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Community strategy for mangrove forest conservation: Conquista Campesina Conservation Easement

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Abstract. The drafting of a community plan for mangrove forest conservation in the communal land of Conquista Campesina (Tapachula, Chiapas, Mexico) is part of a more ambitious project aimed at establishing a protected wetlands corridor in the coastal region of the state of Chiapas. The purpose is to guarantee the conservation, protection and restoration of priority wetlands, placing special emphasis on vulnerable ecosystems.

With the technical support of Pronatura Sur A. C. and after signing a conservation agreement (conservation easement), the inhabitants of the communal land undertook to carry out activities for conserving and restoring 824 hectares of land for common use containing 616 hectares of mangroves and 208 hectares waterbodies between natural water channels (esteros) and grasslands.

Zoning of land use was executed through constant monitoring, pursuant to the physical and biological features of the area, and in agreement with the direct users of the system. In this respect, the proposed categories of action are: ecological rehabilitation areas; areas for the domestic exploitation of mangroves; conservation areas and areas with a potential for exploitation.

On a whole, agreement was reached with respect to these categories with the inhabitants of the Conquista Campesina communal land, in keeping with their interests and needs. The phases of activity identified are: a) use of organic matter, b) use of parts and derivatives and c) rehabilitation of water courses.

Keywords. Mangrove, conservation, community plan, Mexico

1. Introduction.

This study is part of a more ambitious initiative for establishing a protected wetlands corridor in the coastal region of the state of Chiapas, promoted by Pronatura A. C. The ultimate objective of this project is to guarantee the protection and restoration of priority wetlands of the entity through alternative legal conservation mechanisms. In particular, the project focuses on vulnerable ecosystems, due to the absence or inefficiency of official strategies to protect them.

Within this context, the Conquista Campesina communal land is located on the Coastal Plain of Chiapas, in the township of Tapachula. It forms part of the Pozuelos-Murillo lagoons system and is also inside the Gancho Murillo Nature Conservation Zone. Unfortunately, this state reserve has no action plan to guarantee the conservation of the ecosystem of reference in the long term. It contains large extensions of mangroves corresponding to the Rhizophora mangle (red mangrove), Avicennia germinans (black mangrove) and Laguncularia racemosa (white mangrove) species. Due to their nature and extension, these mangrove forests serve as feeding, resting and reproduction areas for a wide range of animal species subject to certain protection categories.

Based on their awareness of the importance of their land, in 2006 the inhabitants of the communal land took the necessary steps to establish the first Community Conservation Easement for protecting and restoring mangrove ecosystems. With the technical support of Pronatura Sur A. C. and after signing this agreement, the inhabitants of the communal land undertook to carry out activities for conserving and restoring 824 hectares of land for common use containing 616 hectares of mangroves and 208 hectares of waterbodies between natural ponds (esteros) and grasslands.

Based on a series of previous diagnoses, this common land has diverse problems, arising mainly from the effects of the natural water dynamics resulting from the silting of natural canals (due to sediment pulses from the mid and high parts of the Cahoacan River basin) and the stagnation of the water column as a result of the felling and accumulation of mangrove trees torn down by hurricanes and tropical storms. Both processes have given rise to serious problems

of hypersalinisation and pyritisation in water and soil across extensive areas of this communal land. The effects are quite evident in the death of many mangrove trees, leading to the loss of arboreal diversity (simplification) and structural changes in individuals and populations. According to the monitoring data in the area, the ecosystem has a change rate of approximately 5% per year.

Faced with this scenario, and supported by Pronatura Sur A. C, the inhabitants of the Conquista Campesina communal land decided to set up a series of basic studies for generating a community intervention plan, based on the development of local capacities, the generation of information in situ and the execution of ecological restoration actions in the region.

2. General Objective

To conserve the mangrove ecosystem in the communal land of Conquista Campesina in Tapachula, Chiapas for the social and environmental benefit of the region, through community planning and the organisation of activities for the ecological rehabilitation and improvement of the area.

3. Specific Objectives

To conserve the communal forest areas in which the mangrove species Rhizophora mangle, Avicennia germinans and Laguncularia racemosa are distributed.

To execute actions aimed at ensuring the rehabilitation and improvement of the ecosystem (hydrological rehabilitation, reforestation, extraction of dead wood) in order to recover and increase the extension of the mangrove populations.

To develop local technical and organisational capacities for controlling the ecosystems and their resources.

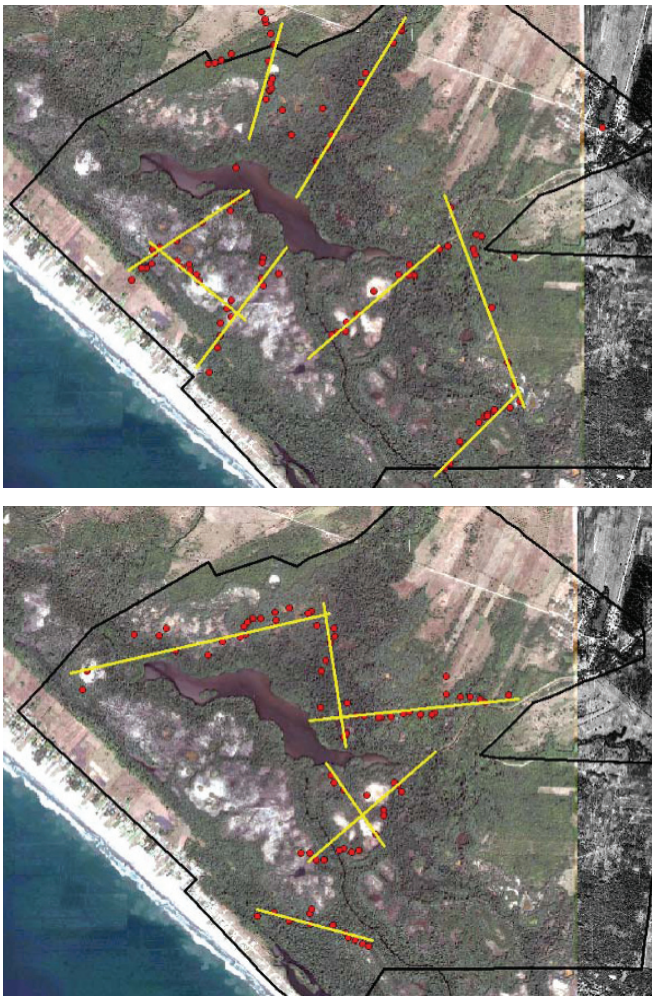
4. Social Participation

As part of the techniques and methods used to analyse complex systems, focus on social participation is an effective tool, not only in terms of local knowledge of the region which is extremely useful for understanding the logic of appropriating the resources, but also because the process includes a definition of the mechanisms for generating responsibility and awareness among the population regarding environmental protection and conservation and a definition of the skills and capacities for achieving that goal.

Within this context, with a view to obtaining field information, diverse participative techniques were established (workshops, meetings, etc.) for the purpose of getting the inhabitants of the Conquista Campesina communal land to participate in defining the work strategies, zoning of the land in keeping with its needs and the available knowledge about it, identifying weaknesses and the capacities needed to execute the work, and envisaging the future with respect to the usefulness and environmental services for the mangrove ecosystem.

In this way, the work was carried out in accordance with their traditional community self-help systems (tequios), all of which concluded with the setting up of a permanent brigade formed by a total of ten persons, who received intensive training on diverse topics related to the following aspects: a) the effect of hurricanes on coastal ecosystems (mangroves, natural water channels, estuaries and coastal lagoons; b) environmental vulnerability and risks; c) main factors determining the structure and function of the mangrove ecosystems: hydrological dynamics, salinity and micro topography; d) biological sucesión and natural regeneration in mangrove forests, e) technical concepts for the selective clearing of seedlings; f) basic principles of ecological rehabilitation in mangrove forests: rehabilitation, improvement, reconstruction and recovery; g) rehabilitation of water flows, their importance and working techniques: removal of silt, digging and consolidation of water channels; h) elements for planning a hydrological rehabilitation project: selection of the sites, diagnosis, design, execution, evaluation and monitoring activities; i) use of tools and equipment for removing the wood in natural water channels and; j) techniques for dispersing organic matter in mangrove forests: concept, criteria and indictors. That training programme had a length of 40 hours of study, divided into eight sessions of five hours, during the course of one month.

Most of these subjects were imparted in theoretical and practical sessions organised in the same areas in which the sampling was done, for the purpose of allowing the brigada to become familiar with the botanical, hydrological and topographical conditions of each site and identify potential limitations.



Figures 1a and 1b. Transects for mangrove linkages mapping

5. Characterisation of plant associations

The spatial layout of the vegetation and its structure makes it possible to identify the trends in the development of the vegetation (succession, colonisation, etc.) and the main factors that determine it.

From the ecological standpoint, it is of vital importance to know those trends, since the success of the different phases of the handling activities depends on this: a) selection of the area; b) identification of the most appropriate species to be handled c) individual density; d) appropriate season for the handling activities and; e) monitoring needs with respect to each site.

Within this context, technicians and locals executed intensive field work campaigns in order to identify the structure and composition of the mangrove forest. To that end, samples were taken in the area from 14 transects, six of which were laid out transversally to the waterbodies, for the purpose of identifying the effects of the water and salinity in the vegetation distribution. The eight remaining transects were perpendicular to the waterbodies, with the aim of corroborating the characterisation model and incorporating the topographical variable as a limiting factor with respect to botanical succession (figures 1a and 1b).

As a result of the above, 198 GPS points were taken, accompanied by 297 photographs. Each point is accompanied by an average of 1.5 photos and an expert description provided by a mangrove forest specialist. The linkage mapping was executed after the first run.

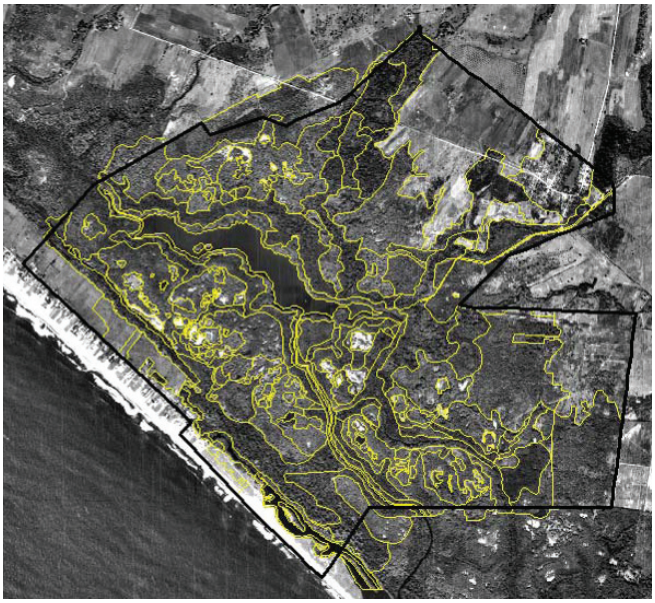


Figure 2. Linkage mapping of vegetation in the Conquista Campesina Community

That mapping was done via a Geographic Information System using the ESRI ArcGIS 9.0 programme. Two different images were used: a 2006 Digital Globe satellite image in colour available in Google Earth and a black and white digital orthophoto from 1996 supplied by INEGI. Using the GPS points with their photos and descriptions, digital signatures were identified for the vegetation in both images. This made it possible to extrapolate from the points for generating polygons or segments representing the vegetation cover in Conquista Campesina.

The final result of this process is the linkage mapping shown in Figure 2, for the Conquista Campesina Conservation Easement. This was digitalised on both images (orthophoto and *Goble* image) through the digital signature recognition arising from the analysis of the information obtained from the transects. In this way, 22 elements in the landscape of the communal area were identified, of which five are non-vegetative geo shapes (water, town, elevated terrain, etc.) and 17 represent natural and induced vegetation groups (Table 1).

Table 1. Linkage mapping categories in the Conquista Campesina Community

Geo shapes	Land Use
Township	Acahual
Water channel	Crops
Open clearing	Inland vegetation
Waterbody	White mangrove
Elevated terrain	Open black mangrove
	Black mangrove
	Red mangrove
	Mixed black and white mangrove forest
	Mixed red and black mangrove forest
	Mixed white and black mangrove forest
	Mixed black and red mangrove forest
	Mixed black mangrove and inland vegetation forest
	Mixed black, red and white mangrove forest
	Mixed red and white mangrove forest
	Red and black mangrove forest mixed with inland vegetation elements
	Mixed red, black and white mangrove forest
	Mixed inland vegetation and mangrove forest

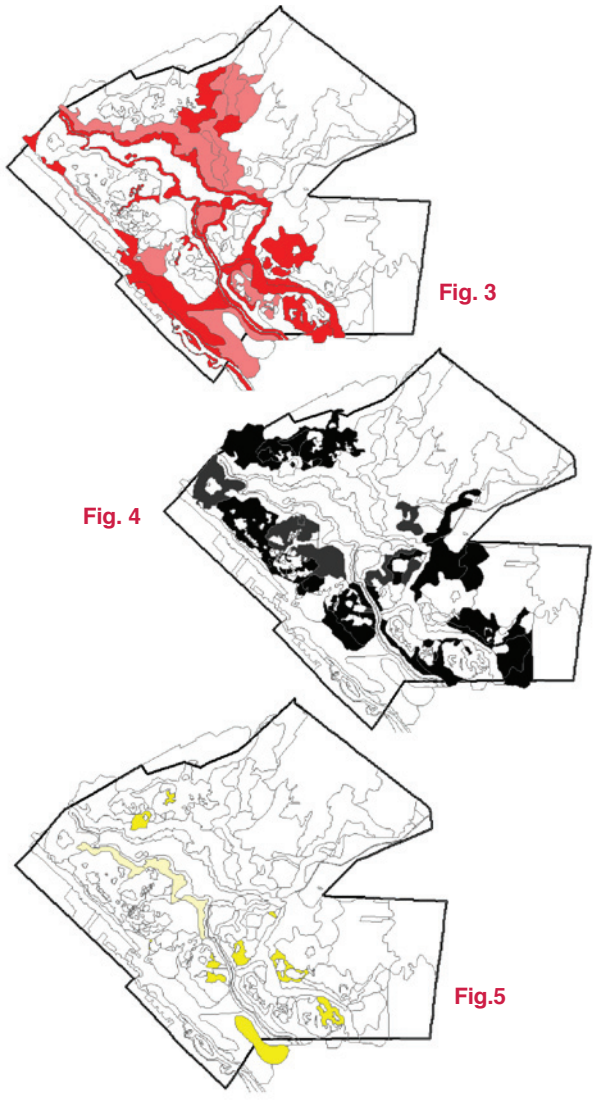
Following an analysis of all the information obtained, it is concluded that the mangrove forest on the communal land of Conquista Campesina is formed by three species: Rhizophora mangle (red mangrove); Avicennia germinans (salt-tolerant black mangrove) and Laguncularia racemosa (white mangrove).

The species with the best distribution (in terms of occupied surface area) is A. germinans which shows a colonising trend due to the salinisation processes in the soil and water currently found in the community. In turn, the distribution of

Rhizophora is affected by the system hydrological behaviour patterns, which determines its establishment only in areas near waterbodies. In the case of Laguncularia, its distribution and abundance is limited by the salinity and by the flooding seasons.

The mapped image is linked to a database with specific information for each segment. This database makes it possible to produce fine-tuned analyses of the structure and composition of the vegetation, in order to make comparisons and identify succession patterns, depending on the different physical and geographical parameters of the region.

As can be seen in Table 1, in the specific case of the mangrove, 14 vegetation patterns were identified, of which four represent segments containing only the species Rhizophora mangle (red mangrove); Avicennia germinans (black or salt-tolerance mangrove) and Laguncularia racemosa (white mangrove) and 10 patterns representing combined segments of two or more of these species and/or non-mangrove vegetation. In each case the number of segments and occupied surface area is shown in order of dominance in figures 3, 4 and 5.



Figures 3, 4 and 5. Distribution of Rhizophora mangle (red), Avicennia germinans (black) and Laguncularia recemosa (yellow)

Table 2. Vegetation in the Mangrove forest of the Conquista Campesina Community

Type	Type of associated vegetation	hectares
2	Black mangrove	168
1	Red mangrove	159
12	Open black mangrove	70
9	Mixed red and black mangrove forest	51
10	Mixed red, black and white mangrove forest	34
6	Mixed black and red mangrove forest	34
7	Mixed black and white mangrove forest	29
4	Mixed white and black mangrove forest	18
3	White mangrove	16
8	Mixed black and red mangrove and inland vegetation forest	14
11	Mixed inland vegetation and mangrove forest	14
7	Mixed black, red and white mangrove forest	9

At present, the entry of freshwater flows into the system and the silting of lagoons and channels have led to important changes in the structure and composition of the mangrove forests. If this trend continues, the "simplification" of the ecosystem will be an increasingly more tangible process, characterised by the gradual dwindling of the Rhizophora and Laguncularia species and greater dominance of Avicennia segments. Nevertheless, the latter will undergo changes in the structure of its populations (decrease in tree height and diameter) in response to the high concentrations of salinity throughout the region.

Having determined the number of segments for each category identified, the next step was to identify the surface areas occupied by type, in order to discriminate those with scarcely relevant extensions (less than three hectares). Of the 14 mangrove groups, 12 were finally selected. The surface areas of the eliminated ones were included in the most similar category (Table 2).

6. Determining the number and location of the sampling units

Based on the method, for each type of vegetation, at least three sampling areas or units were selected (30 X 10 m.) for obtaining information about the population composition and structure. For that purpose, the "XToolsPro" 4.1 extension of the ESRI ArcGIS 9.0 programme was used to superimpose a grid with cells of 30 metres (west-east) by 10 metres (north-south) on the communal area (Figure 6).

Then the grid was cut in accordance with the surface area identified for each of the 12 categories. The "XToolsPro" 4.1 extension was used again to calculate the surface area of each cell remaining after executing the cut. Since only whole cells (30m x 10m = 300 m²) are suitable for the sampling units, those with surface areas of less than 300 m² were ruled out. After calculating the surface area, the cells below 300 m²

were selected and eliminated systematically during an editing session. After this operation, each 300 m² cell was assigned an identification number (ID) in order to submit each group of cells to a "Stratified Random" selection exercise and identify the three samples for each type of vegetation identified.

To make the selection, the Rand function in the Microsoft Office Excel 2003 Programme was used, which returns a random number equal to or greater than 0 and less than 1. Since the Rand function has a range of 0 to 1, each identification number had to include a certain range between 0 and 1.

Figure 6. Grid for selecting the sampling units

For instance, in the case of Red Mangrove, there were 3,293 whole cells (300 m²), each one with its identification number from 1 to 3,293. To select the first cell, ID=1, the Rand function would have to give a value of between 0 and 1/3293=0.00030367. To select unit two, ID=2, it would have to give a value of between 0.00030367 and 0.00060735 etc. This function was repeated three times to obtain the sampling units for each of the 12 types of vegetation.

The result of the foregoing was a total of 36 sampling units (three for each type of vegetation). For each group of three, another random selection exercise was performed in order to select a sampling unit for each type of vegetation, for monitoring on a permanent basis. Figure 7 shows the 36 sampling units, 12 of which have a square identifying those which will be established and monitored over several years, to obtain the necessary information for adapting and fine-tuning the plan for handling the region.

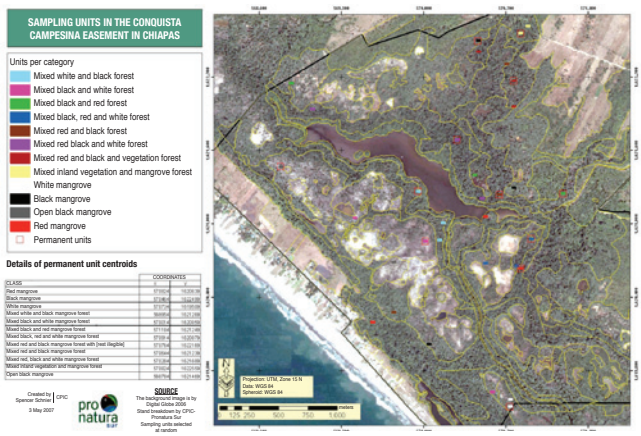
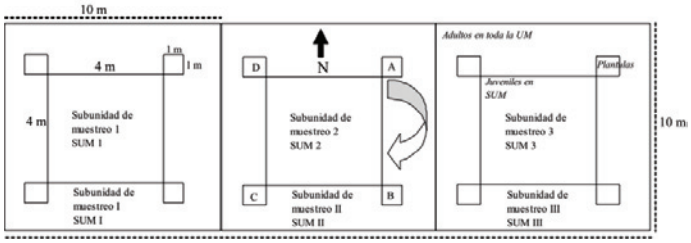


Figure 7. Sampling Units for monitoring the Conquista Campesina Conservation Easement Mangrove

7. Obtaining of information in the sampling units

Having identified the sampling units, the information was obtained for a total of 12 permanent units. To do this, the Valdez (2002) technique was used to prepare mangrove forest handling plans. This technique consists of establishing sampling units with the characteristics shown in Figure 8.



Subunidad de muestreo = Sampling sub-unit
Adultos en toda la UM = Adults in the entire sampling unit
Juveniles en SUM = Juveniles in the sampling sub-unit
Plantulas = Seedlings

Figure 8. Design of Sampling Units (modified Valdez, 2002)

The whole of the sampling unit has a surface area of 300 sq metres (10 X 30; Figure 9), subdivided into 3 units of 100 sq metres (10 X 10). All the mangrove tree trunks (adults) in this subunit were surveyed. In each subunit, another division was established of 5 X 5 metres in which a count was made of the saplings and lastly, 4 more divisions were made of 1 X 1 metres for counting the seedlings.

Figure 9. Establishing of sampling units

The obtaining of data in 12 of these units (carried out by the trained community brigade) included dasometric data and information on architecture, phenology and growth (Figure 10). With respect to the latter aspect, a total of 72 mangrove trees were marked, from all three species. Each month these trees are wounded (López-Ayala et al. 2006) in order to ascertain their development rate (Figure 11). At present each tree has more than 16 wounds. Community monitoring is systemic, pursuant to the monitoring plan.

Figure 10. Obtaining of data in the permanent sampling units

Figure 11. Marking the trees in order to verify their development rate

In each 30X30 metre plot, all the trees with a DPH of more than 7.8 cm were measured and marked. Only in the case of the Rhizophora mangle species was this measurement taken 30cm from the last root of the trunk. In the 5X5 plots, trees thinner than 7.8 cm but taller than 1.5 m were measured for R. mangle and trees higher than 1.3 m for L. racemosa and A. germinans. Lastly, in the 1X1 metre units, measurements were taken of all trees under 1.5 m but taller than 50 cm for R. mangle and trees taller than 30 cm for L. racemosa and A. germinans.

12 types of mangrove forest cover were obtained, characterised by the presence of a single species of the three existing in the study area, and based on the combination of these in landscape dominance layouts. Likewise, the population structure variable for integrating open populations (in a natural manner) occupied by the species A. germinans (Table 3) was included.

As can be seen, the Conquista Campesina Community mangrove occupies a surface area of 616 hectares. Of this area, the Black mangrove and Red mangrove species occupy more than 50% (52 hectares) of the total surface area. With respect to the red mangrove, this is explained by the "edge" effect and the development of this species, particularly on the banks of waterbodies and areas which are flooded for a period of over six months. In the case of the black mangrove, the occupied surface area is closely related to the increase in interstitial salinity throughout the system and the greater tolerance of this species to such conditions. Due to this hypersalinisation in the soil and water, the surface area occupied by L. racemosa (white mangrove) takes on greater significance, since it represents only 2.60% of the total forest cover in the area (16 hectares). Generally speaking, it is seen that white mangrove is the species which has the least tolerance to prolonged periods of flooding and increased salinity. Based on the number of hectares for each type of forest cover and the sampling surface area in plots of 300 m², the sampling intensity in all cases was no more than 1% of the total surface area for each type.

Table 3. Surface area and percentage for mangrove forest cover types

Type	Attributes	hectares	%
2	Black mangrove	168	27.27
1	Red mangrove	159	25.81
12	Open black mangrove	70	11.36
9	Mixed red and black mangrove forest	51	8.28
10	Mixed black and red mangrove forest	34	5.52
6	Mixed red, black and white mangrove forest	34	5.52
7	Mixed black and white mangrove forest	29	4.71
4	Mixed white and black mangrove forest	18	2.92
3	White mangrove	16	2.60
8	Red and black mangrove forest mixed with inland vegetation elements	14	2.27
11	Mixed inland vegetation and mangrove forest	14	2.27
7	Mixed black, red and white mangrove forest	9	1.46
	TOTAL	616	100

Having obtained the results of the community monitoring, the information was submitted by the work brigada to the communal land assembly, in order to report the findings and inform the assembly about the structure of its mangrove forests. In terms of characterisation by type of forest, the community initiated the process of zoning the communal land, based on its potential and fragmentation level. To that end, the following types were identified:

Type 1 Red mangrove: this type class includes segments formed entirely by the species R. mangle. In particular, this area contains the tallest trees (taller than 20 metres) with the greatest longevity in the region. Here, there are many specimens per surface unit, sometimes forming extensive barriers of trees that are practically impossible to penetrate. It is considered an "edge" forest since it is located on the banks of waterbodies and/or areas with prolonged flooding periods. However, it is the area exposed to the greatest risk due to hurricanes and strong winds, due to its enormous exposure and the fact that the forests are established on non-consolidated soil (peat). The average salinity in these areas does not

exceed 40 parts per thousand throughout the whole year. Nonetheless, the area is flooded for long periods of time and so the species has specialised structures in its adventitious roots (lenticel hypertrophy). The tree structure has favourable characteristics (long, straight trunks).

Type 2 Black mangrove: this type includes segments consisting entirely of the species A. germinans. In all, these areas are covered with trees with a height of more than 15 metres with a BHD of more than 12.7 cm (40 cm in circumference). These areas form part of the "basin" mangrove with low humidity periods (less than 3 months). In terms of the lanscape, the cover is comprised of dense canopies with little natural regeneration, due to the concentration of pneumatophores, which makes it impossible for new trees to develop. In general, these areas have few individuals per surface unit. The tree architecture is characterised by being specimens with branches that start practically from the base. However, in these areas, the local population obtains wood from fallen trees or standing dead trees. The salinity in these areas is higher than 50 parts per thousand, and these conditions may increase during the dry season.

Type 3 Open black mangrove: this type of cover is a true reflection of the local problem with regard to fragmentation of the mangrove forest, due to the increase in salinity in both water and soil. In general, they are located in shallow basins where the stagnant water evaporates during the dry season, leaving large areas covered with mineral salts. In such conditions, only this species is able to withstand saline conditions above 90 parts per thousand. However, that concentration affects the development of the trees, for which reason they grow no higher than eight metres. In extremely saline conditions, the tree will obviously die, leaving open spaces that are not usually occupied again by new tree species. This gives rise to the formation of small "clumps" of trees on slightly elevated ground (micro topography), where the effects of the soil hypersalinisation are not serious. The importance of these areas, from the standpoint of local exploitation, is that large quantities of wood can be obtained from them for use as fuel (firewood) due to the high death rate of the trees. Based on the landscape transformation rate results, it can be affirmed that these areas are undergoing a process of extension, due mainly to the entry of water (channels and ponds) throughout the system.

Types 4, 5, 6, 7, 8, 12 Mixed forests: these include the presence of two or three mangrove species. In Table 4, the first name assigned to the type determines the species dominance, which is usually over 70%. These types of cover represent transition areas in which the combination of pure segments generates a corridor of large trees (between 20 and 30 metres). The number of trees per surface unit is also high, and so these areas are normally exploited using traditional selective techniques. The flooding and saline conditions of each site determine the composition of these mixed forests and their dominance.

Type 9: White mangrove: this type consists of segments formed entirely by the species L. racemosa. These areas show high tree densities, usually of the same size. There is a predominance of pre-adult trees with heights of no more than 15 metres. To a large extent, the presence of one size of tree may be due to the selective use of this tree during the juvenile stage, as their characteristics, with straight, think trunks, are highly appreciated for building the roofs of huts and dwellings. However, the scant surface area occupied by this species in pure segments is due to the fact that it has low tolerance to long flooding periods and conditions of extreme salinity. If the current trends of the system in general are maintained, it is extremely likely that this species will eventually cease to exist in the communal land. At present, this type has extended in high areas that are close to waterbodies.

Types 10 and 11: Mixed forests (inland vegetation): forests that include species other than mangrove. In general, these areas are close to farmlands and/or towns where there is a higher number of shrub and grass species that are typically

Table 4. Control mode and surface area

Type of cover	hectares	Control method
White mangrove	16	Conservation area
Red mangrove	159	Ecological improvement area
Black mangrove	168	
Mixed white and black mangrove forest	18	
Mixed black and white mangrove forest	29	
Mixed black and red mangrove forest	34	
Red and black mangrove forest mixed with inland vegetation elements	14	
Mixed red and black mangrove forest	51	
Mixed red, black and white mangrove forest	34	
Mixed inland vegetation and mangrove forest	14	
Open black mangrove	70	Ecological rehabilitation area
Waterbodies	208	

found in middle and high zones of the rainforest. This cover is found on the edge of the system, where the trees are not very tall (less than 20 metres). However, their importance lies in their capacity to house and share mangrove fauna species with other inland ecosystems. From the forest standpoint, they do not represent a resource, since the areas have other species of timber-yielding trees apart from mangrove which are more frequently and more intensively used. Here, in general, the area has no prolonged flooding periods and salinity is usually extremely low or non-existent.

For the purpose of adequate conservation and rehabilitation of the communal land wetlands, the classification was made pursuant to the physical and biological characteristics of the area, and in agreement with the direct users of the system. In this respect, the community zoning proposal included a total of 824 hectares, of which 616 hectares correspond to mangrove forests and 208 to waterbodies between water channels, ponds and grasslands.

Due to the fact that the distribution patterns of the different mangrove species are closely linked to the regional hydrological dynamics, it is of special interest for the Environmental Control Unit Project for the hydrological system to be considered, in order to execute actions that will guarantee the stability of the ecosystem as a whole. Consequently, the control categories established were as follows:

Conservation areas: areas used to conserve the habitat of the flora and fauna identified as being threatened, rare, in danger of extinction or subject to special protection.

Ecological rehabilitation areas: these include areas where forest vegetation, soil productivity and natural hydrological dynamics have been significantly altered, and which therefore require actions aimed at their rehabilitation.

Table 5. Execution of control phases for the methods identified

Method	Phase		
	Removal of dead wood (reduction of the pyritisation process)	Structural control of forest. (improving the forest resistance to strong winds)	Rehabilitation of water courses (reduction in water and soil salinisation)
Conservation	No	No	Yes
Ecological improvement	Yes	No	No
Ecological rehabilitation	Yes	Yes	Yes

Areas requiring ecological correction with respect to mangroves: these are mangrove areas in which there are large quantities of dead wood, resulting from extreme weather conditions, accumulation of mineral salts (salinisation) and soil pyritisation. They also include "edge" forest zones where tropical storms and hurricanes have caused the total or partial felling of trees onto waterbodies, thus provoking the stagnation of the water column.

On a whole, agreement was reached with respect to these categories with the inhabitants of the Conquista Campesina communal land, in keeping with their interests and needs. These are indicated in Table 4. The control phases identified are: a) ecological improvement: removal of wood (parts and derivatives) and sediments; b) structural control of edge forests; and c) rehabilitation of water courses, which will be carried out in accordance with the pertinent phases set out in Table 5.

8. Conservation area

Objective of the area: to maintain the conditions for the adequate development of L. racemosa, a species currently considered to be extremely vulnerable to changes in the environment and to the control of its population.

Benefit of the area: due to the characteristics of the populations of this species (high density of trees with straight trunks) the area is a perfect nesting and resting site for a large variety of migratory and resident birds, many of which are included in some category of protection. Likewise, the populations of this species have been subjected to relative pressure, caused by the use of wood for construction purposes.

Characterisation: tree populations in good conditions of development, but extremely fragile to changes during the hydroperiod and increased salinity. At present, they occupy a small part of the communal land and their populations are clearly declining.

Location: forest cover type 3 "pure white mangrove surface areas" with a total surface area of 16 hectares.

Activities to be carried out

- Improvement in the soil conditions through hydrological rehabilitation work and the erecting of barriers for protecting from high tides.
- Pest and disease control
- Establishing of a monitoring programme on the development of seedlings
- Establishing of a permanent vigilance programme to prevent illegal felling
- Distribution of propagules in areas with optimum conditions for their development
- Establishing of an experiment nursery for this species, for propagation purposes and as support for natural regeneration.

9. Ecological rehabilitation areas

Objective of the area: to restore the natural conditions of soil and water in order to recover areas altered by the silting of natural water channels and salinisation and pyritisation processes.

Benefit of the area: the rehabilitation of this area will lead to a reduction in the mangrove forest transformation rate and halt the salinisation and pyritisation of water and soil. This will prevent the fragmentation of priority habitats for migratory birds and local fauna. On the other hand, water channels, ponds and grasslands are used for fishing and navigation, with fishing being the main economic activity of the community.

Characterisation: at present, this area is occupied by black mangrove (A. germinans) in isolated groups, due to the high salt concentrations (greater than 90 parts per thousand). Due to this, the population structure is characterised by trees no more than 5 metres in height, with branches starting from the base and a poor chance of survival. In relation to the waterbodies, these are mostly silted with sediments and important masses of dead wood due to the effects of hurricanes and strong winds. Generally speaking, the rehabilitation of at least 20 kilometres of natural ponds and water channels is considered necessary.

Location: type of forest cover 12 (70 hectares) and type of waterbody (208 hectares).

Activities to be carried out:

- hydrological rehabilitation in 15 kilometres of natural ponds and water channels
- rehabilitation and building of 5 kilometres of channel "ditches" for storing water, in order to adapt the water flow in seasonally stagnant areas
- removal of dead wood to reduce soil pyritisation processes
- removal of dead wood from natural ponds and water channels
- removal of sediments from "ditches"

10. Ecological improvement area

Objective of the area: to improve and maintain the community forest areas affected by waterbodies which are adjacent to the federal zone. This will be done by reducing soil pyritisation processes caused by the accumulation of vegetation

Table 6. Schedule of activities for each control area and project phase

PHASE	ACTIVITIES	MONTHS											
	CONSERVATION AREA	1	2	3	4	5	6	7	8	9	10	11	12
A3, A2	Improvement of terrain conditions through hydrological rehabilitation work and raising protective edges against tides												
A1	Pest and disease control												
A1	Implementation of a programme for monitoring the development of seedlings												
A1	Implementation of a programme of permanent vigilance to prevent illegal felling												
A1	Dissemination of propagules in areas with optimum conditions for their development												
A1	Implementation of an experimental nursery for this species for propagation purposes and in order to support natural regeneration												
	ECOLOGICAL REHABILITATION AREA												
A3, A2	Hydrological rehabilitation of 15 kilometres of natural ponds and channels												
A3, A2	Rehabilitation and construction of 5 kilometres of channel "ditches" for storing water for the purpose of allowing a correct water flow in seasonally stagnant areas												
A1	Removal of dead wood in order to reduce soil pyritisation processes												
A1	Removal of dead wood from natural ponds and channels												
A2	Removal of sediment from natural ditches												
	ECOLOGICAL IMPROVEMENT AREA												
A1	Removal of dead wood to allow for forest renovation in open areas following the effects of strong winds and hurricanes												
A1	Controlling the population density and pruning of trees partly torn down by strong winds, storms and hurricanes												
A1	Implementation of a vigilance programme to reduce illegal felling												
A1	Pruning of adventitious roots which reduce the water reflection in channels and ponds												
A1	Rescue and transplanting of seedlings totally or partially covered by trees torn down by strong winds, hurricanes and storms												
A1, A2	Pest and disease control												
PHASES: A1 removal of dead wood; A2 removal of sediments; A3 rehabilitation of water courses													

(wood and derivatives).

Benefit of the area: zones with forest cover in good conditions of development with more than one species at different stages of development. This zone is the main barrier against extreme weather events (hurricanes, cyclones and tropical storms). Likewise they are important habitats for a large variety of water birds which shelter in the roots, thus improving the fishing potential in the area.

Characterisation: areas of cover with more than one mangrove species of different sizes. It encompasses forest populations of between 20 and 30 metres in height with a high regeneration capacity. Depending on the cover of the dominant species, these areas show high concentrations of mangrove trees which have been felled due to adverse weather conditions. In general these areas are permanently or seasonally flooded and have non-consolidated soils and a large quantity of organic matter. They are ideal sites for water birds which use the area for nesting, feeding and resting.

Location: type of forest cover 1, 2, 4, 5, 6, 7, 8, 9, 10 and 11, totalling 530 hectares.

Activities to be carried out:

- removal of dead wood to forest regeneration in open areas affected by winds and hurricanes.
- population density control and pruning of trees partly torn down by strong winds, storms and hurricanes.
- implementation of a vigilance programme to reduce illegal felling
- pruning of adventitious roots that reduce the reflection of the water in channels and ponds
- rescue and transplanting of seedlings totally or partially covered by trees torn down by strong winds, hurricanes and storms.
- pest and disease control

In accordance with the definition of control methods for each area in particular, the schedule of activities for a one-year cycle (considering these actions as permanent for conserving the ecosystem) are as follows (Table 6):

The proposed activities for the area of potential use refer to the parts of the common land affected by adverse weather events, such as: hurricane "STAN" (2005) and Tropical Storm Bárbara (2007).

11. Preparing the site

In accordance with the control method, the activities for preparing the site are as follows:

11.1 Conservation area

Planning of hydrological rehabilitation work: identification of historic beds of ponds and natural channels in the area, with a view to designing the hydrological rehabilitation work. For that purpose, traditional knowledge of the area is used to calculate the dimensions (length and breadth) of these waterbodies before they became silted.

Identification of natural regeneration areas and seeding zones for L. racemosa: paying visits to the area to identify areas for gathering propagules for the species L. racemosa. Based on the knowledge of these areas (location, propagules production capacity, etc.) a harvesting plan will be designed for the propagation of this species in segments containing only white mangrove.

Access to conservation areas: determining of potential access routes to the conservation areas by recording traditional footpaths and traces of channels that are partially blocked.

Vigilance: identification of the most appropriate areas for establishing control and vigilance stations in the region. Those areas will be located in the main accesses to the area, to restrict traffic and the illegal felling of trees.

11.2 Ecological rehabilitation areas

Planning of hydrological rehabilitation work (land system): identification of historic beds of ponds and natural channels in the area, with a view to designing the hydrological rehabilitation work. For that purpose, traditional knowledge of the area is used to calculate the dimensions (length and breadth) of these waterbodies before they became silted.

Planning of hydrological rehabilitation work (water system): for each pond and channel rehabilitation area, a work plan will be designed for the removal of submerged and partially submerged wood. In addition, identification of the sites where the wood is finally deposited and/or where alternative use is made of wood using "drill bits" with a low potential for household use.

Reforestation areas: location and recording of conditioned areas in which reforestation could be carried out, due to the reduction in salinity and improvement of the hydroperiod.

Removal of suspended solids: identification and recording of areas in which improvements can be made by removing inorganic suspended solids (waste). Likewise, negotiating a system for stockpiling and controlling inorganic waste from the ecosystem with local and municipal authorities.

11.3 Ecological improvement area

Determining the volume of organic matter which can be used for subsistence purposes: at present an analysis is being made of the information obtained in a total of 20 sampling units. The purpose of this is to calculate the volume of wood torn down by hurricane "STAN" and Tropical Storm "Bárbara". To that end, all the trees felled were measured, in order to calculate the average volume per surface unit.

Sample gaps and access routes to the area: due to the seedling volumes (natural regeneration) present in the area, making of the necessary calculations for implementing an "elevated" access system to the zones from which the felled trees are to be removed. In this way, the wood will be transported from the area using "elevated" ropes and cables, to reduce the impact on natural regeneration. Access by land for monitoring the zone is done through the water channels during the dry season.

Rescue of seedlings buried by fallen trees: estimations are made of the number of seedlings buried by fallen trees, which will be removed and transplanted in areas with the same water and saline stress characteristics.

Planning of hydrological rehabilitation work: for prevention purposes, identification of historic beds of natural ponds and water channels in the area, with a view to designing the hydrological rehabilitation work. For that purpose, traditional knowledge of the area is used to calculate the dimensions (length and breadth) of these waterbodies before they became silted.

Vigilance: identification of the most appropriate areas for establishing control and vigilance stations in the region. Those areas will be located in the main accesses to the area, to restrict traffic and the illegal felling of trees.

12. Description of the provisional work and activities included in the project

The only work considered that is common to all areas with control methods is work that is aimed at rehabilitating the hydrological dynamics of the ecosystem. In this regard, the provision activity consists of:

Rehabilitation of water flows in natural channels and ponds (water medium): this activity does not include the building of structures in the area. Its execution is aimed at restoring the natural dynamics of the water column (flows and reflows). No major machinery is used in designing and executing the work, but tools with a low impact, such as large knives, pulleys and ropes. The strategy consists of mechanically removing submerged wood from natural ponds and water channels. To that end, the local inhabitants are divided up into work brigades, with the mission of identifying areas of the channels that are partially blocked, and one of the brigades explores the water medium in order to identify the logs and branches that must be removed. That waste is moored and lifted using pulleys with a capacity of one ton and a half (Figure 12).

Figure 12. Procedure for rehabilitating natural ponds and water channels

In the event that the waste material consists of branches, these are chopped and cut into lengths of no more than 20 cm and then distributed evenly in the undergrowth of the ecosystem where it is reduced and integrated into the substrate. In the case of logs, these are removed and transported from the area to sites inside the community where they are stored and dried, for use as firewood. Using this system, the landscape of the area remains unaltered. However, some temporary alterations may occur in relation to the cloudiness of the water and generation of noise which has an effect on the behaviour of the fauna in the areas of distribution. Such alterations are not permanent and limited only to the time during which the activity is carried out.

13. Construction phase

Rehabilitation of natural ponds or "ditches": this activity is designed to rehabilitate natural water channels known locally as "ditches", which are partly or totally blocked by accumulated sediments. The entry of these channels into the area is the main cause of the death of the mangroves due to the hypersalinisation and pyritisation of the water and soil. The poor circulation of the water gives rise to the stagnation of surface run-off water, which tends to disappear during the dry season, leading to the concentration of large quantities of mineral salts in the area. To reverse this effect, works are designed to open up natural "ditches" in order to recover the correct flow of tidal waters and prevent water stagnation. To execute such work, the former water "veins" are identified and the sediments are removed and retained at both sides of the channel through the construction of barriers (palisades) with dead vegetable matter (branches and logs, see Figure 13 and 14).

Figure 13. Rehabilitation of "ditches"

Figure 14. Example of the rehabilitation of a "ditch", with the work completed

Then these barriers are consolidated by reforestation to prevent them from being damaged by the effects of the tide. The orientation and dimensions of each natural channel are

calculated based on traditional knowledge of the region by the inhabitants. In this way, the hydrological conditions of these small channels are rehabilitated, which do not usually exceed two metres in width by 1.5 metres in depth.

Like the rehabilitation and pond activities, the "ditch" rehabilitation activities cause certain temporary effects on the behaviour of local fauna, due to the presence of the inhabitants and the residual noise caused by the activity. However, in rehabilitating these natural channels, such rehabilitation does not last for long periods of time, and so the impact is temporary and generates no subsequent effects.

The work and activities described above have a long useful life given, provided that no extreme weather conditions develop (hurricanes and storms). In such cases, the structure and design of the work are aimed at guaranteeing resistance and permanence, and so a permanent monitoring and maintenance programme is set up simultaneously.

14. Operating and maintenance phase

Once the hydrological rehabilitation work has concluded, which are common for all the control areas, an operating and maintenance programme is set up which includes the removal of wood from channels and ponds (water medium) in the event of trees falling due to strong winds, or due to disease or damage to the trees. In the communal land area, most of the "edge" mangrove forests show important inclinations over the waterbodies, and therefore it is necessary to implement a programme for pruning and removing certain specimens, in order to maintain the best conditions in terms of hydrological dynamics. For that purpose, specimens that pose a "risk" are identified and treatment is applied (pruning or removing), depending on their probability of falling. The organic derivatives of this activity have an adequate potential in terms of subsistence use.

In the case of work for rehabilitating "ditches", the maintenance thereof is only required in the event of hurricanes and tropical storms. Due to its design and architecture, this work is intended to guarantee a long useful life, without the need to implement a permanent maintenance programme. In the event of an accident, the activities to be considered are aimed at removing accumulated sediment, the removal of felled wood, the reconstruction of edges and their subsequent consolidation and reforestation.

The operating and maintenance activities pose no permanent environmental risk in either case. Their application only has effects that are temporary or limited, such as: alteration of the distribution patterns of some species of fauna associated with the site, increase in the cloudiness of the water due to removing sediments from the bottom of the channels, possible changes in the water quality due to accidental spills of fuel from launches, surface changes in the soil structure due to the compacting caused by the movement of the work brigades and possible accidental deaths of seedlings resulting from removing silt and the movements of local inhabitants in natural regeneration areas. The containment of such impacts is attenuated by the adequate training of the inhabitants and limitations in the use of mechanical equipment running on fossil fuels (launch motors, chain saws, diggers and in particular, all the major equipment used to remove silt from the channels.

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