ADAPTIVE ECOLOGICAL RESTORATION IN DISTRIBUTION AREAS OF MESOCLEMMYS DAHLI

ABSTRACT

The Dahl's sea turtle (Mesoclemmys dahli) is a freshwater species endemic to the tropical dry forest (tDF) of the Colombian Caribbean. Its historical distribution is restricted to drainage systems associated with floodplains, seasonal streams, and riparian forests in the departments of Córdoba, Magdalena, Atlántico, and Bolívar. It is categorized as Critically Endangered (CR) by the International Union for Conservation of Nature (IUCN) due to intense anthropogenic transformation of the landscape, loss of ecological connectivity, reduction of dry forest cover, hydrological alteration, and pressures from productive land use. The species exhibits an ecology closely linked to temporary and permanent aquatic microhabitats, with activity cycles conditioned by the climatic seasonality characteristic of the tDF.

Between 2014 and 2017, local initiatives aimed at conserving populations of *M. dahli* in ravines draining into the Grande marsh complex in the municipality of Lorica (Córdoba) were promoted through participatory processes with rural communities. As a result, community conservation agreements were established, facilitating the ecological restoration of approximately 45 hectares of riparian forest, a critical habitat for the species and a strategic source of water for local communities. The implemented actions included controlling stressors in riparian zones (such as overgrazing and deforestation), establishing more than 3,700 propagules of native and threatened forest species, rehabilitating degraded productive areas, and promoting sustainable production systems compatible with conservation.

In parallel, the documentation of local ecological knowledge about the biology, behavior, and habitat use of *M. dahli* was strengthened, integrating traditional knowledge into monitoring and adaptive management processes. These interventions contributed to strengthening territorial governance for conservation, promoting community co-responsibility in the protection of the tropical dry forest and the socio-ecological resilience of aquatic systems associated with the species.

INTRODUCTION

The tropical dry forest (TDF) is considered one of the most threatened ecosystems in the Neotropics (Janzen 1988). Several drivers of transformation, primarily the expansion of the agricultural frontier, are cited as causes of its degradation (Miles et al. 2006; Carvajal-Cogollo & Urbina-Cardona 2008). Furthermore, the TDF in Colombia is one of the least known ecosystems and has the lowest representation in the system of protected natural areas (Álvarez et al. 1997; Forero-Medina et al. 2010; Pizano & García 2014).

In the municipality of Lorica, Sucre Department, northern Colombia, cultural practices associated with livestock farming, such as the lack of pasture rotation without renewal, the absence of alternative forages, and direct access of livestock to streams, have resulted in extensive areas of degraded land and a loss of water security (sensu Sadoff & Muller 2010). The search for alternatives to guarantee water for livestock has historically led the community to relocate them to the Ciénaga Grande wetlands. This scenario of degradation and the lack of diversification of family income translates into socio-environmental conflicts that alter patterns of diversity and distribution of wildlife (Gascon et al. 1999). A particularly worrying example among reptiles is the Dahli's Turtle (Mesoclemmys dahli), a species considered endangered globally (TFTSG 1996) and nationally (Morales-Betancourt et al. 2015; Forero-Medina et al. 2014). Wild populations of this species are vulnerable to extinction as a result of the loss of riparian forest cover in the Ts-B (Medem 1966; Rueda-Almonacid et al. 2007; Forero-Medina et al. 2012).

The ecological restoration of habitats and the establishment of protected areas have been considered key actions to mitigate the impacts of Ts-B transformation on Dahli's Turtle populations (Forero-Medina et al. 2013). Aspects related to the establishment of protected areas in the northern Colombian biogeographical zone and the conservation of amphibians and reptiles present there are reviewed in Chapters IX and X of this book. Regarding habitat restoration for freshwater turtles, there are various techniques that include direct actions on the physical space (e.g., creation of artificial wetlands or ponds), restoration of water bodies, improvement of food availability and vegetation cover (refuge), control and eradication of invasive exotic species, and landscape management through the rehabilitation of productive systems (e.g., increased structural complexity) that mitigate impacts on relict habitats (Baker et al. 2011; Bailey et al. 2006).

Between 2014 and 2017, community stakeholders in the municipality of Chimichagua participated in the planning, design, and implementation of specific actions for the ecological restoration of the habitat of the Dahl's turtle (M. dahli) in ravines that drain into the Ciénaga Grande wetlands. To this end, a landscape conservation management model was designed that included improving productive conditions (sustainable use), valuing local knowledge, raising awareness about the importance of the species (education, knowledge), and ecological restoration. This chapter presents an overview of the conceptual framework applied to the execution of this project and the achievements obtained in its first phase, from 2014 to 2017.

CONCEPTUAL FRAMEWORK

Human activities frequently generate changes in natural ecosystems to such a degree of impact that, on their own, they would require a great deal of time and complex environmental conditions to return to a natural state. It is here that ecological restoration emerges as a practice that seeks to “assist the recovery of an ecosystem that has been degraded, damaged, or destroyed” (SER 2004; McDonald et al. 2016). Ecological restoration is based on learning about native reference ecosystems within a framework of environmental change, identifying key attributes of the target ecosystem, assisting natural recovery processes, and making the “best and greatest effort” toward full recovery (McDonald et al. 2016). In particular, ecological habitat restoration improves or maintains the environment's capacity to provide appropriate conditions for the persistence of individuals and populations (e.g., habitat quality and quantity) and the maintenance of connectivity processes at various spatial scales (Morrison 2013).

To undertake habitat restoration processes, Miller & Hobbs (2007) established a series of considerations, including determining the target species for restoration, the key elements to be restored in the habitat, and the assessment of the landscape context (Fig. 1). Furthermore, these considerations should include the generation of social benefits (Aronson et al. 2006; Clewell & Aronson 2006), such as the improvement of production systems and job creation, which, in turn, would be linked to the maintenance of strategic ecosystem services for communities, for example, the management of timber species, the preservation of riparian zones, and pollution control. With the aim of improving the availability of shelter and food resources for the M. dahli turtle, the assisted nucleation technique was applied to favor the increase in the density and diversity of colonizing plant species (Corbin & Holl 2012); this through plantings of native species in focal sites of ravines, recognized as part of the habitat of this species.

Figure 1. Key considerations for setting goals in habitat restoration projects (adapted from Miller & Hobbs 2007).

STUDY AREA AND HABITAT OF MESOCLEMMYS DAHLI

The project was developed in the rural area of the municipality of Lorica (9.28°N; 73.79°W), Sucre Department, Colombia; specifically, the Sinú River, which drains into the Ciénaga Grande (Fig. 2). Populations of M. dahli have been recorded in the first stream (Forero-Medina et al. 2011), while in the second stream, its presence was recorded by the local community.

In their bioecological description of the mountain turtle, Forero-Medina et al. (2012) provide key details for identifying reference systems that guided the ecological restoration in this project. For example, M. dahli is a species typical of the bs-T ecosystem between 100 and 250 meters above sea level, frequenting areas with high percentages of riparian vegetation cover (>82%) on ravines between 1 and 10 meters wide and deep wells (depth greater than 78 cm) and a low flow rate (< 0.2 m/s).

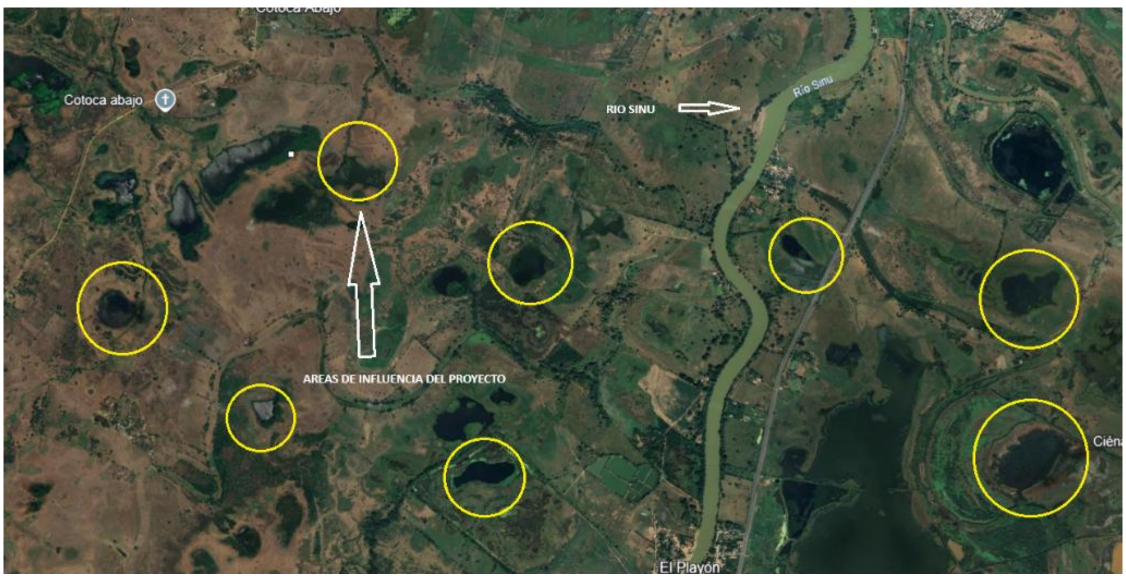


Figure 2. Satellite images of the study area in the department of Sucre, Colombia. Location of the project's area of influence with respect to the municipality of Lorica and the Ciénaga Grande (A). Close-up showing the Sinú River draining into the Ciénaga Grande and the project's intervention corridor (B). The shaded circles indicate the areas of conservation agreements and where restoration actions were carried out (Google Earth images 2024).

METHODS

The project was developed between 2024 and 2025 through a participatory strategy with a Participatory Action Research approach (Fals-Borda 1980). This strategy initially yielded the identification of aspects considered critical for the sustainability of the territory, such as access to water, the improvement of silvopastoral systems, and the conservation of streams. The project is based on integrated biodiversity management, focused on an ecological restoration strategy for riparian forests and the rehabilitation of degraded agricultural areas. The four subsystems proposed by MADS (2015) were adapted as follows: preservation based on conservation agreements; restoration through assisted natural regeneration to improve the supply of ecosystem services and the habitat of M. dahli (Aronson et al. 2006, 2007); Sustainable use through the rehabilitation of productive areas degraded by overgrazing and water scarcity; and finally, the construction of knowledge and information through the recovery of local memory about turtle ecology, knowledge transfer, and an approach to governance for conservation.

The Sinú River was considered to be in a state of “intermediate resilience,” which implied the need to integrate restoration and landscape management techniques (Clewell et al. 2000; Morrison et al. 2006; Lozano-Zambrano 2009; Morrison 2009, 2013) through four phases. Phase I comprised the identification of the main socio-environmental conflicts of the community and the description of disturbance regimes (Fig. 3). In this phase, ecological filters and alternatives for obtaining plant material were also identified.

Phase II began with an exploration of local knowledge about the Dahl's turtle (M. dahli) and its habitat, as well as the collaborative identification of tools for the rehabilitation of degraded productive areas and the ecosystem attributes to be considered in ecological restoration.

Reference ecosystems (McDonald et al. 2016) and intermediate references (Clewell & Aronson 2013) were described. The best-preserved riparian forests along the Sinú River were considered as reference ecosystems; their flora was described in collaboration with the community. Possible expressions of ecological succession (intermediate references), a basic model of riparian forest development, and a restoration plan were proposed (Fig. 4). During this phase, training and exchange sessions were held, and information on agroforestry, food security, and silvopastoral models was shared. In Phase III, specific actions (e.g., restoration, rehabilitation) were defined for each property, along with their specifications. Finally, in Phase IV, conservation agreements were established, and participatory monitoring was formulated. In this last phase, semi-structured interviews were also conducted (Brancalion et al. 2014) to understand the benefits generated by the project and identified by the community, as well as to gather information that would guide future cycles of the restoration process.

Figure 3. Example of degraded area types in the rural area of the municipality of Lorica, Sucre Department, Colombia. Floodplain area transformed for grazing (A). Degraded riparian forest transformed for grazing (B). Degraded pastures of exotic grasses in upland areas (C). Riparian forest affected by selective logging (D).

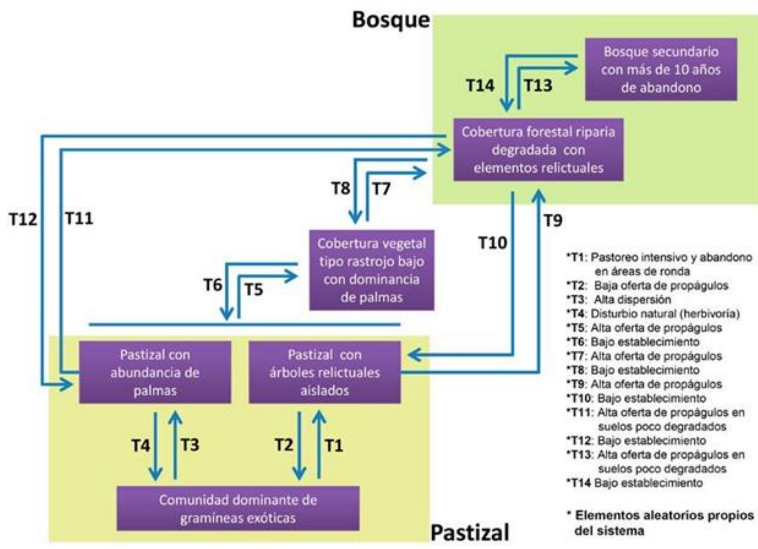


Figure 4. Proposal of ecological trajectories in areas of interest for the restoration of habitat of the mountain turtle M. dahli in the sinu river, municipality of Lorica, department of Sucrer, Colombia.

Ecosystem Attributes Considered in Ecological Restoration

The community identified the following as key attributes for improving the habitat of the mountain turtle: increasing tree diversity, protecting beaches, and expanding riparian corridors through plantations protected by fences. They also identified the ecological trajectory to follow (T1-T5-T7-T14; Fig. 4), which involved expanding the riparian forest's advance over pastures to generate greater forest cover in the medium term. The project addressed processes of spontaneous restoration and assisted natural regeneration. The former consisted of isolating the watercourses of the disturbed ravines with wire fences and conserving small floodplains. The latter involved planting locally threatened native species to promote the advance of riparian forests over pastures.

Selection of Plant Species for Restoration

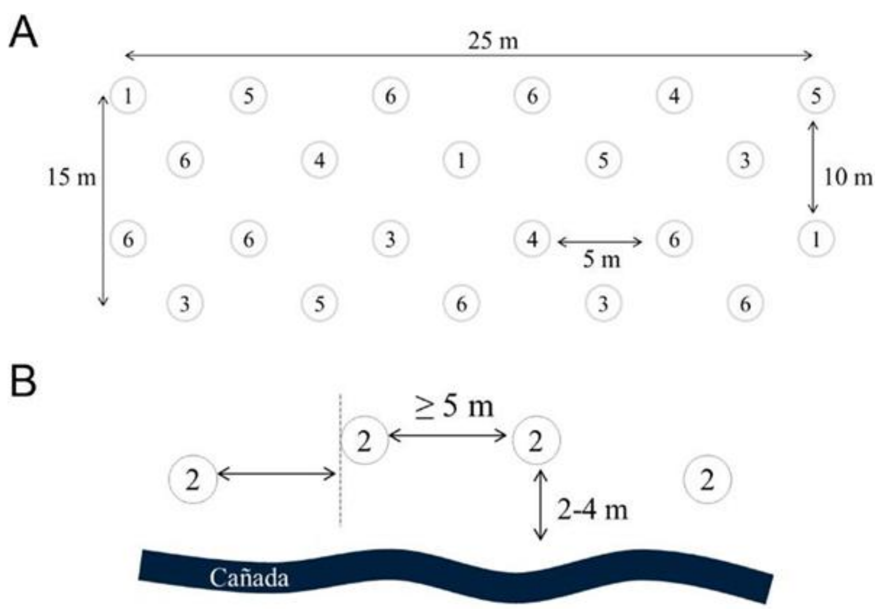
Species were selected based on four criteria: 1) native species with local distribution, 2) species prioritized for local conservation by community consensus, 3) life history traits of the species (dispersal agent, pollination vector, seed bank, and plant type), and 4) availability of propagules. To apply the selection criteria, field surveys were conducted and secondary information was reviewed (e.g., Vargas 2015; Mendoza-C 1999). With the local community, 52 native species were preliminarily identified, of which 24 were considered priorities (22 trees and 2 palms) for management due to their locally threatened status from overexploitation. Among the tree species, the oil palm Elaeis oleifera (Calderón et al. 2005) was identified by the local community as a food source for the Dahl's tortoise (M. dahli). In total, 3745 seedlings of 24 species (21 forest species and three palms) were propagated and rescued. Propagation took place in a family nursery and at the “Cerveleón Padilla Lascarro” Technical Educational Institution. The rescued seedlings were obtained with the support of the community (Table 1).

Table 1. List of native species with their respective quantities and origin of propagules used in the ecological restoration process of the habitat of the M. dahli turtle. The "planting year" column shows the two periods during which the plantings were carried out: 2014 and 2017. The forest species that had plantings in both periods (2014 and 2017) specifically indicate in the "propagule origin" column the number of seedlings and the year in which their planting corresponded.

ESPECIES FORESTALES	AÑO DE PLANTACION	ORIGEN DE PROPÁGULOS		TOTAL
		VIVERO	RESCATE	
Anacardiaceae				
Anacardium excelsum (Bertero ex Kunth) Skeels	2014	0	274	274
Astronium graveolens Jacq.	2014/2017	23 (2014)	41 (2017)	64
Apocynaceae				
Aspidosperma spruceanum Benth. ex Müll.Arg.	2017	20	0	20
Tabernaemontana cymosa Jacq.	2014	0	11	11
Arecaceae				
Astrocaryum malybo H.Karst.	2014	24	20	44
Elaeis oleifera (Kunth) Cortés	2014/2017	0	90 (2014) 400 (2017)	490
Oenocarpus minor Mart.	2014	0	41	41
Bignoniaceae				
Handroanthus chrysanthus (Jacq.) S.O.Grose	2017	0	25	25
Handroanthus ochraceus (Cham.) Mattos	2017	0	30	30
Jacaranda caucana Pittier	2014/2017	10 (2017)	165 (2014) [illegible]	215
Tabebuia rosea (Bertol.) Bertero ex A.DC.	2014/2017	73 (2014) 80 (2014)	338 (2018) 53 (2017)	524
Boraginaceae				
Cordia gerascanthus L.	2014	0	60	60
Capparaceae				
Crateva tapia L.	2014/2017	18 (2014)	17 (2014) 68 (2017)	103
Euphorbiaceae				
Hura crepitans L.	2014/2017	162 (2014) 362 (2017)	0	524
Lauraceae				
Nectandra cuspidata Nees & Mart.	2014	0	8	8
Nectandra turbacensis (Kunth) Nees	2014	0	21	21
Leguminosae				
Albizia guachapele (Kunth) Dugand	2017	689	0	689
Albizia niopoides (Benth.) Burkart	2017	150	0	150
Albizia saman (Jacq.) Merr.	2014/2017	16 (2014) 60 (2017)	0	76
Enterolobium cyclocarpum (Jacq.) Griseb.	2014/2017	50 (2017)	11 (2014)	61
Pseudosamanea guachapele (Kunth) Harms	2014	0	262	262
Malvaceae				
Sterculia apetala (Jacq.) H.Karst.	2017	49	4	53
TOTAL		1786	1959	3745

Design and Establishment of Plantations for Restoration

A total of 45.23 ha were agreed upon with the community for restoration: 34.83 ha for spontaneous restoration and 10.4 ha for assisted natural regeneration. In the latter case, plantations of forest and tree species were established in two periods (2024 and 2025). The species were grouped into functional plant types (Díaz et al. 2007) based on life-attribute traits and their spatial distribution, which corresponded to the microsite characteristics of each plot (Fig. 5a). One hundred and forty-four blocks of up to 375 m² were established, with a maximum of six species and 22 individuals per block. The palms were planted in a linear fashion (Fig. 5b-c). All plantings (restoration and rehabilitation) were carried out during the period of high rainfall (April) to reduce the risk of seedling loss due to drought and/or herbivory, and with the following specifications: 40 x 40 x 40 cm planting hole and substrate resulting from mixing original soil with 200 gr of ABIMGRA phosphoric® fertilizer (mineralized organic fertilizer), 150 gr of mycorrhizae and 2 gr of water retainer.



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Especie	Número
Astronium/Aspidosperma /Nectandra /Anacardium	1
Astrocaryum /Elaeis/Oenocarpus	2
Tabebuia/Jacaranda/Handroanthus	3
Crateva/Tabernaemontana	4
Hura/ Sterculia	5
Albizia/Enterolobium /Cordia	6

Figure 5. Design and establishment of plantations for the ecological restoration of the habitat of the mountain tortoise M. dahli. Planting arrangement for forest species (A) and palm species (B). List of species planted in both arrangements (C). The numbers identify the spatial location of the species.

Participatory monitoring was conducted annually for the 2014 planting and twice quarterly for the 2017 planting. The community committed to maintaining this process for another year, after which they believed the successful establishment of the plant material would be evident (Table 2).

Table 2. Short-term indicators of the habitat restoration project for the Dahl's tortoise (M. dahli).

COMPONENTE DEL PROYECTO	INDICADOR	CUANTIFICADOR	CRITERIO DE CUMPLIMIENTO
Restauración ecológica	Material vegetal establecido	Proporción de material vegetal establecido	Aceptable: a 50 % de individuos alcanza la etapa de latizal* al segundo semestre de 2019. Óptimo: a 75 % de individuos alcanza la etapa de latizal* al segundo semestre de 2019.
	Estado de la cobertura vegetal	Cambio en la complejidad estructural de la vegetación (ΔEx)	Aceptable: a 30 % de cobertura vegetal en núcleos está comprendida por especies nativas, al segundo semestre de 2019. Óptimo: a 60 % de cobertura vegetal en núcleos está comprendida por especies nativas, al segundo semestre de 2019.
Conservación	Observación de tortuga *M. dahli*	Presencia de la tortuga *M. dahli* en sector en restauración	Aceptable: Presencia de la tortuga en jagueyes cerca al rio sinu. Óptimo: Presencia de la tortuga en los jagueyes del rio sinu.
Participación	Mantenimiento de acuerdos de conservación	Mantenimiento de los acuerdos de conservación	Aceptable: 100 % de las familias beneficiarias respetan los acuerdos de conservación.

modificado de Pinelo (2004)

RESULTS

Diagnosis for Ecological Restoration

In community spaces, the following were identified as the main internal ecological filters for the early stages of ecological succession: 1) the availability of propagules of native species, 2) microsite conditions, and 3) competition between native species and exotic grasses in the areas to be restored. The community concluded that the scarcity of resources for the Dahl's tortoise (M. dahli) is primarily the result of the loss of vegetation cover in the ravines. Finally, the existence of fragments of tropical dry forest (bs-T) in the ravines to be restored and the interest of the rural community in restoring their ravines to guarantee access to water were identified as relevant aspects for restoring the tortoise's habitat.

Description of the flora of the riu sinu and the momposina depression

The study of the vegetation in the bs-T relicts allowed the identification of species such as Randia aculeata, Lonchocarpus sp., Tabebuia ochracea, T. chrysantha, T. rosea, Ficus citrifolia, Albizia saman, A. niopoides, Caesalpinia corería, Ma-tayba elegans, Jacaranda caucana, Inga sp., Chrysobalanus icaco, Citharexylum kunthianum, Sapindus saponaria, S. apetala, Quassia amara, Hirtella america-na, Pseudosamanea guachapele, A. excelsum, A. graveolens, A. spruceanum, Brosimum alicastrum, H. crepitans, Coccoloba caracasana, Cydista diversifolia, Dialium guianense, Licania apetala, Talisia olivaeformis, Bursera simaruba, and C. tapia. These species are considered native to the riparian forests of the Caribbean region (Olascuaga-Vargas et al. 2016; Berdugo-Lattke & Rangel-Ch 2015; Mendoza-C 1999) and offer significant biotic potential as a source of propagules for habitat restoration for the Dahl's sea turtle (M. dahli). Species associated with the Arecaceae family were also observed, including: Bactris brongniartii, B. guineensis, Attalea butyracea, Oenocarpus minor, Sabal mauritiiformis, Elaeis oleifera, and Astrocaryum malybo. In the intermediate ecological references (i.e., grasslands with varying periods of abandonment), exotic grass species dominated: Panicum maximum, Dichanthium aristatum, Brachiaria brizantha, and Pennisetum clandestinum, and to a lesser extent, Attalea butyracea (wine palm) and some adult individuals of Enterolobium cyclocarpum, P. guachapele, and A. saman.

Identification of rehabilitation and restoration opportunities

Among the actions agreed upon with the beneficiary families of the project were the implementation of living fences, watering troughs for livestock, home gardens, planting of native timber species for domestic use, access to drinking water, livestock rotation, enclosure of waterways with wire fencing, planting of native species for restoration, control of burning, selective logging, and conservation of riverbanks. Each action was adapted to the needs of the family and the specific characteristics of their property. Living fences were established on the properties with the largest areas of degraded pastureland, belonging to four families. After the installation of wire fences, 400 Gliricidia sepium stakes and more than 225 seedlings of seven plant species (Inga sp., T. rosea, J. caucana, T. ochracea, A. guachapele, A. saman, and A. niopoides) were planted. Gliricidia sepium was one of the alternative forages for the livestock (Figure 6a). Three watering troughs were constructed to control livestock access to the streams (Figure 6b); additionally, four structures and their equipment were implemented for the extraction and conveyance of water for domestic use (Figure 6c-e).

To promote the diversification of orchards, six families received seeds of fruit species (e.g., Cucumis melo, Tamarindus indica, and Melicoccus bijugatus), vegetables (e.g., tomato, scallion, cilantro, parsley, chili pepper, and bell pepper), medicinal species (e.g., chamomile, lemongrass, and sage), and some ornamentals (e.g., Viola tricolor and succulents). Different species were distributed among the families to encourage exchange. As special cases, one family planted 25 guamo trees (Inga sp.), while another family established a small grafted orange grove, a crop typical of the local economy, which aims to diversify income and contributes to the rehabilitation of degraded lands.

Figure 6. Implementation of living fences, livestock watering troughs, and improvement of artesian wells. Example of Gliricidia sepium planting by cuttings, planted 70 cm inward of the wire fences established by the project (A). Example of a "ring-type" watering trough to control stress factors (e.g., trampling and/or browsing by livestock) on natural regeneration in riparian zones (B). Initial state of some water catchment points; note the lack of infrastructure to facilitate water collection (C). Construction process of the well base using concrete rings (D). Top of the well still without final finishes (E). Seven of the beneficiary families adopted livestock rotation in their management practices. To this end, maintenance was performed on existing fences, new fences and gates were erected (Fig. 7a,b), and pastures suitable to the environmental conditions and degradation of each property were established (Fig. 7c,d). To avoid encouraging the felling of native species, the construction and maintenance of fences were carried out using trees with forestry permits issued by CORPO-CORDOBA, either because they were dead from natural causes or due to sanitary reasons, location, or mechanical damage.

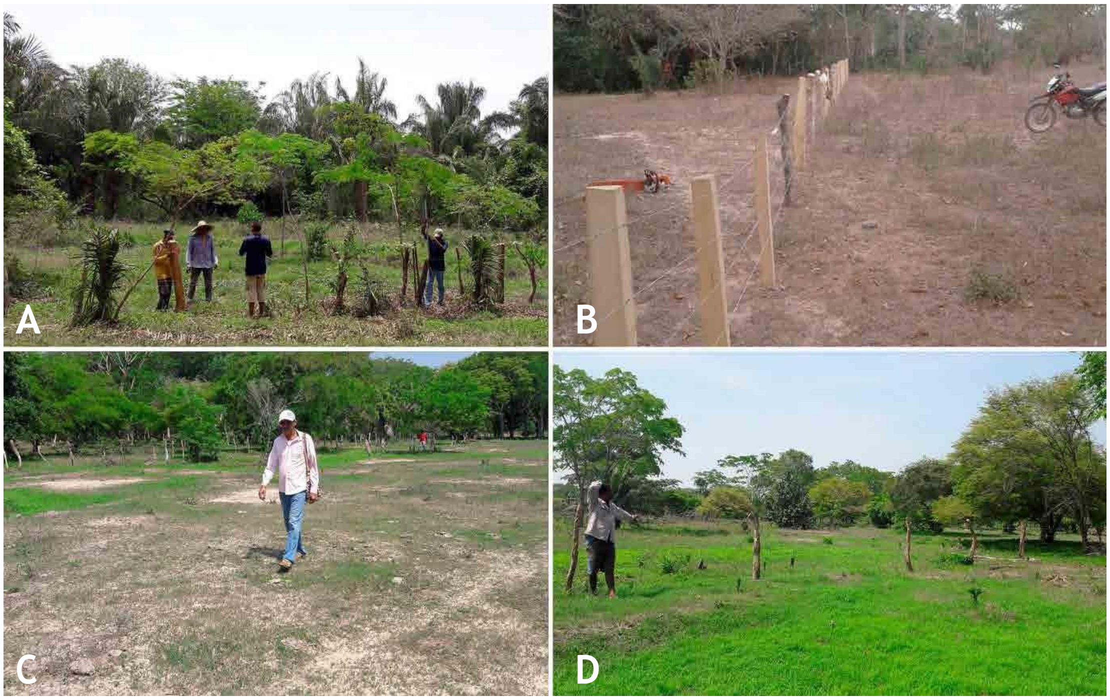

Figure 7. Isolation of areas for pasture rotation and pasture improvement. Example of pastures divided by new fences (A). Community work day for fence installation (B). Eroded area undergoing rehabilitation for agricultural production (C) and the same area after one month of rehabilitation (D). Note the successful establishment of grasses after the implementation of soil management techniques.

Participation in rehabilitation and restoration

A total of seven families participated in the project and adopted almost all of the planned strategies (Fig. 8). The greatest reluctance was regarding the adoption of productive forest plantations (4 families); this was due to the persistent misconception of a “permanent supply of trees.” This occurred despite their own conclusion that some species are locally endangered due to overexploitation. More than 30 people participated in training sessions on silvopastoral systems, food security, and ecological restoration. The idea arose to create a women's group for food sovereignty (Fig. 9).

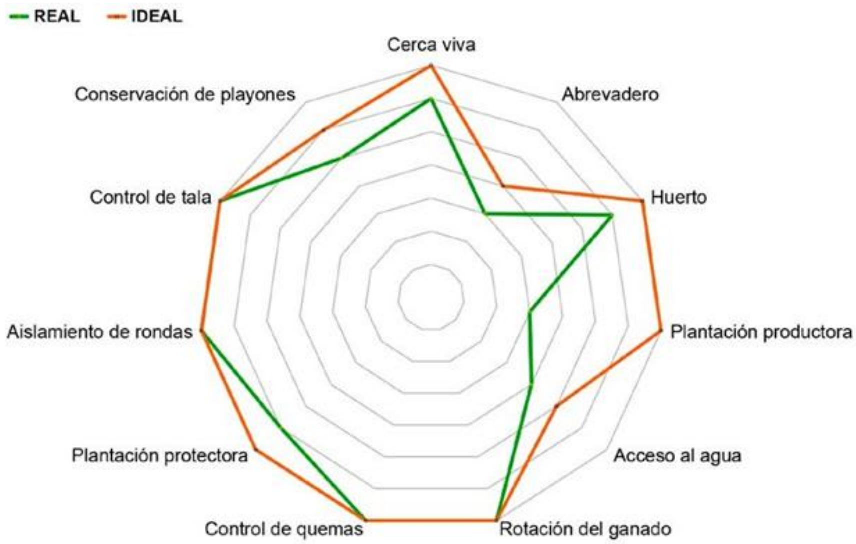

Figure 8. Radial graph reflecting the trend achieved in seven participating families in the ecological restoration project of the habitat of the turtle M. dahli.

Figure 9. Training process for sustainable production systems and ecological restoration. Cover of the educational booklet delivered to local communities (A). Image of one of the project beneficiaries practicing ecological restoration techniques (B).

Species Establishment

In the first planting period (2014), one year after implementation, the survival rate was 43%. In the second planting period (2017), this percentage increased to 89%. Species such as A. graveolens, C. tapia, E. oleifera, E. cyclocarpum, and C. gerascanthus showed the highest survival rates (78%) for both planting periods, confirming their potential for expanding the forest cover of the bs-T from the early stages of the process, under similar microsite conditions observed in Lorica.

When comparing the establishment success between the two planting periods (2014 and 2017) based on the origin of the propagules, no clearly differentiated result was observed between nursery propagation and rescued seedlings. A high percentage of establishment resulted from species originating in nurseries; However, some rescued species showed establishment rates above 85% (C. tapia, J. caucana, and T. rosea). This suggests that both methods may be useful for obtaining propagules. Seven species were observed in common among the plantings carried out in 2014 and 2017 (Fig. 10), of which H. crepitans, J. caucana, and T. rosea showed highly variable survival rates, ranging from 35% to 47% in 2014 and exceeding 90% in 2017. The remaining four species showed similar behavior in both periods, with a survival rate above 70%.

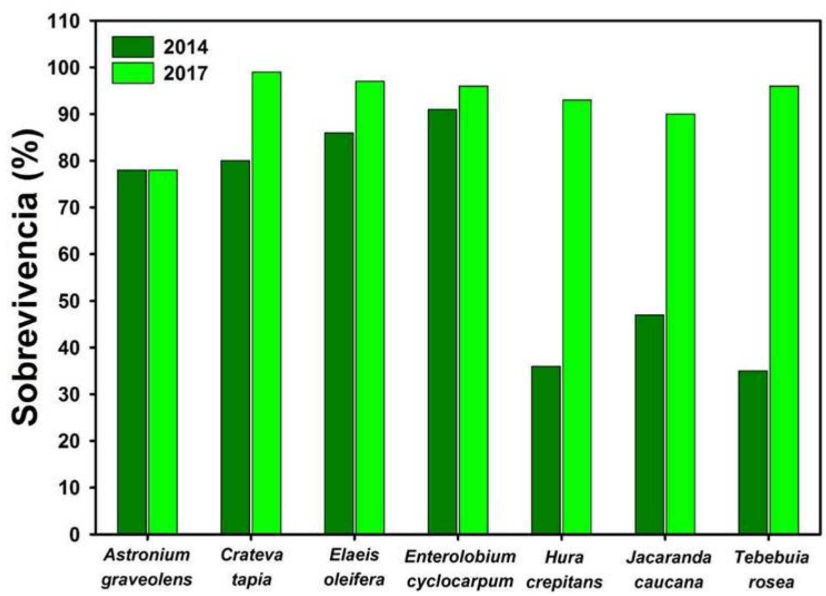

Figure 10. Survival rate of species planted in both 2014 and 2017.

The survival rate of the species planted in 2017 differed between the two monitoring periods. The highest mortality rates were observed in the species A. spruceanum (15%), A. saman (13%), J. caucana (10%), and H. ochraceus (10%). For the other species, mortality did not exceed 10%. The species A. graveolens and E. cyclocarpum showed similar behavior between planting periods, even though those planted in the first period (2014) came from rescue stock and those planted in the second period (2017) came from the nursery.

CONCLUSIONS AND PERSPECTIVES

The ecological restoration of the tropical dry forest (bs-T) in Colombia has not progressed as it has in other ecosystems or in other countries (Murcia & Guariguata 2014). This reality is reflected when proposing habitat restoration initiatives for fauna associated with the bs-T, such as the Dahl's tortoise (M. dahli).

The ecological restoration project presented in this book chapter was based on a broader conservation strategy oriented toward the integrated management of biodiversity and its ecosystem services (MADS 2015), which modified some land use patterns on properties belonging to seven participating families, with benefits for the community at large.

The restoration of the mountain tortoise habitat was an innovative concept for the beneficiary families and helped to unite social actors and integrate their actions around the ravines. It successfully focused the community's attention on this tortoise species. The dialogue among social actors resulted in conservation agreements and evidence of local empowerment for turtle conservation.

Among the elements for continuing the conservation of M. dahli is a community that fosters and builds ideas while simultaneously implementing actions. Social acceptance of the proposed actions was fundamental to linking the practice of a scientific discipline (restoration ecology) with the social fabric. The convergence of different forms of knowledge resulted in decision-making for ecological restoration and contributed to achieving credibility, acceptability, practicality, utility, and accessibility. Only in this way was trust built among the project's stakeholders and reflected in more efficient activities for the conservation of M. dahli.

No prior habitat restoration efforts for M. dahli were identified in the locality. The project advanced our understanding of how various anthropogenic factors affect populations, communities, and the ecosystem as a whole (Bond & Lake 2003). For the conservation of the Dahl's tortoise (M. dahli), it will be essential to continue deepening our knowledge of its ecological niche, the disturbance regimes in its habitat, and their effect on wild populations, as well as to address the considerations proposed by Miller & Hobbs (2007) for establishing habitat restoration goals.

Promoting connectivity between forest remnants, as a necessary process to improve the habitat of the mountain tortoise, involves rehabilitating productive areas to prevent the expansion of its range into riparian forests. Water scarcity and climate variability in the region increase the complexity of achieving restoration objectives. This project is a first step in supporting the Lorica community in building a community-based environmental ethic, with the aim of advancing toward a holistic landscape restoration. One of the first results was the improvement of the habitat of Dahl's tortoise (M. dahli).

The Guaraguau ravine was identified as a new area with a presence of Dahl's tortoise. Local plantations were established to expand riparian forest edges, and conservation agreements were reached for forests and floodplains, totaling 45 hectares of protected areas along almost 4 kilometers of the Sinú River. A network of families interested in continuing the restoration process was also formed. All of this translates into opportunities for the conservation of Dahl's tortoise habitat.

The mountain tortoise is omnivorous, but has only occasionally been observed feeding on plant material. The community reported having observed it consuming the fruit of the Erythema oleifera palm. If this observation is confirmed, the inclusion of this palm in the restoration of M. dahli habitat would be important. A survival rate of 85.6% in 2014 and 97.3% in 2017 demonstrates the apparent ease with which E. oleifera can become established. Furthermore, M. dahli individuals have been observed estivating in the leaf litter of riparian forests. If leaf litter can play a relevant role as a turtle refuge during local temperature and humidity changes, then when promoting the development of forest cover, plant species that contribute a high quantity of leaf litter should be incorporated, such as Anacardium excelsum and Astronium sp. (Bonilla et al. 2008).

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