that actually facilitate regeneration and regrowth (Ewel et al 1998).

ecosystem. The presence or absence of employment opportunities, the nature of the local labor market and the abundance of environmental inputs for subsistence and artisanal activities are likely to stimulate changes in in-migration and out-migration, affecting both population density and the demands for ecosystem goods and services. The availability of concessions to convert the mangroves, or the *de facto* ability of existing institutions to enforce property rights also shape incentives to use and transform the ecosystem.

Section II: Historical Overview of the Mangroves in El Salvador 1950-1993

Any historical analysis of the mangroves in El Salvador is complicated by the sparse and erratic nature of the data and the incompatibilities and inconsistencies that arise as a result of comparing data generated by surface mapping, aerial photography and satellite imagery. Despite these cautions, the data available do present a description of the use and transformation of the mangrove ecosystem that are consistent with the economic, social and institutional changes to which these systems have been subject.

The mangroves in El Salvador were estimated to cover an extension of 31,830 hectares in 1994 (Ministerio de Agricultura 1994). They comprise six species of mangrove: *Rhizophora mangle, Rhizophora racemosa, Avicennia germinans, Avicennia bicolor, Laguncularia racemosa* and *Conocarpus erecta*. This system, whilst not notably extensive, is under continual and increasing pressure from conversion, pollution and extraction and provides a good example of the competing uses to which the mangroves have been put in Central America. To date the mangroves of El Salvador have experienced encroachment and degradation from: agricultural conversion on the periphery; the relocation and settlement of communities displaced by civil war; clearance and excavation for commercial aquaculture and salt production; and, commercial and individual extraction for timber and fuelwood. Unsustainable logging practices and pressures for conversion have led to deforestation rates in the region of 1,887 hectares per year over the period 1950 to 1978, a rate which dropped to approximately 773 hectares per year between 1978 and 1989. Although estimates vary, since 1990 the recorded loss of mangrove stands has been approximately 681 hectares per year throughout El Salvador (Ministerio de Agricultura 1994; Yanes et al 1991). The loss of mangrove stands has resulted in significant trade-offs between other use values offered by

[6] Rodríguez and Windelvoxhel (1998) estimate that the estuaries and coastal lagoons have been subject to sedimentation that has reached 500 tons/ha/year during the last few decades.

the mangrove ecosystem (such as shoreline stabilization, barrier services, ground-water recharge, and as nurseries for estuarine and marine fauna) that rely on the forest stand remaining intact (PROGOLFO 1999; Gammage 1997; Hamilton and Snedaker 1984).

Local and regional concern over rapid rates of deforestation prompted the government to introduce a complete ban on mangrove logging throughout the country, which took effect from May 1992. Surrounding communities are permitted to gather dry and broken wood for subsistence purposes, but anecdotal evidence suggests that illegal logging and fuelwood collection continues in El Salvador reducing the extent and density of the mangrove stands. In direct response to the ban on mangrove logging and fuelwood gathering, these activities have become more clandestine over the last 8 years.[7]

Other conversion activities and externalities that impact upon the health of the mangrove ecosystem and contribute to the loss of biodiversity and habitat continue largely without abatement or regulation: encroachment from agriculture; contamination of waterways by runoff from chemical fertilizers and pesticides domestic waste and organic matter; downstream siltation and sedimentation; and the conversion of mangroves to salt and shrimp ponds.

Figure 1 (see Annex for all figures and tables) reveals that the coastal mangroves in El Salvador have been depleted over time, with the greatest loss occurring between 1950 and 1961. Since 1961, there appears to have been a recovery that has led to significant growth and regeneration. This recovery is consistent with the changes in the patterns of extraction of timber and tannins and the use of mangrove stands for charcoal, and salt production that occurred between 1960 and the late 1970s. The recovery may also be a feature of the inconsistencies in the data that cause physical mapping techniques, photographic and satellite imaging to produce divergent estimates of extension and density. Certainly data for mangrove extension from maps made in the 70s and late 80s produce wildly different estimates of coverage and deforestation. Data from 1974 indicate that the mangroves covered approximately 34,424 hectares, whereas data from 1978 report that the mangroves covered 45,283 hectares (Foer 1991; Martínez 1991; Paredes et al 1991; Ministerio de Agricultura y Ganadería 1978). Marroquín (1992) reports that in 1989 the extent of the area that delimited the mangroves was estimated to be 45,867 hectares of which 58.4 percent

[7] The persistence of illegal harvesting was corroborated with key informant interviews, mapping exercises and from data gathered in a variety of different focus group fora and through survey questionnaires between 1992 and 1999. In many cases, the informants believe that the harvesting was being undertaken by members outside the communities that are located on the periphery of the mangroves.

was defined as mangrove, 22.4 percent channels and waterways, 16.6 percent agricultural production within the mangroves and 2.4 percent was dedicated to salt ponds. In contrast to this estimate, Yanes et al (1991) estimate overall mangrove extension to be 35, 234 hectare s in 1990. It is clear, therefore, that the data presented in Figure 1 for 1990 and 1994 are likely to be incomparable and may include estimates of channels and waterways.

A more consistent picture of deforestation and regeneration can be gleaned from careful observations of particular ecosystems over time. Figure 2 reports changes in mangrove extension between 1961 and 1989. In all cases, excluding missing observations for the Barra Salada, the mangroves increased in size during the 1970s falling below their 1961 level by the end of the 1980s. This may be attributed in part to the decline of extraction activities such as logging for charcoal and the tanning of hides that required tannins derived from mangrove bark. These activities disappeared largely because cheaper synthetic substitutes became available, and because the demand for Central American leather exports declined. The 12 year civil conflict from 1978-1992 also interrupted economic activities that had a deleterious effect on the mangroves prompting the decline in cotton production and the contraction of livestock farming. Yet war impelled many families to migrate from highland to coastal areas and may have increased population pressure on the remaining mangrove stands. Despite the influx of migrants to the coastal zones, there is a general consensus in the literature, that pressure on the mangroves decreased substantially throughout the conflict (Rubio, Germain and Góchez 1997; Paredes et al 1991). In the wake of the 1992 peace agreements, the return of flight capital has placed renewed pressure on the mangroves. The impetus to diversify exports stimulated by the application of adjustment and liberalization measures has led to the growth of aquaculture and melon production, the development of coastal tourism and the restocking of cattle ranches on the periphery of the mangroves. Changes in the regulatory framework that assign access and use rights to the mangroves have also prompted the intensification of activities that either directly or indirectly lead to the loss of mangrove stands and undermine the health of the ecosystem.

Unfortunately, the few data that exist on the coverage of mangroves provide a very general picture of the health of the overall ecosystem. Information on the density of mangrove stands, the portfolio of biodiversity; the quality of the water, its turbidity, turgidity and chemical content are also required. Few data of this nature are available. A recent study of the mangrove ecosystem in the Gulf of Fonseca funded by the IUCN concluded that there has been little overall change in the extent of the mangroves in the Salvadoran reaches of the Gulf between 1986 and 1997 (PROGOLFO 1999).[8] There has however been a significant loss of biodiversity, particularly in the mangrove ecosystem (PROGOLFO 1999). Furthermore, the quality of the water in the tributaries and estuaries indicate high levels of contamination from chemical and organic sources (PROGOLFO 1999; Michaels, Camacho and Platais 1998; Requena and Myton 1991).

Section III: Population-Consumption-Environment Linkages in a Mangrove Ecosystem

The population that depends on the environment or uses and transforms environmental goods and services in the mangroves in El Salvador, as elsewhere, is heterogeneous. There are multiple stakeholders often with competing interests in the use and transformation of the ecosystem. This heterogeneous population exerts pressure on the ecosystem through consumption activities that summarize the use, transformation and management of the ecosystem (see Figure 3). These consumption activities impact upon the mangrove ecosystem directly and indirectly changing the ecosystem and modifying or enhancing the delivery of environmental services that the ecosystem renders. In turn, the ecosystem is subject to exogenous hazards such as hurricanes, high tides, climatic changes, and seismic activity that also affect the health and extent of the ecosystem. The net effect on the ecosystem determines the level of environmental goods and services available and may subsequently affect the economic activities that the population of stakeholders undertakes.

Figure 4 provides a graphical overview of these multiple stakeholders and their relationship to the mangrove ecosystem in El Salvador.[9] The stakeholders are divided into households and fisher people, salt producers, tourists, agribusiness and small farmers, and aquaculturists. These groups represent those sectors whose activities impact on the mangrove ecosystem in a defined watershed. These groups use and transform ecosystem goods and services in a variety of different ways. Stakeholders are not confined exclusively to one interest

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[8] This conclusion is sensitive to the time span over which the analysis was conducted and the type of analysis undertaken. Although the satellite imagery data indicate only 84 hectares of mangrove were lost between 1986 and 1997, mapping and aerial photography from the Ministry of Agriculture indicate a net loss of over 1,130 hectares of mangrove between 1982 and 1997. While data from surface mapping indicate a net gain of mangrove extension over the decade of the 80s (PROGOLFO 1999).

[9] The figure was compiled using information derived from a variety of participatory exercises undertaken between 1993 and 1998 ranking the key threats to the ecosystem and describing how stakeholders use and transform the ecosystem in two mangrove communities in the Barra de Santiago and El Tamarindo, El Salvador.

group. In many cases individuals and households may be party to a variety of different stakeholder interests in the use and transformation of the ecosystem with divergent or coincident incentives to conserve, consume or degrade the ecosystem. Households may render labor to and receive income from salt-producers, agribusiness and aquaculture as well as deriving income from artisanal fishing. A fishing family may also farm small plots of land adjacent to the mangroves. An aquaculturist may also have a vacation home in the area.

The interdepencies among the groups are cemented by economic relationships in addition to those that emerge as a result of competition over a shared environmental resource base (Benítez et al 2000). This competition, however, is not necessarily atomistic or antagonistic and has the potential to be harmonized by defining appropriate property rights to the ecosystem that preserve the interests of all parties. The complexity of this cooperative and competitive relationship between and among stakeholders gives rise to the need and potential for coordination. There are incentive compatibilities that may be exploited to ensure the sustainable management of the ecosystem that guarantees the preservation of livelihoods and habitats[10]. Mangrove inhabitants, artisanal fishers and aquaculturists suffer the consequences of pollution contaminating water quality and shrimp larvae in the estuary, reducing biodiversity and undermining livelihoods. Carefully devised property rights that recognize the rights of the different stakeholders and enforce pollution restrictions within the ecosystem as well as beyond it can provide the appropriate incentives to capitalize on these shared interests to conserve biodiversity in the estuary and maintain water quality.

Local actors are not exclusively responsible for pressure on the remaining mangrove stands or for activities that undermine the health and well-being of the ecosystem. A national fuelwood deficit continues to place pressure on the mangroves. During the course of this research (between 1993 and 1999) mangrove fuelwood was observed for sale in inland urban markets in Santa Ana, San Miguel, San Salvador, and Usulután. The chemical runoff from pesticides and fertilizers applied to upland as well as local farms contributes to the loss of mangrove forest buffer zone of trees such as *curumo* and *mangollano* has had a dilaterious effect on nutrient regeneration, drainage and filtration and has increased pressure on the remaining mangrove stands.

[10] Incentive compatibilities occur where members of different stakeholder groups face incentives to act collaboratively or cooperatively in accordance with a shared interest.

The loss of habitat and contamination from pollution has directly reduced the shrimp catch both in the estuaries and consequently in the Gulf and at sea (HHW Consultants 1991; Hernandez 1989; Ministerio de Agricultura 1990; Villegas, Godínez and Ulloa 1985; Ulloa and Bernal 1980). As estuarine and marine fisheries are threatened, livelihoods are undermined with the most susceptible being those whose survival depends directly on artisanal and subsistence production. The cumulative effect of local and national pressures on the environment also heightens coastal vulnerability to floods and hurricanes (Vosti 1999; Adger 1997). As the ecosystem is transformed through these interactions, the actors themselves are often required to modify their behavior in response to increasing environmental vulnerability.[11] Continued degradation in the mangroves reduces the barrier services that the ecosystem secures. With a heightened vulnerability to floods and hurricanes, fishing, agriculture, aquaculture, tourism, and salt production is threatened.[12]

(i) *Households and Individuals: The Demand For Fuelwood*

The combination of high and sustained rates rural poverty, internal migration, population growth and changes access rights have increased pressure on common property resources in El Salvador (Panayotou et al 1997; CENITEC 1992; Foy and Daly 1988; Leonard 1987). In the face of weak institutions, common property regimes have degenerated into *de facto* open access systems. Landlessness, unemployment, and economic dislocation place more than a third of Salvador's population in a situation of acute poverty (CEPAL 2000, 1993; World Bank 1998, 1993; Acevedo, Barry and Rosa 1995; Seligson 1993). In many instances, falling household incomes, heightened food insecurity and rising rural unemployment intensify both a household's and an individual's reliance on unpriced environmental inputs (Vosti and Reardon 1994; Pinstrup-Andersen and Pandya-Lorch 1994; Boyce 1994).

Although fuelwood consumption is not the sole source of pressure on the remaining forest stands it clearly contributes to deforestation in El Salvador. Understanding those factors that contribute to the demand for fuelwood are essential if we are to alleviate pressure on the remaining forest stands and upon the mangroves in El Salvador.

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[11] An example of this is provided by the recent hurricane Mitch in November 1998 in the region. The estimated damage to aquaculture was more than $55.2 million with more than 60 percent of the damage concentrated in Honduras. The loss of mangrove barrier services undoubtedly contributed to the extensive damage in the face of flooding, heavy siltation and mudslides (Honduran Government 1999; OXFAM 1999(a-d); CEPAL 1999(a-d)).

[12] Those producers with greater access to financial and physical capital may undertake defensive expenditures to protect their investments; those who cannot, must suffer damaged harvests, and ultimately lose capital.

Estimates from the 1995 household survey reveal that 29 percent of urban and 87 percent of rural households use fuelwood as a primary source of domestic energy for cooking. Table 1 reports the estimated fuelwood demand for the residential sector. The estimates are based on cross section data from a sample of 1,023 households in 1990 which give average fuelwood demand per person in rural and urban areas as well as for the metropolitan area of San Salvador (Current and Juaréz 1992). Applying these cross-section parameters to the population estimates in each segment in 1995 gives a total domestic demand for fuelwood of 3.5 million metric tons per year.

Estimates of the net pressure on the forest resources as a result of excess fuelwood demand, are calculated using the forecast total sustainable supply of woody biomass in El Salvador. Table 2 gives estimates of the total sustainable fuelwood supply, that is, the quantity that may be harvested without drawing down the stock of the forest. These estimates were derived by estimating fuelwood demand over the period 1990 to 1995 from the household survey and applying the 1990 fuelwood consumption parameters in order to draw down the forest reserves by the observed deficit between fuelwood demand and supply.

The few remaining forests in El Salvador are national parks or reserves. Harvesting fuelwood and timber is controlled in all of the national parks and reserves. While these parks and reserves do provide fuelwood for national consumption they are less important than other areas of vegetation for woody biomass. In these simulations, the estimated excess demand for fuelwood was applied in sequence to shrub and diverse vegetation, broadleaf and coniferous trees as well as mangrove. The forested land extension was drawn down in proportion to the total combustible woody biomass available per hectare.

Applying this methodology, it is clear that a substantial deficit existed in 1995 between forecast fuelwood supply and fuelwood demand.[13] Some of this deficit may be made up by largely illegal imported fuelwood that crosses the permeable land and sea borders between El Salvador and Guatemala, Honduras and Nicaragua. It is possible, therefore, that the forecast reduction in forest cover is slightly overestimated. Yet comparing these estimates of deforestation attributable to excess fuelwood demand with those overall rates documented in the 70s and 80s, they appear quite conservative. Between 1975 and 1990 broadleaf forest and conifers lost almost 43 and 48 percent of their total extension (Current and Juarez 1989). The forecast total natural forest extension lost to excess fuelwood demand between 1990 and 1995 is a little less than 5 percent of the 1990 area.

With less than 5 percent of the national territory forested, coffee plantations are of critical importance as a source of fuelwood in El Salvador (Acevedo et al 1995; Rubio et al 1996; Current and Juarez 1992; Heckadon Moreno 1990).[14] Yet the combined pressures of falling coffee prices and rapid rates of urbanization are conspiring to reduce the area dedicated to coffee production and, therefore, the amount of fuelwood that is available to be harvested from the plantations.[15] The estimated deficit of 1,121,523 metric tons per year between demand and sustainable supply provides an indicator of the pressure on the remaining forest stands.

Table 3 gives the coefficient estimates of the determinants of household fuelwood demand. The coefficients reveal that income-poverty and location are the principal factors that influence the likelihood that a household consumes fuelwood. The model expresses the probability (P) of a given household using fuelwood. This probability is a function of a number of characteristics (X) such as whether or not the household is poor, the number of household members, if the household is located in a rural or urban area and whether it is in a former conflictive zone. Where: $P = 1/(1+e^{-\sum \beta i Xi})$

The reported coefficients from estimating this model can be expressed as partial derivatives indicating the change in the probability of a given household consuming fuelwood relative to a one unit change in any one of the independent variables, such that: $\frac{\delta P}{\delta Xi} = \beta i P(1-P)$, where P is the probability of the household consuming fuelwood, β is the logit coefficient and X is the dependent variable in question. The value of the partial derivative corresponds to the marginal effects given in Table 4.

The results in Table 3 indicate that in 1995, whether the household is defined as being under the relevant income-poverty line for rural or urban areas increases the likelihood that the household consumes fuelwood by more than 5.5 times. Similarly, whether the household is extremely poor increases the likelihood that fuelwood is consumed by approximately 5 times.

[13] We do not attempt to estimate fuelwood demand for commercial activities such as bakeries, brick-ovens, tortilla production. Current and Juarez (1992) estimate that commercial demand is approximately 6 percent of total fuelwood demand, and as such is relatively small compared to domestic demand.

[14] Rubio et al (1996) estimate that approximately 38 percent of the total fuelwood supply comprises wood from coffee plantations.

Fuelwood consumption increases with the number of household member. Those households where there are more than 6 members are more likely to consume fuelwood. Whether the household is female-headed also affects the likelihood that the household consumes fuelwood. This relationship holds controlling for poverty and extreme poverty. This would indicate that the headship variable is not capturing a disproportionate dependency on fuelwood because these households are more likely to be poor or extremely poor. Indeed, the comparison of *de jure* female headship and maintenance variable may reveal what is driving this association.[16] Households that are female-maintained may have been formerly male-maintained. The change in the gender portfolio of income may come about because male income earners have become unemployed or under-employed, have migrated, or are shifting from one sector to another. It may be that the asset base of the household was accumulated when that household was not female-maintained. Since female maintained households are more likely to have a gas stove as compared with female-headed households, it may be that the headship and maintenance variables are proxying stove ownership.[17]

There are also locational factors that influence whether a household consumes fuelwood. Urban households are much less likely to consume fuelwood than rural households. Whether the household is located in a former conflictive zone also increases the likelihood that the household consumes fuelwood by a little over 2.5 times. The influence of the former conflictive zones may be explained by the relative abundance of fuelwood in combination with degraded infrastructure, poor communications and the lack of available fuelwood substitutes such as kerosene or propane gas. The former conflictive zones are concentrated in the north where the last remaining tracts of forest that are not national parks are to be found. Since many of the roads and bridges connecting the few markets in these areas have yet to be repaired, the transport of goods to the former conflictive zones is costly and time-consuming.[18] Fuelwood substitutes are

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[15] The amount of land dedicated to coffee production has declined from a peak of approximately 188,000 hectares in 1980 to 162,000 hectares in 1999 (Merlos 2000; PROCAFE 1998).

[16] De jure female headship refers to whether the household was defined as female-headed in the interview. Female maintained households are those where more than 50 percent of total household income is generated by women.

[17] Few households cook exclusively using gas or electricity. Even those households that posess a gas or electric stove often use fuelwood to cook maize, beans and tortillas. In rural areas fuelwood consumption is often determined by temporary cash or liquidity constraints which bind households into gathering or purchasing fuelwood instead of propane gas or kerosene (Gammage 1997).

[18] El Salvador has approximately 12,400 kilometers of roads, only 1,936 kms are paved with 68 percent of these in need of repair (World Bank 1996). It has been estimated that of the approximately 4,000 kilometers of roads to be

comparatively scarce and expensive in these locations. It is not surprising, therefore, that even after controlling for poverty, whether the household is located in a former conflictive zone increases the likelihood that the household depends on fuelwood for its primary source of domestic energy.

Out-migration in El Salvador is a consistent strategy to meet household subsistence needs in the face of declining rural employment and rising poverty (Gammage 1998; Funkhouser 1997, Lungo et al 1997; Mahler 1995). The combination of a stagnating agricultural sector, civil conflict and the recent impact of hurricane Mitch has increased the economic isolation and marginalization of the rural poor in Central America. The collapse of productive opportunities has led to a tremendous exodus. Networks that were developed during the conflict to enable households and individuals to flee from conflict have continued to serve to meet the needs of economic migrants searching for opportunities in the North. For many rural households the relevant labor market for rural areas is the service sector in the United States (Funkhouser 1997; Mahler 1995). An average of 40 percent of farming families and 34 percent of rural families reported that at least one family member had left El Salvador between 1985 and 1994 (FUSADES 1996). Approximately 73 percent of farming families nationally and 56 percent of all rural families are receiving remittances (ibid). Migration peaked during the war, with an estimated 129,000 individuals recorded crossing a land border or leaving from the international airport. (DIGESTYC inteview 1999; EHPM 1988-1998). Although migration rates have decline subsequently, official figures estimate that 4.7 migrants per 1000 leaving the country or a loss of 27,035 people each year (MIPLAN 1992).

Migration is likely to affect fuelwood consumption. Migration can reduce the demand for fuelwood directly by reducing the number of household members. The receipt of dollar remittances may enable households to purchase alternatives to fuelwood such as propane gas, kerosene or electrical stoves. Remittances can also stimulate increased fuelwood consumption by raising incomes and permitting households to purchase more fuelwood. The net effect of migration and the receipt of remittances is therefore ambiguous and may depend acutely on the location of the household, the stability of the remittance income stream and the availability of alternatives to fuelwood for domestic energy. The regression results are inconclusive. In specifications (1) through (3) the receipt of remittances appears to increase the likelihood that a

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repaired and upgraded as part of the reconstruction plan established in the Peace Accords, close to 68 percent are in the former conflictive zones (FIS interview May 1998, FUSADES 1997, Murray et al 1994).

household consumes fuelwood. Specification (4) through (6) reveal that the receipt of remittances decreases the likelihood that a household consumes fuelwood. Since the majority of migrants are rural, it is probable that the receipt of remittances proxies rural residence for these households and mirrors the effect of location on fuelwood consumption.

Table 4 gives the marginal effects associated with specification 1 in Table 3. The estimates of the marginal effects indicate that in El Salvador in 1995 being poor is expected to increase the likelihood that a household consume fuelwood by 42 percent, controlling for all other factors in the regression.[19] The most influential factor affecting whether the household consumes fuelwood is whether the household is in an urban area. Being in an urban area decreases the likelihood of using fuelwood as a primary source of domestic energy by as much as 74 percent.

Intervening factors such as gender, poverty, household size and composition, access to alternative technologies, and sectoral attachment also shape fuelwood consumption in the mangrove ecosystem. The majority of the fuelwood consumed in the community of El Tamarindo, La Unión, appears to be mangrove, however, there is a general reluctance to admit to the use of mangrove fuelwood because of changes in access rights in 1992 that prohibited the collection of any mangrove wood that is not already dead and dry. A little over 32 percent of 134 randomly chosen households surveyed in 1997 reported that they consumed mangrove fuelwood.[20] An additional 31 percent did not declare the type of fuelwood consumed. Even if the majority of fuelwood consumed in the community is mangrove it is not clear that it comes from the local mangroves. There is evidence that some mangrove fuelwood and timber in the community is being smuggled in from other areas within El Salvador where logging and fuelwood gathering resitrictions are less strictly enforced. Mangrove fuelwood and timber may also enter the community clandestinely from Nicaragua and Honduras.[21]

Table 5 provides some descriptive statistics for fuelwood consumption in the dry season in El Tamarindo in 1997. The data aggregate domestic and commercial use of fuelwood, largely

[19] Given the non-linearity of the logit model, the value of the partial derivative depends on the value of all explanatory variables (Deaton 1997; Johnston and Dinardo 1997).
[20] The household survey undertaken in 1997 was a randomly selected sample of approximately 15 percent of the population residing on a small spit protecting the estuary of the El Tamarindo mangrove ecosystem.
[21] Interviews with members of the communities in El Tamarindo and the Barra de Santiago, El Salvador and in Playa Grande and San Lorenzo, Honduras reveal that mangrove fuelwood and timber is brought from Guatemala, Honduras and Nicaragua at night in boats. The relative scarcity of fuelwood in El Salvador has driven prices up to such an extent that smuggling timber and fuelwood can be a profitable enterprise.

because households do not differentiate between these uses. Approximately 40 percent of the community use fuelwood for limited productive activities such as preparing fish and shrimp for sale, making tortillas and baking bread. Fuelwood consumption in the community is broken down by key attributes to explore how these intervening factors shape resource use. Poor and extremely poor households nationally typically consume more fuelwood in than non-poor households in El Salvador. Yet within the community of El Tamarindo, where less than 10 percent of all households in the sample do not use fuelwood, the converse is true. Non-poor households consume more fuelwood per capita and in total than poor and extremely poor households. The difference of means test reported in Table 5 reveal that extremely poor households consume significantly less fuelwood than non-poor households. Although poor and extremely poor households are larger, they may often be more time constrained and, therefore, invest less time in fuelwood gathering than households that are poor or non-poor or have less cash to purchase fuelwood. Furthermore, it is likely that poor and extremely poor households eat meals of lower volume and nutritional content and cook less frequently, or maintain their stoves lit for shorter periods of time (Benitez and Machado 2000; Gammage, Benítez, and Machado 1999).[22]

The net effect of the receipt of remittances does not appear to affect per capita fuelwood consumption locally. Although total fuelwood consumption per household is smaller in those households that report receiving remittances, this difference is not statistically significant.

Urban households nationally consume significantly less fuelwood, highlighting the importance of the role that technology can play in alleviating fuelwood demands. The ownership of a gas stove in the community of El Tamarindo, however, is clearly not sufficient to reduce fuelwood consumption. Few households with a gas propane stove use the stove exclusively for cooking. Supplies of gas propane in the community are erratic and cannot be relied upon. Furthermore, there are positive preferences for certain foods cooked over an open fuelwood stove. Even if propane gas is available, not all households will have the cash to purchase it. Consequently, very few households use propane gas exclusively as a source of domestic energy.

[22] Extremely poor households typically have higher economic and demographic dependency ratios , there are fewer income earners and fewer members who can dedicate their time to gathering fuelwood among the many subsistence tasks that they engage in. On average, these households spend less on food and consume fewer calories (Benítez and Machado 2000).

Households were categorized as female-maintained and *de facto* female-headed using earned income in an attempt to explore gendered patterns in fuelwood consumption.[23] Female-headed and female-maintained households appear to be particularly dependent on fuelwood. The difference of means tests are significant at the 2 and 1 percent levels. It is clear that in order to meet their subsistence needs or to provide income, these households rely disproportionately on gathered fuelwood for domestic and productive activities. Incomes are typically lower and have higher variance in female-headed and female-maintained households than in their male-headed and male-maintained counterparts in the community. Even though these households are disproportionately likely to own a gas propane stove, they use fuelwood more consistently for productive activities.

The clear association of poverty and location with the consumption of fuelwood is hardly surprising in the national data. The finding that non-poor households also consume fuelwood within the mangrove ecosystem does not contradict the analysis of the national data, but serves to highlight some of the problems analyzing human-environment interactions by focusing on the local populations' consumption demands. Small samples are notoriously homogenous and exhibit little variation. The community of El Tamarindo is rural, and its fuelwood consumption patterns reflect its isolation from markets, high levels of poverty, and the lack of alternative technologies for domestic energy. The utility of the analysis can only be to inform policy design that focuses on rural energy provision at a national level, the promotion of alternative technologies, and the creation of extensive buffer zones to provide transitional sources of renewable energy. Merely prohibiting fuelwood gathering and timber collection risks criminalizing activities that will continue because of the acute nature of the poverty that compels individuals and households to use fuelwood and a source of domestic energy.

(ii) Aquaculture and Salt Production

Shrimp and salt ponds represent one of the principal alternative land-uses for mangroves in El Salvador. Historically in El Salvador, the expansion of salt production and aquaculture has resulted in a direct loss of mangrove coverage (Rodríguez and Windevoxhel 1998; Funes and Blanco 1983). In 1996, an estimated 2,548 hectares of land located adjacent to or in mangrove

[23] A household is defined as *de facto* female-headed if a woman in the household generates the majority of income in the week prior to the survey. Remittances are not included in the definition of earned income.

forests in El Salvador had been converted to shrimp and salt production (see Table 6).[24] Of this, 2,378 hectares of land were being actively used for extensive mariculture, producing approximately 1,100 pounds of shrimp per hectare per year. An additional 164 hectares were dedicated to intensive shrimp cultivation yielding an average of 4,789 pounds of shrimp per hectare per year (PROGOLFO 1999; CENDEPESCA 1993). Among these ponds, only 46 hectares were outside estuary systems in rocky areas (Marroquin 1992). Regardless of where these ponds and tanks are located, mariculture depends upon the estuaries and mangroves for supplies of postlarval shrimp to supplement or substitute for laboratory or imported larvae.

The growth of salt production and aquaculture has been difficult to monitor in El Salvador. The Fishing Directorate (CENDEPESCA) reports figures for salt ponds as well as intensive and extensive aquaculture from 1985 onwards although this does not necessarily correspond to the development and growth of salt and shrimp cultivation. Table 7 reports data for extensive and intensive shrimp cultivation and salt production in artificial ponds. The data reveal certain inconsistencies in the definition of extensive and intensive shrimp cultivation, largely as a result of the dual use of salt ponds for extensive shrimp cultivation during the rainy season. The data appear to indicate that intensive shrimp production has decreased, while extensive cultivation has risen over the period 1986 to 1996.

The combination of extensive and intensive shrimp farming generates significant revenues and is a highly profitable activity in the region and has been responsible for clearing a little over 24,000 hectares of mangrove in the Gulf of Fonseca in El Salvador, Honduras, and Nicaragua (Rodríguez and Windevoxhel 1998; Stanley 1999, 1996; DeWalt et al 1997) (see Table 7).[25] Various studies of aquaculture potential in El Salvador indicate that between 9,000 and 13,460 hectares may be suitable for aquacultural production (Paredes et al 1991; Cheney et al 1988; FUSADES 1988). The high value added from aquaculture in artificial ponds is generated as a result of using generally low-cost, labour-intensive inputs. Shrimp commands a high price both in the domestic and international markets. However, the profitability of this exercise must be evaluated in

[24] Subsequent estimates reveal that a little over 1,540 hectares were being used for rustic salt and shrimp production as well as semi-intensive shrimp cultivation in 1997 (PROGOLFO 1999).

[25] Estimates of aquaculture potential in El Salvador indicate that at full capacity intensive aquaculture could generate in excess of 2,177 kg per hectare per year in comparison with an average of 500 kg per hectare per year for extensive aquaculture (Marroquin 1992). At 1999 export prices of US$7.00 per kilogram this corresponds to approximately $15,239 per hectare (Banco Central de Reserva 1999). It is important to note, however that the majority of post-larvae are extracted from the estuaries, reducing biodiversity in the estuaries and affecting both artisanal and industrial fisheries in the estuary and offshore.

the light of the full costs incurred (Parks and Bonifaz 1995). The external costs of deforestation, drainage interruption, habitat and biodiversity loss impact primarily upon the surrounding community and the marine fisheries and are not felt by the shrimp producers themselves. It is this 'cost shifting' that misrepresents the true economic returns to shrimp farming.[26]

Aquaculture has been actively promoted as part of a concerted effort to diversify agricultural exports in El Salvador. The agricultural diversification unit DIVAGRO at the Salvadoran Foundation for Economic and Social Development (FUSADES) placed considerable emphasis on providing potential investors with sufficient information to attract flows of foreign direct investment capital to El Salvador. A handbook commissioned by DIVAGRO entitled the Shrimp Farm Investors Handbook states that: "Shrimp is of major interest to DIVAGRO due to its potential for large export earnings", (Mendola and Guier 1989:3).

In this handbook a commitment was made to a 'master plan' to be enacted in two phases, to assist with the development of 1,000 hectares of shrimp ponds during the next three years and a subsequent phase where 4,000 hectares were to be developed over a five-year horizon. As part of phase 1, FUSADES declared that it would "strive to remove all bureaucratic obstacles and provide competent state of the art technical assistance for all approved projects", (Mendola and Guier (1989:3). Although reference is made to the use of hatcheries for cultured post-larvae several manuals and technical assistance documents produced by FUSADES stress that wild larvae are most resistant and that few hatcheries are available in El Salvador, necessitating the importation of cultivated post-larvae from Honduras or Ecuador (Marroquin 1992; FUSADES 1990; Mendola and Guier 1989; Cheney et al 1989; Zapata 1987). Consequently, the majority of peneid post-larva are caught in the wild in El Salvador, depleting the stock of shrimp and reducing biodiversity in the estuaries (Marroquin 1992; Cheney et al 1989).

The expansion of shrimp cultivation in El Salvador, is in great part attributable to the efforts to attract foreign direct investment and to develop this industry. Financing was made readily available; subsidies were applied to inputs and interest rates, as well as to the delivery of technical and logistic support. The decline of the industry is also in part a function of the abandonment of

[26] It is important to note that aquaculture is not necessarily in conflict with mangrove conservation or preservation. The ponds need not be located in the mangroves and the larvae does not have to be culled from the estuary, depleting stocks and involving the unnecessary loss of bycatch (Corrales 1998). Moreover, the profitability of mariculture and aquaculture may depend ultimately on the health of the entire ecosystem, thus potential exists for externalities associated with mariculture and aquaculture to be internalized if the horizon of investment is sufficiently long (Parks and Bonifaz 1995).

aquaculture promotion as one of the key elements of a diversification strategy within USAID and FUSADES (USAID 2000; FUSADES 2000).

The imposition of a ban on mangrove felling and encroachment in 1992 also affected aquaculture. The legislative process through which the current environmental law was developed began in earnest in 1994 (MARN 1999). The separation of narrow economic objectives from legislative and normative ones allowed for the development of an environmental law that was not necessarily consonant with the objectives of industry, agribusiness, shrimp and salt producers.[27] As a result of the adoption of this environmental law, an increasing number of ponds have been abandoned or have ceased operation (Ministerio de Agricultura 1990-1997). Unfortunately, little has been done to enforce the restoration of areas formerly dedicated to rustic shrimp and salt-production and the net impact on the mangrove ecosystem remains deleterious.

(iii) Agriculture and Livestock Production

Over the period 1950 to the present, there was considerable conversion of land on the periphery of the mangrove forests to agriculture and pasture. There is little potential for further agricultural encroachment, as the existing forest stand is based on salty and partially flooded soils that are more suitable for shrimp farming and salt production. Despite the cessation of conversion to agriculture, agricultural activities continue to impact upon the mangrove ecosystem as runoff from chemical inputs, pesticides, herbicides and fertilizers enter the estuaries and waterways of the mangroves.

Agriculture and livestock production has affected the mangrove ecosystem both directly and indirectly, converting land on the periphery, interrupting drainage and contributing to the runoff of effluent, organic and chemical waste. The most important sources of water contamination in El Salvador are sewage from human and animal waste, industrial effluents and agricultural discharge. [28]High levels of contamination have been documented consistently over the last decade. Excessive quantities of untreated household and municipal waste, industrial effluent, sediments and solid wastes, as well as agricultural runoff have rendered many of the rivers and waterways unusable for irrigation, consumption and bathing (Michaels, Camacho and Platais 1998). The principal industrial

[27] The controversial nature of the environmental law is particularly apparent in the extensive nature of the regulation on economic activity that impacts upon the environment and the requirement of active and decentralized participation by civil society in the evaluation and enforcement of that law.

[28] A 1991 study of water quality in the mangrove ecosystem of the Barra de Santiago found that all samples exceeded the minimum limit for coliforms of 10/100 ml. In more than half of the smples the number of coliforms per ml of water exceeded the limit by as much as 2,400% (Requena and Myton 1991).

wastes that pollute rivers and waterways and percolate into the groundwater subsystem derive largely from agribusiness. Coffee and sugar processing accounts for almost 23 percent of industrial waste in rivers and streams and would require an estimated US$43.5 million to treat each year (Michaels, Camacho and Platais 1998). The most common agrochemical pollutants are from pesticides, the most intensive application of which was for cotton plantations. A 1985 USAID document reports figures from Mckee and Wolf (1976) that estimate concentrations of DDT of 0.1 mg/liter over a period of 12 hours can kill almost all fish and fauna in any body of water. Requena and Myton (1991) report that concentrations as high as 3.15 mg/liter of DDT have been found in the Río Grande in San Miguel. These quantities in many cases exceed the lethal limit and the residues are likely to concentrate downstream in estuaries or along the shoreline in aquatic organisms (Requena and Myton 1991).

The runoff from chemical inputs applied to agricultural production has contributed to elevated levels of organophosphates and organochlorides in sediments, groundwater and in rivers and estuaries (see Tables 8 and 9). As a result of bioaccumulation, these concentrations are often highest in the organisms that inhabit these waters. Average levels of contamination in the estuaries of mangrove ecosystems throughout El Salvador indicate that both surface and groundwater have been polluted by chemical runoff from pesticides and herbicides. In the Jaltepeque estuary, seven distinct agrochemicals were identified in samples of animal fat, water and in sediments, these included Parathion, Methyl Parathion, Ethyl Parathion, Aldrin, Endrin, DDT and Heptachlor. The greatest concentration of such pesticides can be found in molluscs and crustaceans that inhabit the estuary waters and are an important source of proteins for coastal populations (Rubio 1997; Rubio, Germain and Góchez 1996; Requeña and Myton 1991). Mendola and Guier (1989) in their analysis of aquaculture potential in El Salavdor state that: "[E]vidence is accumulating that pollution from agricultural runoff (pesticides and herbicides), is severely contaminating the nursery grounds of the shrimp." (Mendola and Guier 1989:104).

Studies of the concentration of agrochemicals in ground and surface water have been very localized and infrequent. The need for consistent data on water quality limits the extent to which actions that impact upon the health of the mangrove ecosystem can be monitored. The absence of such data also prevent environmental impact assessment being undertaken in a manner that would facilitate the implementation of the environmental law that came into effect in 1998.

Section IV: Property Rights to the Mangroves

The absence of clearly defined local and national property rights to the mangroves contributes to degradation by failing to guarantee incentives for conservation or to define beneficiaries to whom compensation should be paid for degrading the ecosystem. The sale of concessions to convert or log the mangroves has reduced the coverage and density of the existing system and concentrated pressure on the remaining mangrove stands. Where legislation concerning the amount of land to be converted under these concessions is not adequately enforced violations occur. The extent to which infractors are prosecuted or fined signals the presence or absence of economic opportunity. The unequal nature of prosecutions and the existence of impunity means that some infractors can evade punishment while others cannot. If wealthy landowners have been able to evade prosecution for persistent infractions, they will continue to undertake investments in economic activities that degrade the mangroves. Unless the system of property and access rights is made transparent and the infractors and authorities accountable, the incentive to 'cheat' will exacerbate environmental degradation in the mangroves.

Over the last 30 years, the central government in El Salvador established property rights to the mangroves that were mandated under law and enforced through the Forestry Service. The conclusion of 12 years of civil war set in motion the revision of normative and regulatory institutions. These changes respond to the combined impetus of civil society actors seeking greater decentralization and participation and pressures on government agencies to downsize and trim expenditures. External and internal pressures to develop new institutional relationships and incorporate civil society actors in resource management have evolved from consensus-driven national and international agreements to broaden democratic participation at all levels in the post-war period. Simultaneously, however, the implementation of structural adjustment measures have placed considerable pressure on the public sector budget and restricted the ability of the forestry service and other government agencies to deliver services, monitor infractions and enforce environmental legislation (PROGOLFO 1999; IICA 1997).

The forestry service and key agencies such as the National Center for Agricultural and Forest Technology (CENTA) along with the General Directorate for Natural Renewable Resources (DGRNR) have been restructured and downsized, experiencing a significant reduction in the funds available for investment and operations which have undermined their ability to monitor, review and enforce the law or provide extension services. CENTA, an extension agency whose role is to reduce environmental degradation and contamination through the use of appropriate, small-scale and low cost technologies, should be a key element in any strategy to reduce pressure on the mangrove ecosystem. Sadly, CENTA has lost both personnel and financial resources, reducing its national coverage and effectiveness, limiting its research activities and restricting its ability to deliver timely and appropriate technical assistance to small farmers. The DGRNR also lost a substantial portion of its operating budget in 1988 and as a result has been downsized dramatically. Some of the programs formerly conducted through the DGRNR have been passed over to other agencies in the Secretariat of the Environment (SEMA) and later the Ministry of Environment, as well as the Ministry of Agriculture. There is evidence, however, that not all of these programs survived the restructuring and that key monitoring and research activities have been suspended (PROGOLFO 1999; interviews with staff of the Ministry of Environment and Forestry Service 1995-2000).

Increasingly, there is a dissonance between the laws and policies that are on the books and the institutional capacity to enforce these laws or uphold these policies.[29] It is clear in examining the rules and regulations governing the use and transformation of environmental goods and services in the mangroves that there is a real need for coordination between different government agencies, and partnership between the state and private sector and civil society actors. In particular there is an urgent need to review the existing environmental law and the 1973 forestry law for inconsistencies, and to define acceptable management practices and establish effective, democratic and transparent institutions that can administer and regulate sustainable mangrove management (Benítez et al 2000).

The 1860 Civil Code established a set of rights to the mangroves in El Salvador that allowed the owner (be that an individual or the state) to exploit these resources in whichever fashion was consistent with their goals of land conversion or logging. Only after 1949 with the modification of the Agrarian Law, was mention made of the need for the rational use and conservation of forest resources. In that same year, Decree 115 established that the mangroves were state property, although the decree had little effect on the uses to which the mangroves were put. Not until 1969, was there a decree that established norms for the use and conservation of the mangroves.

[29] Many of the laws and statutes that govern resource use in the mangroves are also contradictory or give rise to divergent legal opinions about the use and transformation of resources int he mangroves.

The forestry law that came into effect in 1973 provides the basis for the current assignation of property and access rights to the mangroves. This law defines the terms under which the mangroves may be cut down for logging and fuelwood or converted to other uses. To administer and enforce the forestry law the Forestry Service, a subset of the Ministry of Agriculture, was brought into being. Petitions for rights to use forest land to convert to agriculture, salt, or shrimp ponds were made to the Forestry Service, which would review the claims, and if approved, estimate the number of trees to be cut down, and apply a stumpage fee. The stumpage fee paid to the state was 25 centavos (less than US$0.05 in 1992) for each mangrove tree felled. In May 1992 this fee rose to 2.5 colones per tree as part of a comprehensive revision of law regarding the use and transformation of the mangroves (Paredes et al 1991; MADELEÑA 1992). The stumpage fee was unrelated to the replacement cost and environmental damage, and was too low to provide an effective disincentive for illegal felling or encroachment. Further, because of staffing and budget constraints, the scheme was generally self-reporting, requiring those who had committed the infraction to declare the extent of the mangroves cleared. Occasionally the forestry service was able to verify the amount of mangrove cleared, but in general the stumpage fees levied were not subject to effective monitoring or enforcement (Martínez 1991; Paredes et al 1991; MADELEÑA 1980-1992).

As a result of the partial and inconsistent application of the legal statutes the mangroves became effectively open access resources, where individuals, communities and commercial interests used, transformed and consumed ecosystem goods and services largely without any formal regulation. In response to extensive mangrove deforestation, a logging ban was introduced in May 1992 that forbade further clearance and forest conversion. The ban extended to all use for fuelwood, construction, and commercial trade. Licenses to convert tracts of mangrove forest to for grazing, agriculture, shrimp ponds, or salt flats were also suspended. However, the logging and clearance ban only applied to trees that were being serviced by the tides. If it was possible to establish that the tides no longer service an area of mangrove, an application can be made to remove the remaining mangrove trees. There was no preclusion for 'moral hazard', and the strategic construction of levées and barriers to temporarily starve existing mangroves of tidal influx may have been used to enable the applicant to qualify for land conversion rights.

Enforcement of the 1992 ban was sporadic and uneven. Those under suspicion for illegal logging or mangrove clearance could have been placed under arrest for up to 72 hours. If the party wass found guilty, all physical capital (saws, boats, machinery, etc) may be impounded and a discretionary fine levied. However, such cases seldom come to prosecution, and few infractors have been found guilty of violating the existing law (interview with local branches of the Policía Nacional Civil, 1994). As a result of the lack of enforcement the 1992 ban proved ineffective, and illegal logging and land conversion continued, because of corruption, the lack of appropriate policing and enforcement mechanisms, and inadequate disincentives.

In 1998, a new environmental law was drawn up. The current Environmental Law and the Municipal Code provide a normative framework for communities and citizens to participate actively, democratically and with equal voice in the design and implementation of strategies to reduce environmental degradation (República de El Salvador 1998). As part of an effort to incorporate environmental planning into all aspects of economic and social development, mention is made in the law of the need to undertake comprehensive environmental impact assessments. Any investment, economic or social undertaking that may impact upon the environment is required to have submitted and made public an assessment of the potential environmental damage and those measures that can be taken to mitigate the damage. These impact assessments must have been evaluated within 60 days of their being presented to the Ministry of the Environment and Natural Resources (MARN), a process that includes a public consultation with any interested and aggrieved parties. Once approved, the proposed activity must be subject to periodic evaluation to ensure that the agency or individual is in compliance with the law and undertaking the required mitigation of environmental costs. Moreover, the investor must secure the economic activity by demonstrating that funds are available equivalent to the total cost of the investment itself in the event that compliance is not observed. The investor or investing agency must therefore self-insure for any failure to comply in full with the environmental law.

While some activities have been undertaken in compliance with the new environmental law, it appears that the burden of reporting, monitoring and evaluation placed on the executive branch of the government by the legislature may render complete compliance with this law particularly difficult to ensure. Furthermore, unless communities are given access to complex environmental information and the means to interpret and organize in response to this information, full participation of all affected parties cannot be guaranteed in this process.

Despite these shortcomings, the environmental law provides for all of the attendant monitoring and regulatory requirements that could support collective common property management of the mangroves by multiple stakeholders. Some revision would be necessary however for common property mangrove management to be set in place. The passing of the 1998 Environment Law has led to conflicting mandates with the existing Forestry Law and resulted in the revision of legislation that fails to address the current pressures on the mangrove ecosystem. The enactment of the environmental law passed the normative and regulatory responsibility for protected areas to the Ministry of the Environment and Natural Resources (MARN). However, the Forestry Service retains the responsibility for implementing the Forestry Law. The division of responsibilities and separation of normative and regulatory roles of each of these institutions is still not clearly defined.

In the case of the mangroves, this new environment law requires that MARN implement agreements with the municipalities and other competent local authorities to establish parameters for the protection of natural resources in the coastal – marine zone, developing an integrated management regime. The planning process and its execution, as it is defined in the environment law, requires the participation of all institutional actors and other interested sectors.

Notwithstanding the requirement of a participatory process of negotiation and agreement in El Salvador, the mangroves are defined in the current environment law as “ecological reserves in which no alteration will be allowed”, because they are considered to be highly fragile and vulnerable ecosystems. Unfortunately, the concept of an “ecological reserve” is not adequately defined in the environmental law and no guidelines have been set for how such a reserve can be managed. Furthermore, the rigidity of a mandate that does not permit “any alteration” is inconsistent with the national and local reality, where coastal populations depend on environmental goods and services for their livelihoods. Such a mandate is impractical, as its application will only result in the criminalization of activities and practices that are unlikely to change in the absence of measures to relieve environmental dependence and channel resources to these coastal populations, or to modify and regulate upstream activities that undermine the health of the mangrove ecosystem

Although the controlled extraction of mangrove timber and fuelwood is not permitted under the current environmental law, it is permitted under the existing forestry law. With both laws active, it is uncertain which takes precedence. These contradictions have created confusion among resource users and mangrove public officials alike. The different mandates have been temporarily resolved creating an unofficial procedural loophole that allows an individual or group to petition the Ministry of Environment for the right to clear or cut mangrove trees. The Ministry of Environment must undertake an official inspection to determine that the proposed activity does not damage the ecosystem. If this is established, the Ministry of Environment can then issue a 'technical opinion' with which the individual or group may go to the Forestry Service to seek a permit to cut or fell trees. The legality of this procedure remains in question and it is unclear how many of such permits have actually been sought.

Section V: Conclusions

Poorly defined property rights in combination with the lack of an institutional mandate to harmonize the competing interests of a diverse range of stakeholders in the mangroves exacerbates pressures on the remaining mangrove stands and has contributed to the degradation of the ecosystem in El Salvador. Opportunities exist in El Salvador to redefine property rights, in such a way as to guarantee the sustainable management of the ecosystem while preserving both livelihoods and habitats.

The 1998 Environmental Law provides the rubric for regulated common property management to be devised and enforced. Both national and community rights to the mangroves need to be established to provide clear incentives for the conservation of the ecosystem. Common property rights could be established that recognize both the community access and use rights as well as those of other actors such as industrial and artisanal fishers, aquaculturists and salt producers. The current environmental law and regulatory bodies potentially provide a normative framework for multiple stakeholders to participate actively and democratically in the design and implementation of strategies to reduce environmental degradation. A system of tradeable extraction permits could be devised to ensure that only the sustainable supply of mangrove fuelwood and timber was harvested, with the majority of these permits being given to the local communities within a specified radius of the ecosystem. These permits could be issued through the municipalities and enforced by the environmental division of the National Civilian Police (PNC). Upstream activities that contribute to downstream pollution and sedimentation can also be regulated under the 1998 environmental law but will require further investment in monitoring and enforcement.

Further revision of the legislation and the regulatory framework will be required in El Salvador to produce a workable definition of sustainable mangrove management that incorporates the competing uses and pressures to which the mangrove ecosystem is subject. Resources will also need to be dedicated to strengthening national local institutions to ensure their full and active participation in this process. It is vital that efforts are undertaken to strengthen those administrative bodies that oversee the management of the mangroves in El Salvador and to provide financial support for extension and technology transfer service agencies. The revision of the legislative and regulatory framework should not only focus on governmental structures and functions, emphasis also needs to be placed on the participation of local and community institutions. Enhancing local management capacity is critical for the promotion of more decentralized sustainable management practices. Resources must be dedicated to institutional strengthening, information dissemination and education at the local level with a view to supporting the development of effective and transparent administrative systems that guarantee the protection of the environment and the wellbeing of coastal populations.

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Annex - Tables and Figures

Table 1. Estimated Domestic Fuelwood Demand 1995

	Households	Percent of Households Using Fuelwood	Individuals	Average Demand per Person [a] kg/person/day	Total Demand by Sector Metric Tons per year
Urban	363,118	29	1,615,613	1.19	1,147,366
Rural	482,936	87	2,476,222	3.04	2,335,474
MASS[b]	323,400	36	1,372,350	0.93	97,827
TOTAL	1,169,454	55	5,464,185	1.96	3,580,667

[a] Applying parameters from Current and Juarez 1992. Averages include households that consume and those that do not consume fuelwood, these averages can, therefore, be applied to the whole population.
[b] Metropolitan Area of San Salvador (MASS).
Source: Authors' analysis of the Encuesta de Hogares de Propósitos Múltiples, 1995

Table 2. Estimated Sustainable Fuelwood Supply in 1995

Area that Produces Woody Biomass [a]	Area (ha)	Sustainable Supply (m3/year/ha)	Total Sustainable Supply (m3/year)
Shrub Vegetation	130,528	1	130,528
Diverse Vegetation	165,310	1	165,310
Broadleaf Vegetation[b]	248,185	6	1,489,109
Conifers	27,799	1.8	50,038
Coffee Plantations (low altitude)	99,738	13.7	1,366,411
Coffee Plantations (medium altitude)	42,303	10.85	458,993
Coffee Plantations (high altitude)	21,735	5.15	111,934
Mangrove	42,551	5.4	229,779
Plantation Forest	7,000	6.2	43,400
Without Forest Cover	103,220	0.5	51,609
Total m3			4,097,112
- non-combustible woody biomass m3			826,451
Sustainable Supply in m3			3,270,661
Sustainable Supply in Metric Tons			2,459,144

[a] No account has been taken of the loss of forest due to forest fires.

[b]Includes 52,000 hectares of broadleaf trees and 196,185 hectares of broadleaf vegetation, which comprises broadleaf shrubs, bushes and other woody biomass.

Source: Author's analysis of CEL, CATIE, and BCR data

Table 3. Household Determinants of Domestic Fuelwood Demand in El Salvador, 1995 (s.e.'s)

	Average	**(1) Odds Ratios**	**(2) Odds Ratios**	**(3) Odds Ratios**	**(4) Odds Ratios**	**(5) Odds Ratios**	**(6) Odds Ratios**
Per capita income less than the poverty line	0.54	5.524 ** (0.374)	5.575 ** (0.378)	5.538 ** (0.375)	--	--	--
Per capita income less than the extreme poverty line	0.27	--	--	--	4.996 ** (0.361)	5.216 ** (0.384)	5.045 ** (0.366)
More than 6 household members	0.30	1.548 ** (0.103)	1.499 ** (0.099)	1.518 ** (0.101)	1.695 ** (0.112)	1.620 ** (0.106)	1.651 ** (0.109)
Female-Headed Household	0.28	1.428 ** (0.096)	--	--	1.429 ** (0.095)	--	--
Female-Maintained Household	0.38	--	0.994 (0.062)	--	--	0.895 # (0.057)	--
Headship and Maintenance	0.24	--	--	1.121 # (0.084)	--	--	1.091 (0.081)
Urban Area	0.59	0.049 ** (0.003)	0.051 ** (0.003)	0.051 ** (0.003)	0.057 ** (0.004)	0.058 ** (0.004)	0.058 ** (0.004)
Ex-Conflictive Zone	0.17	2.709 ** (0.224)	2.677 ** (0.221)	2.683 ** (0.221)	2.621 ** (0.216)	2.596 ** (0.214)	2.598 ** (0.214)
Receipt of Remittances	0.15	1.050 (0.092)	1.138 # (0.100)	1.113 (0.098)	0.753 ** (0.063)	0.840 * (0.071)	0.802 * (0.067)
		Chi(6) =4607 n=8482	Chi(6)= 4578 n=8482	Chi(6) = 4580 n=8482	Chi(6) = 4423 n=8482	Chi(6) = 4397 n=8482	Chi(6) = 4395 n=8482

** significant at P<0.01, * significant at P<0.05, # significant at P<0.10

Source: Authors' analysis of data from the Encuesta de Hogares de Propósitos Múltiples, Ministerio de Planificación

Table 4. Marginal Effects of Logit Coefficients for Fuelwood Consumption Regressions

Independent Variable	Logit Coefficient	Variable Mean	Marginal Effect
Poor	1.709	0.54	42.3
Number Household Members>6	0.437	0.30	10.8
Female Headed Household	0.356	0.28	8.8
Urban	-3.002	0.59	-74.3
Ex-conflictive Zone	0.997	0.17	24.7
Remittances	0.049	0.15	1.2
Constant	0.279		
Chi Square	4607		
N	8482		

Table 5. Per Capita Fuelwood Consumption, El Tamarindo, La Unión, 1997

Household Characteristics	Per Capita Fuelwood Consumption Lbs per capita per week	Difference of Means **H₀:** $\overline{x_0} - \overline{x_1} = 0$ **H₁:** $\overline{x_0} - \overline{x_1} > 0$ **H₁':** $\overline{x_0} - \overline{x_1} < 0$	Total Amount of Fuelwood Consumed Each Week Lbs per household per week	Difference of Means **H₀:** $\overline{x_0} - \overline{x_1} = 0$ **H₁:** $\overline{x_0} - \overline{x_1} > 0$ **H₁':** $\overline{x_0} - \overline{x_1} < 0$
Non-Poor Households [a]	48.83	$H_{1'}$: 0.16	153.46	H_1: 0.39
Poor Households [b]	46.67	(1) H_1: 0.45 (2) $H_{1'}$: 0.14	189.43	(1) $H_{1'}$: 0.25 (2) H_1: 0.18
Extremely Poor [c] Households	33.38	H_1: 0.08	146.10	H_1: 0.42
With gas cooker	31.50	H_1: 0.35	125.28	H_1: 0.37
Without gas cooker	43.02		159.99	
With Remittances	40.74	H_1: 0.38	131.89	H_1: 0.11
Without Remittances	43.95		176.70	
Defacto Female-Headed	61.13	$H_{1'}$: 0.02	183.46	$H_{1'}$: 0.19
Defact Male-Headed	35.23		147.52	
Female-Maintained Households	62.80	$H_{1'}$: 0.01	186.16	$H_{1'}$: 0.19
Male-Maintained Households	36.06		150.01	
Fishing Households	43.08	$H_{1'}$: 0.47	172.19	$H_{1'}$: 0.20
Non-fishing Households	42.20		143.13	
Total (n=134)	42.68		158.95	

[a] The non-poor are compared with poor and extremely poor
[b] poor are compared with (1) non-poor and with (2) extremely poor
[c] extremely poor are compared with non-poor.

Notes: Domestic consumption and commercial use are combined. Per capita consumption normalizes total consumption by household size and does not represent only that amount used for household consumption.
The poverty line is defined using the minimum cost of a basket of basic goods. This corresponds to 84.18 colones per person per week in 1997. The extreme poverty line is half of the poverty line. The exchange rate was $1=8.8 colones in 1997.
Source: CEASDES Household Survey data El Tamarindo 1997

Table 6. Shrimp and Salt Cultivation, 1985-1996

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1996
Extensive Shrimp Cultivation	261	238	238	222	222	222	220	2542	1381	2378
Intensive Shrimp Cultivation	.	232	381	197	197	197	44	27	35	164
Salt Ponds	2,978	2,508	2,359	2,558	2,558	2,258	2,300	2,542	2,421	2,548

Source: Author's calculations from CENDEPESCA 1985-1996, PROGOLFO 1998, IUCN/DANIDA 1992

Table 7. Variation in Vegetative Cover and Land Use in the Gulf of Fonseca, Hectares

Land Use	1976	1997	Absolute Difference
Woods	202,026	150,484	-51,542
Fallow	216,868	155,555	-61,313
Cultivated	94,823	154,047	59,224
Pasture	56,957	101,516	44,559
Areas Cleared by Burning	9,147	7,774	-1,373
Denuded Soils	202	53,575	53,373
Shrimp and Salt Ponds	6,920	24,309	17,389

Source: PROGOLFO, 1999

Table 8. Results of an Analysis of Sediments in Estuaries and Confluences in El Salvador, 1990

Site		Concentration of Arsenic (ppm)
Barra de Santiago	Estuary and mangrove ecosystem	54.8
Barra Salada	Estuary and mangrove ecosystem	74.7
La Herradura	Estuary and mangrove ecosystem	54.6
Puerto El Triunfo	Estuary and port	41.1
Puerto Parada	Estuary and mangrove ecosystem	74.9

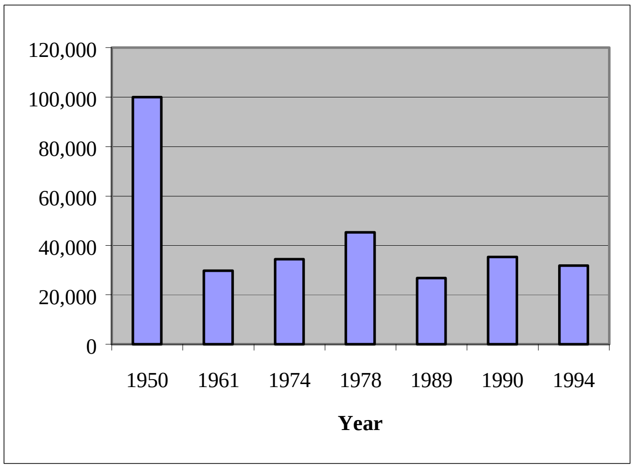
Source: Adapted from Requena and Myton (1991)

Table 9. Contamination of Surface and Underground Water in El Salvador 1989, Percentages

	Nitrates	Nitrites	Amonium Nitrate	Phosphate
Surface Water	97.87	71.12	88.24	96.26
Underground Water	95.85	81.25	83.33	95.85

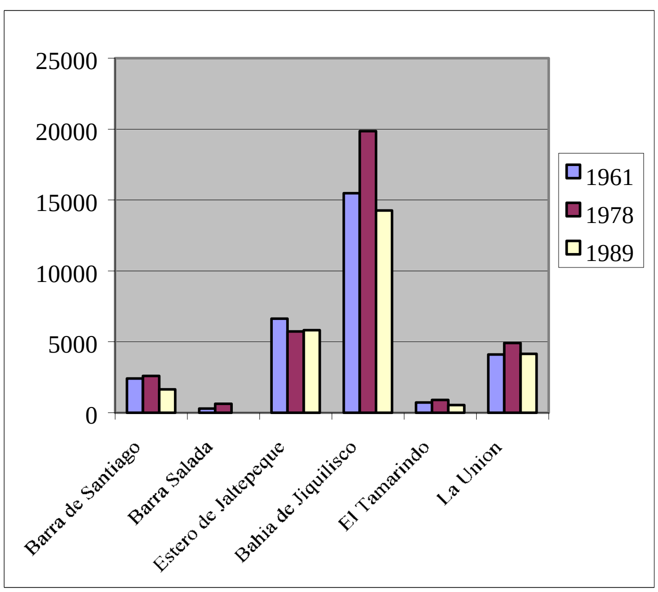
Source: M. Méndez, R. Miranda and G. Ramirez (1989), cited in Rubio, Germain and Góchez (1996)

Figure 1. Mangrove Extension in Hectares in El Salvador, 1950-1994



Source: Rubio et al 1997; Ministerio de Agricultura y Ganaderia 1994, 1978; Cueva 1962

Figure 2. Mangrove Extension in Specific Ecosystems in El Salvador



Source: Rubio et al 1997; Ministerio de Agricultura y Ganaderia 1994, 1978; Funes and Villagran 1994; Cueva 1962

Figure 3. Population-Consumption-Environment Linkages

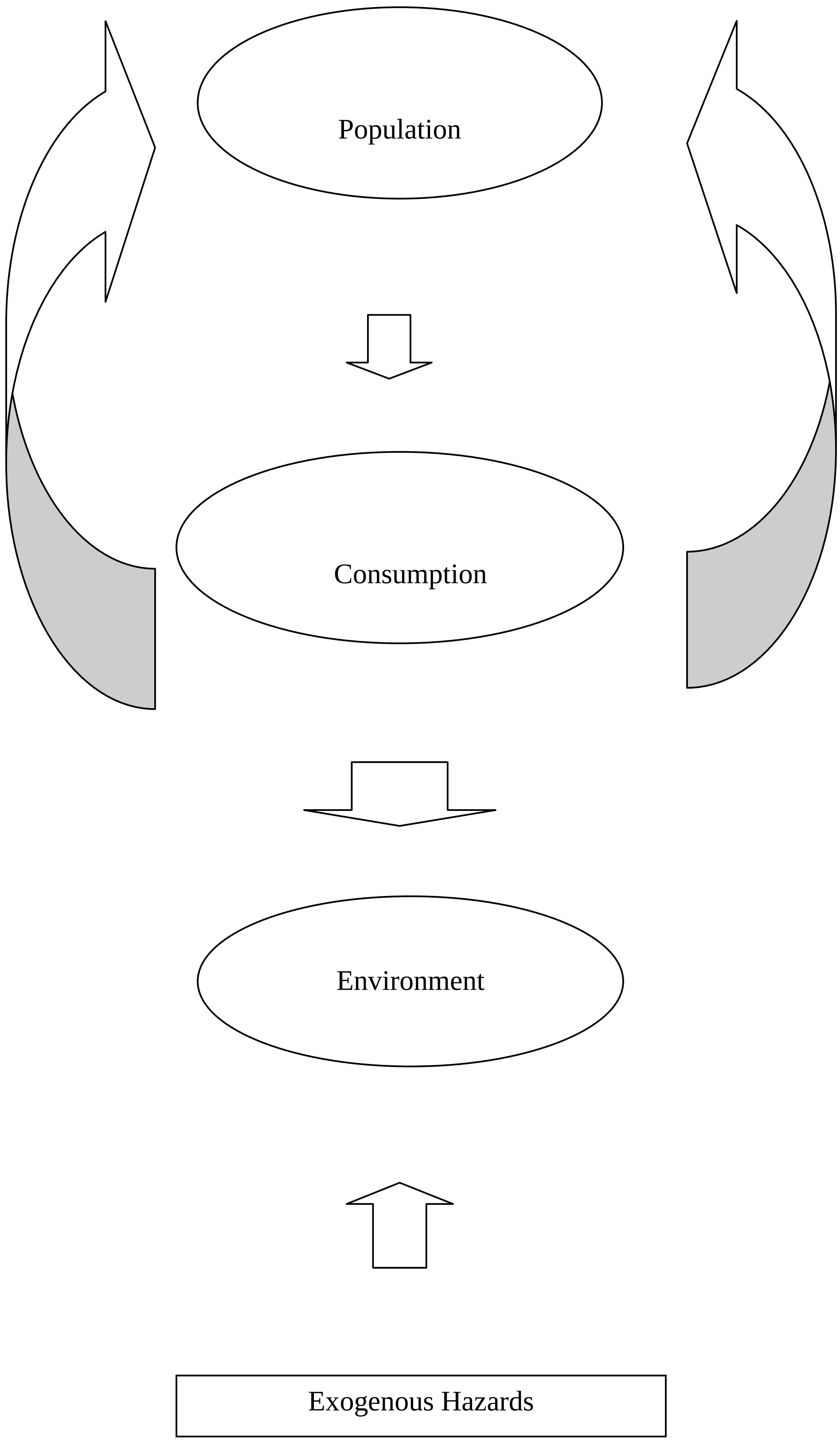


Figure 4. A Profile of Key Stakeholders and Human-Environment Interactions in the