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AN ECONOMIC MODEL OF THE LOS OLIVITOS MANGROVE ECOSYSTEM IN VENEZUELA

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ABSTRACT.- An economic model that will allow us to analyze different management options for the Los Olivitos mangrove ecosystem, in western Venezuela, is presented. A basic economic problem behind any ecosystem management decision is the allocation of natural resources. It is a matter of making the appropriate "trade-off" between preservation and changes in resource uses. This trade-off requires a value analysis of the variable functions and goods provided by the wetland. The model takes into account the ecological knowledge presently available; and considers eight ecosystem features: S_1 = the current stock of mangrove (mangrove biomass), S_2 = the fish stock, S_3 = a vector which describes all the Los Olivitos characteristics eventually attracting tourists, S_4 = carbon sequestration mangrove service, S_5 =

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nutrient stock, S_6 = salinity, S_7 = biodiversity, and A = area above sea level. The different components of the economic value of the ecosystem will be estimated via eight equations. *Received*: 29 May 1996, *Accepted*: 25 September 1996.

Key words: Economic model, ecosystem management, mangrove, Los Olivitos, wildlife refuge, Zulia State, Venezuela.

MODELO ECONÓMICO DEL ECOSISTEMA DE MANGLAR DE LOS OLIVITOS EN VENEZUELA

RESUMEN.- Presentamos un modelo económico que nos permitirá analizar las diferentes opciones de manejo del ecosistema de manglar de Los Olivitos en el occidente de Venezuela. Toda decisión de manejo de ecosistemas conlleva un problema económico de asignación de recursos. Se debe escoger entre conservar o modificar los recursos. La toma de una decisión óptima requiere de un análisis del valor que tienen los diversos bienes y servicios suministrados por los humedales. El modelo toma en consideración la información ecológica actualmente disponible para describir los vínculos entre las principales características del ecosistema: S_1 = biomasa del manglar (cantidad actual de manglar), S_2 = la cantidad de peces, S_3 = el vector que describe los principales atractivos turísticos de Los Olivitos, S_4 = cantidad de Carbono secuestrado por el bosque de manglar, S_5 = cantidad de nutrientes almacenados, y S_6 = salinidad, S_7 = biodiversidad y A = área por encima del nivel del mar. Se definen ocho ecuaciones a través de las cuales se podrán estimar los diferentes componentes del valor económico del ecosistema. *Recibido*: 29 de Mayo de 1996, *Aceptado*: 25 de Septiembre de 1996.

Palabras claves: Modelo económico, manejo de ecosistemas, manglar, refugio de fauna, Los Olivitos, Estado Zulia, Venezuela.

INTRODUCTION

Mangrove ecosystems provide a number of services to society, but unfortunately, mangroves have diminished considerably in the

World. The decision makers, not having information about the goods and services that society derives from mangroves very often select to convert them to other uses. It also happens that even if they have the appropriate information, they many lack the incentive to appreciate all the services available.

There is always a basic economic problem behind any ecosystem management decision: the allocation of the natural resources. It is a matter of making the appropriate "trade-off" between preservation or changes in resource uses. This trade-off requires a value analysis of the available functions provided by the wetlands. To do that, quantitative models of mangrove forests as ecosystems must be established.

In the early 1980's, the Los Olivitos area (Fig. 1) was claimed by industrial capital (shrimp and salt production). Initially, the industrialists contemplated the almost total elimination of the Los Olivitos mangrove; and a national debate started about how to allocate the land. As a result, a trade-off among the different parties involved in the debate was made in 1986 and another in 1991. The area was then distributed allocating pieces of the land for the shrimp, salt and conservation activities (Fig. 2). Since then, about 20.000 ha has been declared a wildlife refuge and fishing reserve and is under the administration of Profauna, an autonomous institution within the Environmental and Renewable Natural Resources Ministry (MARNR). However, due to the Venezuelan financial crises in the second half of the 1980's, these salt and shrimp industries never started to produce. During this time (from the mid 1980's to the present) only Profauna has continued activities. The national economic situation is now turning to a more liberal economy with more open markets and new capitals are forthcoming. For instance, salt production will resume in the near future with the aid of foreign capital. At the same time, the severe fiscal deficit may eventually cause a relaxation of the countries' conservation policies. Profauna would need to look for new funds.

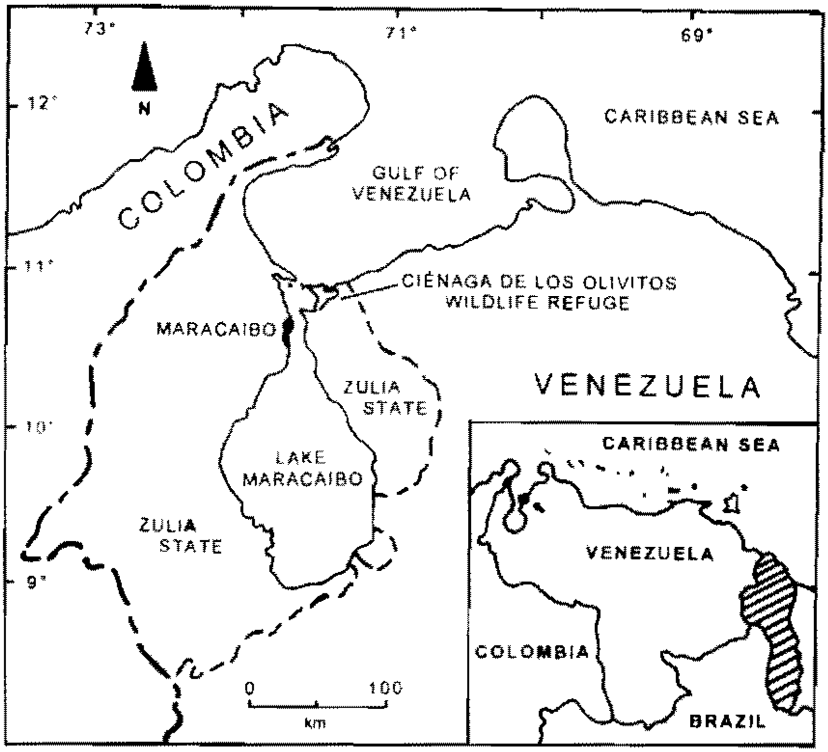

FIGURE 1. Location of the Ciénaga de Los Olivitos Wildlife Refuge and Fishing Reserve in the Los Olivitos estuary, Northeast of Maracaibo, Western Venezuela (10° 48' - 10° 59' N; 71° 20' - 71° 33' W).

According to this situation three different scenarios may occur: 1) No changes in the actual situation, 2) conservation policies will change to improve a sustainable development of the area, and 3) industrial activities along side or even inside the wildlife refuge.

In order to establish a conceptual framework for dealing with these issues, a very simple model will be developed, without taking into account all relevant ecological factors but only those that are available. Thus, the aim of this paper is to develop a model that

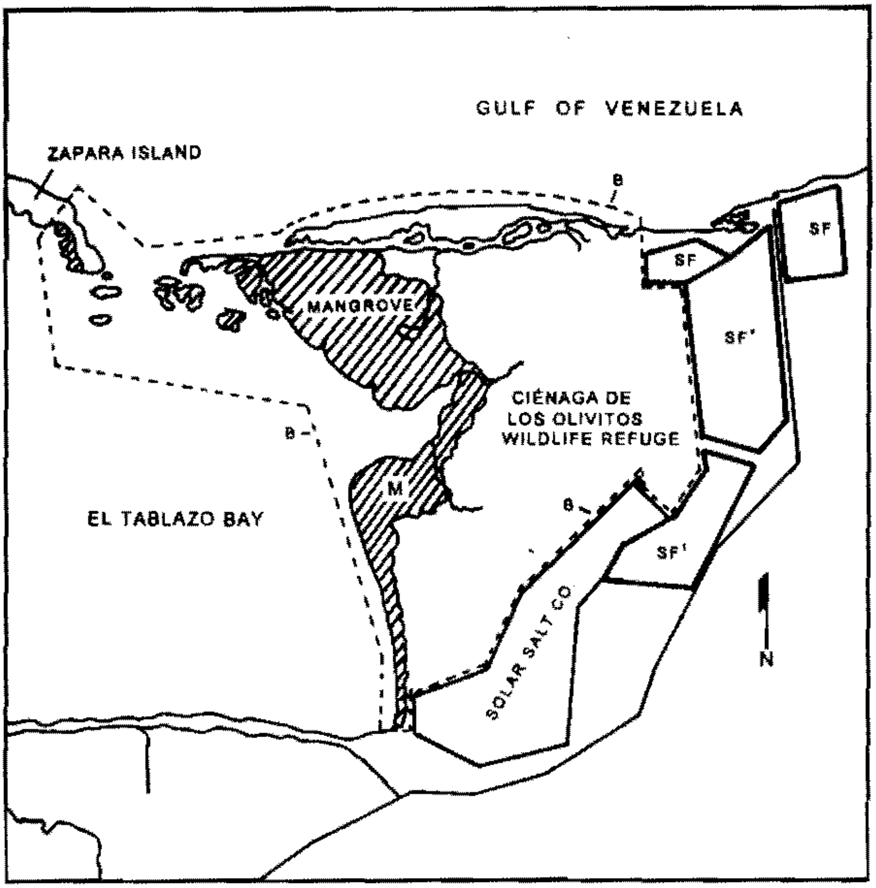

FIGURE 2. Los Olivitos estuary, showing boundary lines of the Ciénaga de Los Olivitos Wildlife Refuge and Fishing Reserve, shrimp farms (SF), and the solar salt company (construction in progress). [1] = not yet constructed; M = mangrove forest.

allows us to analyze different management options for the Los Olivitos mangrove ecosystem, and represents a methodological approach for a consistent economic valuation of the area.

We first describe the main goods and services that the Los Olivitos mangrove ecosystem offers. We then describe the relevant ecological and economic links present in the area by means of a set of mathematical expressions; and finally, we identify the economic valuation techniques that could be applied in each case.

This methodology is presently being implemented by an interdisciplinary team of economists, biologists, an ornithologist, and an ecologist belonging to three different faculties of the University of Zulia (Maracaibo, Venezuela) with advice from the Beijer International Institute of Ecological Economics, Stockholm, Sweden.

Los Olivitos: main goods and services.

In the Southern Caribbean Sea, the more important environments include the Maracaibo System, much of the Gulf of Venezuela, the Ciénaga Grande de Santa Marta, and the Gulf of Urabá. The Los Olivitos mangrove lies within the Maracaibo estuary, second in importance only to the Orinoco Delta. The estuary receives the outflow of both Lake Maracaibo (12,500 km^2) from the South, and the Limón River from the Northwest (Cervigón *et al.* 1993). Approximately 15,000 ha of the Los Olivitos estuary has been declared (1986 and 1991) a wildlife refuge and fishing reserve.

The Los Olivitos mangrove forest consists of about 5,346 ha, located in Northeast Zulia State, Venezuela. It is irrigated from the west by estuarine waters of El Tablazo Bay, from the North by marine waters of the Gulf of Venezuela, and from the East by freshwater from the Palmar and Cocuiza River's floodplains. Four types of forest are present: Red Mangrove (*Rizophora mangle*), Black Mangrove (*Avicenia nitida*), mixed forest and White Mangrove (*Laguncularia racemosa*); Buttonwood (*Conocarpus erectus*) is present in very small quantities. Together with adjacent habitats, Los Olivitos estuary covers about 20,000 ha (Casler and Lira 1983, Galue and Nucette 1982). In general, the ecosystem can be divided into four habitats: mangrove forest, open water areas, salt flats, and sandy beaches with some small dunes.

Los Olivitos is an important resting, feeding and nesting site for many species of birds. To date, 112 species of birds have been observed, and 33 % are migratory from North America. This estimate is conservative because many small terrestrial species have not yet been adequately inventoried. Bird species include the Greater Flamingo, Brown Pelican, Magnificent Frigatebird, Neotropic Cormorant, and several species of herons, migratory terns and shorebirds (Casler and Lira 1983, Casler 1987, Pirela *et al.* 1992, Casler *et al.* 1994). Some species in Los Olivitos are found in low numbers or are threatened. Such is the case for the Greater Flamingo, Osprey, Red Knot, Reddish Egret, and the Scarlet Ibis. Also, it is the only Venezuelan site where flamingos are known to nest. In 1987, the Los Olivitos flamingo colony was the largest in the Southern Caribbean, with 4,015 nests, or about 8,000 breeding birds (Casler *et al.* 1994).

Los Olivitos is also an important trophic zone and nursery area for several commercial fish species, crustaceans, and other aquatic organisms. The mangroves of San Carlos (western shore of Lake Maracaibo) and Los Olivitos contribute to 50 % of the catch of Zulia State (ICLAM 1983). Among Colombia, Trinidad and Tobago, Guyana, Suriname and French Guyana, Venezuela is the most important fishing nation with an annual catch of about 250,000 tons. Seventy percent is from the high productivity area of the coastal upwelling zone, including 40,000 to 70,000 tons of sardines. Artisan fisheries contribute 60-65 % of the total Venezuelan catch (Cervigón *et al.* 1993). The Los Olivitos mangrove serves as a nursery area for economically important species (González and Brito 1987, Ferrer 1994). Both white shrimp and blue crabs are exported from Zulia State. Los Olivitos supports *in situ* fishing of white shrimp and some bivalve mollusks. Oyster fishing has declined however, due to over exploitation and poor fishing practices (unpubl. data).

Historically, mangrove trees at Los Olivitos were once used commercially for firewood, but this activity declined with the introduction of the gas stove. At present, there is little timber harvesting, except for the immediate needs of the local fishermen (unpubl. data).

Local inhabitants have also hunted at Los Olivitos for some traditional game species such as the green iguana, and ducks. During the 1940's, the coastal crocodile was hunted extensively.

Since the 1950's, the southern part of the estuary has been used by small salt producers. Within the Los Olivitos system, about 3,400 ha will be utilized by Produsal to harvest salt commercially. Also, within the wildlife refuge, it is legal to exploit up to 3,500 ha for salt harvesting. Actually, however, there are only 4 ha within the refuge where salt is harvested, and by hand.

Because the area is inaccessible by road, it still remains relatively unknown by both regional inhabitants and out-of-state visitors. Recreational activities along the beaches of Quisiro (available by road), to the East of Los Olivitos, are more developed for this purpose, and are similar to the Los Olivitos beaches.

Theoretical framework for economic analysis

We previously emphasized that fish, shrimp and salt production are significant economic activities actually in process at Los Olivitos. Also, it is evident that Los Olivitos has been a potential place for tourism activities, such as bird watching, beach recreation and nature enjoyment. Timber harvesting is not an important activity, probably due to the legal protection, and, as such, represents another source of value of the mangrove ecosystem. The ecosystem also provides other important services like carbon sequestration, shoreline and biodiversity protection.

What follows should only be interpreted as a preliminary outline of one of the possible models for a complex ecological system and the services it provides for the local community. It considers the different sources of value and the ecological relationships that exist among them.

Description of the model

Let S_1, S_2, S_3, S_4, S_5, S_6, S_7 and A, be the following ecosystem features:

S_1: Current stock of mangrove (mangrove biomass),
S_2: Fish stock,
S_3: A vector describing the major tourist attractions of Los Olivitos,
S_4: Carbon sequestration by mangrove,
S_5: Nutrient stock,
S_6: Salinity,
S_7: Biodiversity, and
A: Area above sea level.

In the following equations we are able to express mathematically that these ecosystem features are not independent of each other, but on the contrary, are tied together through the ecosystem as shown in the following model:

1) $dS_1/dt = g_1(S_1, S_6) - q_1$,
2) $dS_2/dt = g_2(S_1, S_2, S_5) - q_2$,
3) $S_3 = (S_1, S_2, S_5, H)$,
4) $dS_4/dt = \alpha\, g_4(dS_1/dt)$,
5) $z = f^4(S_1, S_2, K_z, L_z)$,
6) $dS_6/dt = m - \beta y$,
7) $S_7 = (S_1, S_2)$, and
8) $dA/dt = \gamma dS_1/dt$.

Timber.- Equation No. 1 expresses that changes in the Los Olivitos biomass depend on the changes that may occur in the current stock of mangrove, the salinity and the harvest (q_1):

1) $dS_1/dt = g_1(S_1, S_6) - q_1$

The harvest variable is probably not high because the mangrove at Los Olivitos is in a wildlife refuge.

We will estimate the timber use value as follows: timber use value = $p_t \cdot q_1$ - c, where p_t = market price of wood (or market price of a substitute for mangrove wood, as cutting mangroves is illegal), q = the amount of wood harvested, and c = the opportunity cost of labor.

Fishery.- The fishery at Los Olivitos is very important. Equation No. 2 expresses that changes in the fish stock will depend on the mangrove stock, the fish stock itself, the nutrient stock and the catch (q_2):

$$2)\ dS_2/dt = g_2(S_1, S_2, S_5) - q_2.$$

Estimation of the fishing use value of mangroves will require a special model to be described in a future paper.

Tourism.- Equation No. 3 describes the attractive ecosystem features of Los Olivitos that can affect tourism there, such as enjoyment of biodiversity, sport fishing and beaches. An excess of nutrients in the water could eventually affect the tourism appeal in an adverse manner. So does an improvement in the infrastructure, included in our model as H (the amount of capital invested in infrastructure):

$$3)\ S_3 = (S_1, S_2, S_5, H),$$

where the current mangrove stock is used as a proxy for biodiversity.

We will derive the demand function for Los Olivitos as a tourist destination $f^3(p, I, S_3)$, where p = cost of the travel and stay there, and I = income.

This estimation would be an application of the travel cost method.

Carbon sequestration.- Los Olivitos serves society as a sink for greenhouse gases. This function of carbon sequestration depends directly on the stock of biomass, and it is represented in the model by equation No. 4:

$$4)\ dS_4/dt = \alpha g_4\,(dS_1/dt).$$

We will estimate this value using the available information from joint implementation agreements. They give us an international price for reduction of carbon content in the atmosphere. The amount of carbon absorbed by the Los Olivitos mangrove will be determined by normal ecological measures (Odum 1972).

Shrimp production.- The production of shrimp (z) will depend on the mangrove area, the fish stock, amount of nutrients, and salinity. It also depends on the inputs in capital (K_z) and labor (L_z):

$$5)\ z = f^5(S_1, S_2, K_z, L_z).$$

The shrimp use value will be estimated by determining income for shrimp sales and deducting production costs.

Salt production.- The salinity depends on the inflow of seawater (m) and the salt production:

$$6)\ dS_6/dt = m - \beta y,$$

where β is a parameter, $y = f(S_6, K_s, L_s)$, and $m = f(K_m, L_m, \delta)$, being δ the natural sedimentation.

The use value of Los Olivitos due to salt production would be the difference between the sale revenues and the production costs. That is $(p_s \cdot y) - (rK - wL)$, ($p_s$, r and w are the corresponding prices).

Biodiversity.- We considered biodiversity a non use value. To estimate the willingness to pay by Venezuelan citizens for biodiversity changes when we switch from one scenario to another, we will undertake a contingent evaluation study, which is currently being designed:

$$7)\ S_7 = (S_1, S_2).$$

Shoreline protection.- Shoreline protection against the energy of waves and wind is another important function accomplished by mangrove forests, and is related to the mangrove area (A):

$$8)\ dA/dt = \gamma dS_1/dt.$$

The effects of the changes in the shoreline produced by a substantial reduction of the mangrove area are not well known. The value of the losses could perhaps be estimated by the cost of an artificial barrier.

This description of the system should make absolutely clear that the economic analysis of mangrove forests must be an exercise in capital theory. There are many stocks of assets involved - the amount of biomass, the fish population, the nutrient stock, and the extent of the shoreline. The returns on these assets will, in general, affect the well-being of individuals.

Although this is a non linear model, it represents a very simplified description of the interactions in a mangrove ecosystem, and is sufficiently complete to raise some important questions that must be addressed in the future. In particular, the system is a dynamic system, that evolves over time. It is well known that systems like this may have some peculiar properties (Devaney 1987; Holling 1973, 1987; Drazin 1992). In particular, if the system is disturbed (by pollution, by changes in sea level, by changes in local hydrology, etc.), it may change into a completely different stability domain. What we observe today is mainly an equilibrium which presumably is stable under small perturbations. However, if the system is perturbed sufficiently, we may see a bifurcation. A bifurcation is an abrupt change in the behavior of the system due to such perturbations. In other words, the system may, perhaps irreversibly, change into a very different equilibrium. Resilience is defined simply as the size of disturbances the system can be exposed to without undergoing such bifurcations. Thus, resilience is the buffer capacity of the ecological system. In our empirical analysis, we will not be able to take such dynamic effects into account, as we do not know the dynamics of the system well enough.

The system may also be chaotic. That is, it may be impossible to predict the future equilibrium of the ecological system because the equilibrium will depend very much on its present state and we will never know that state sufficiently well. There are well known cases where ecosystems have been found to be chaotic. For example, Professor Pastor (pers. commun.), ecologist at the Univ. of Minnesota, has shown that interactions between various tree species and wildlife create chaos in some northern boreal forests. Similarly, chaos is known to occur in fisheries. In fact, Costa Duarte (1994) has shown that fishery management may cause chaos and unpredictability of the future state of the fishery.

Is Los Olivitos chaotic? We do not know but chaos is usually occurring when the growth rates of some species are high. Perhaps some subsystems are chaotic, for example, the increasing population of cormorants at Los Olivitos.

More relevant are the possibilities of bifurcations. The reason why this should be addressed is that almost all non-linear systems have bifurcations. There are thresholds in most ecological systems. What are the thresholds in Los Olivitos? Our present study ignores this issue, but the question What is the resilience of the Los Olivitos mangrove forest? should be addressed in the future.

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