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SILVOPASTORAL SYSTEMS AND ECOLOGICAL CONNECTIVITY IN A GRAZING LANDSCAPE OF THE MAGDALENA MEDIO REGION, COLOMBIA

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ABSTRACT: We summarize the results of a six-year collaborative project in which CIPAV and ranchers of Riberas del San Juan (Cimitarra, Santander, Colombia) designed and implemented silvopastoral and agroforestry systems aimed at enhancing farm productivity, biodiversity conservation and ecosystem services. This process was part of Proyecto Vida Silvestre (PVS), an initiative that promoted the conservation of five endangered species in the Magdalena Medio region. Livestock practices had generated severe soil degradation in the deforested landscape of Riberas del San Juan, forest fragments were destined to become new pastures, and ranchers had a negative view of trees and forests. The component of the PVS coordinated by CIPAV had been planned to focus on the conservation of *Aspidosperma polyneuron* Müll. Arg. and other endangered trees. However, given the challenging conditions of the farms and the rural community of Riberas del San Juan, it was not reasonable to start this collaboration with conservation and ecological restoration actions. Instead, we focused on the ranchers' top priority, that is, improving their farming system. We describe the continued dialogue and training that led to the adoption of the first silvopastoral practices in the area and to the co-design of agroforestry systems that simultaneously contribute to food sovereignty, productive efficiency, and ecological connectivity in the fragmented landscape. With time, farm planning, paddock subdivision, the integration of shade trees and the production of quality forages, enhanced farm efficiency, allowing ranchers to release strategic land for restoration of riparian buffers and ecological rehabilitation with agroforestry systems. The cultural barrier against trees was overcome as farmers understood the productive and environmental benefits of woody plants. The actions aimed at strengthening the

resilience and productivity of cattle production motivated the community to plan activities that contribute to the ecological restoration and conservation of the focal species and biodiversity of this landscape.

KEYWORDS: Agroforestry, Biodiversity conservation, Forest landscape management.

SISTEMAS SILVOPASTORIS E CONECTIVIDADE ECOLÓGICA EM UMA PAISAGEM DE PASTAGEM DA REGIÃO MAGDALENA MÉDIO, COLÔMBIA

RESUMO: Este artigo resume um esforço colaborativo de seis anos durante o qual o CIPAV e pecuaristas da cidade de Riberas del San Juan (Cimitarra, Santander) projetaram e implementaram sistemas silvipastoris e agroflorestais com o objetivo de melhorar a produtividade pecuária e gerar condições adequadas para a conservação da biodiversidade e serviços ecossistêmicos. Este processo fez parte do Projeto Vida Selvagem (PVS), uma iniciativa para a conservação de cinco espécies ameaçadas de extinção em Magdalena Medio. Na paisagem desmatada de Riberas del San Juan, as práticas de pecuária geraram forte degradação do solo, os fragmentos florestais foram destinados a se tornar novos pastos e os fazendeiros tinham uma visão negativa das árvores e florestas. O componente do PVS coordenado pelo CIPAV teve como foco a conservação da peroba-rosa (*Aspidosperma polyneuron* Müll. Arg.) e outras árvores em perigo de extinção local. No entanto, as condições do terreno e da comunidade de Riberas del San Juan não eram adequadas para iniciar o trabalho com ações diretas de conservação e restauração ecológica. Antes disso, era preciso atender à prioridade dos pecuaristas, ou seja, a melhoria de seu sistema produtivo. Descreve-se o processo de diálogo e formação que levou à adoção das primeiras práticas silvipastoris na área e ao co-desenho de sistemas agroflorestais que contribuem simultaneamente para a soberania alimentar, eficiência produtiva e conectividade ecológica na paisagem fragmentada. Ao longo do tempo, o planejamento das fazendas, o parcelamento das pastagens, a integração das árvores de sombra e a produção de forragem de qualidade, contribuíram para melhorar a eficiência produtiva das propriedades e possibilitaram a liberação de algumas áreas estratégicas para a recomposição das matas ciliares. Corredores e reabilitação ecológica com sistemas agroflorestais. A barreira cultural dos agricultores em relação às árvores foi superada na medida em que eles entenderam os benefícios produtivos e ambientais das plantas lenhosas. As ações voltadas para o fortalecimento da resiliência e produtividade da pecuária sensibilizaram a comunidade para o planejamento de novas ações de restauração ecológica e conservação das espécies focais do PVS e da biodiversidade de seu território.

PALAVRAS-CHAVE: Agrossilvicultura, Conservação da biodiversidade, Gestão da paisagem florestal.

SISTEMAS SILVOPASTORILES Y CONECTIVIDAD ECOLÓGICA EN UN PAISAJE DE PASTOREO DE LA REGIÓN DEL MAGDALENA MEDIO, COLOMBIA

RESUMEN: Este artículo resume un trabajo colaborativo de seis años durante el cual CIPAV y los ganaderos de la localidad de Riberas del San Juan (Cimitarra, Santander), diseñaron e implementaron sistemas silvopastoriles y agroforestales con el objetivo de mejorar la productividad de la ganadería y generar condiciones adecuadas para la conservación de la biodiversidad y los servicios ecosistémicos. Este proceso se enmarcó en el Proyecto Vida Silvestre (PVS), una iniciativa para la conservación de cinco especies en peligro de extinción en el Magdalena Medio. En el paisaje deforestado de Riberas del San Juan, las prácticas ganaderas habían generado una fuerte degradación de los suelos, los fragmentos de bosque estaban destinados a convertirse en nuevos potreros y los ganaderos tenían una visión negativa de los árboles y los bosques. El componente del PVS coordinado por CIPAV debía enfocarse en la conservación del carreto colorado (*Aspidosperma polyneuron* Müll. Arg.) y otros árboles en peligro de extinción local. Sin embargo, las condiciones del terreno y de la comunidad de Riberas del San Juan no eran adecuadas para iniciar el trabajo con acciones directas de conservación y restauración ecológica. Antes de eso, era necesario atender la prioridad de los ganaderos, es decir, el mejoramiento de su sistema productivo. Se describe el proceso de diálogo y capacitación que condujo a la adopción de las primeras prácticas silvopastoriles en la zona y al co-diseño de sistemas agroforestales que contribuyen simultáneamente a la soberanía alimentaria, la eficiencia productiva y la conectividad ecológica en el paisaje fragmentado. Con el tiempo, la planificación de las fincas, la subdivisión de los potreros, la integración de árboles de sombrío y la producción de forrajes de calidad, contribuyeron a mejorar la eficiencia productiva de los predios e hicieron posible la liberación de algunas áreas estratégicas para la restauración de corredores ribereños y la rehabilitación ecológica con sistemas agroforestales. La barrera cultural de los ganaderos hacia los árboles se superó en la medida en que ellos comprendieron los beneficios productivos y ambientales de las plantas leñosas. Las acciones encaminadas a fortalecer la resiliencia y productividad de la ganadería sensibilizaron a la comunidad para planificar nuevas acciones de restauración ecológica y conservación de las especies focales del PVS y la biodiversidad de su territorio.

PALABRAS CLAVES: Agroforestería, Conservación de la biodiversidad, Gestión del paisaje forestal.

INTRODUCTION

The region known as Magdalena Medio, located between the Central and Eastern cordilleras (mountain ranges) in the Magdalena inter-Andean valley, was covered by tropical rain forest until the 1930s, when oil exploration and the construction of the railway accelerated the transformation of this landscape through colonization, timber extraction, fishing, and livestock. For almost a century, agricultural failures drove settlers and peasants towards extensive cattle ranching. This region has been hit by the absence of the State, which is reflected in low rates of schooling and coverage of health services, poor roads, and control of the territory by illegal groups (MOLANO, 2009).

The project described below was carried out in the village of Riberas del San Juan, in the municipality of Cimitarra, Santander. Between 2014 and 2021, the Proyecto Vida Silvestre (PVS or Wildlife Project, supported by Ecopetrol, the Julio Mario Santo Domingo Foundation and Fondo Acción, and managed by WCS), carried out a series of actions to conserve focal species in the Magdalena Medio region, in partnership with several local and national organizations, including CIPAV. Conservation agreements were complemented with ecological restoration and the promotion of sustainable farming alternatives, based on a careful landscape analysis. The five focal species of the PVS have been affected by the unplanned expansion of grazing livestock. On the one hand, the vulnerability of the three terrestrial species (the blue-crested curassow - *Crax alberti*, the choibo monkey - *Ateles hybridus* and the tree *Aspidosperma polyneuron* Müll. Arg.) is linked to deforestation and forest fragmentation. On the other hand, the population declines of the two aquatic species (the manatee - *Trichechus manatus* and the striped catfish - *Pseudoplatystoma magdaleniatum*) are related to sedimentation and turbidity as a result of erosion.

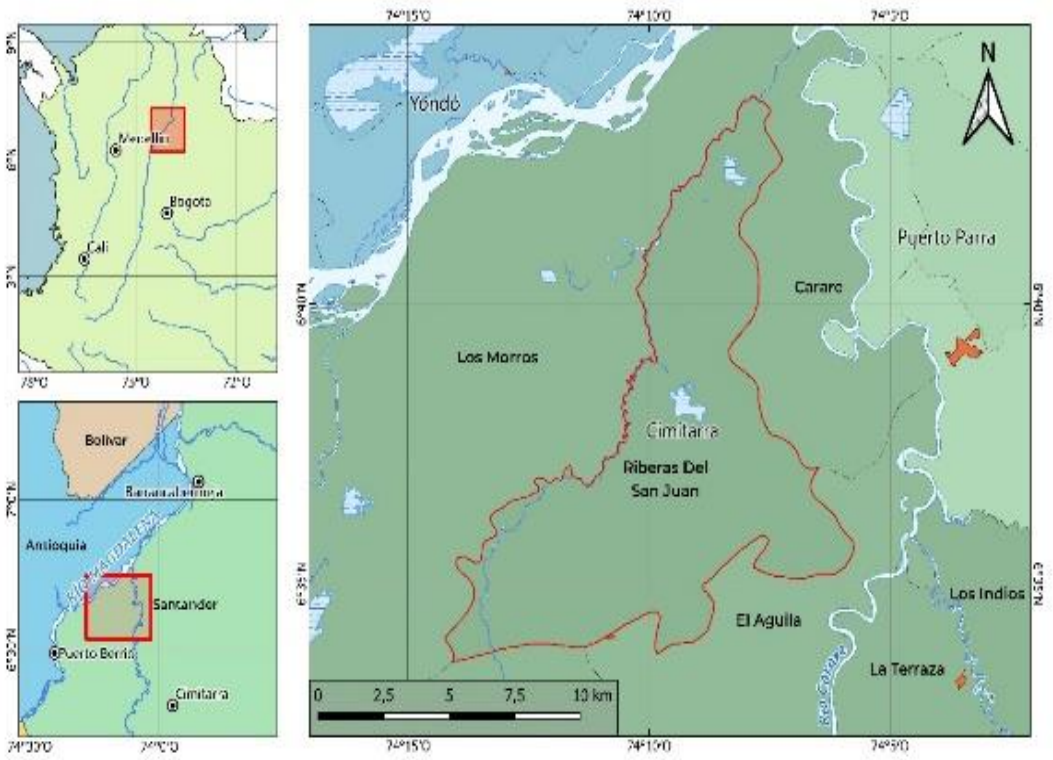
CIPAV's activities in the PVS sought to facilitate the adoption of practices aimed at transforming grass monocultures, which depend on synthetic inputs, into

tree-based livestock systems, which rely on biological processes (CHARÁ, et al., 2020). Such biodiversity friendly livestock practices were encouraged to enhance habitat for the project's focal species. The main barrier to this cultural change was the farmers' deeply ingrained view about trees and forests as enemies.

MATERIALS AND METHODS

The village of Riberas del San Juan, in the municipality of Cimitarra, Santander (Figure 1), is a place with temperatures between 23 and 33°C and annual rainfall of 2,500 - 3,000 mm. Rain is bimodally distributed, with maximum values on April - June and September - November. The area is classified as wet forest in the Holdridge life zone system (GALVIS-APONTE; QUINTERO-FRAGOZO, 2016). Cattle farms are located between 107 and 133m above sea level.

Figure 1. Project area (Riberas del San Juan, Cimitarra, Santander).



Source: Map by Bernardo Murgueitio (2021).

In the alluvial terrace landscape of the Magdalena Medio, flat areas alternate with low, rounded and gently sloping hills. An important system of wetlands and swamps, including La San Juana and La Colorada, both connected through the San Juan River, collects water from streams that cross extensive deforested land.

he clay loam and acid soils, are characterized by a thin organic layer, and the rocky profile is visible few centimeters under the soil surface. As a result of geology, rainfall and high temperatures, soils are acidic (pH of 4.33 - 4.45), with high aluminum and low nutrient levels. Low natural fertility is worsened by deforestation, burning and excessive use of agrochemicals. The high costs of liming and chemical fertilization limit intensive agriculture in Riberas del San Juan. Grazing lands show widespread sheet erosion and gullies.

The rapid growth of cattle ranching in this forest landscape has accelerated soil degradation. On the other hand, the expansion of livestock systems, the extraction of fine timber trees and the use of forests fragments as resting places for livestock have increased forest fragmentation and degradation (MARÍN-VALENCIA, et al., 2018). The burning of mature and young forests to establish new pastures has strong negative impacts on forest fragments and their biodiversity (BENÍTEZ; SERNA; ÁLVAREZ, 2011).

All farms in Riberas del San Juan are dedicated to cattle ranching. The CIPAV team worked on 19 farms, 13 of them small or medium sized (12 - 65 hectares), and 6 larger ones (200 - 2,500 hectares). As a result of the loss of riparian forests and the use of swampy areas for grazing, the flows of important bodies of water in the area, such as the San Juana swamp and the San Juan River (tributary of the Carare River), show large fluctuations throughout the year.

At the beginning of the project, several ranchers expressed their desire to modernize their production system by adopting specialized seeds and additional synthetic inputs. With the aim of broadening the perspective of

ranchers and opening their minds to a holistic transformation of their farming system, initial conversations focused on sustainable ranching practices and farm planning to comply with environmental regulations, starting with the protection of riparian buffers. The fact that several ranchers had large debts with the input suppliers facilitated the dialogue on productive alternatives to reduce production costs, improve the profitability of livestock and eliminate dependence on external inputs.

The project began with a participatory landscape diagnosis. Water bodies, forest fragments, and farming systems were analyzed with the farmers to identify priorities in terms of sustainable practices, ecological restoration, and conservation. Conversations with the community elders played a key role in understanding forest conversion and identifying springs and watercourses that had disappeared after deforestation. Planning exercises integrated the visions of three generations (grandparents, parents, and grandchildren).

The CIPAV team stayed in the project area for periods of several months. This allowed close exchange with families, as well as ongoing training in productive and environmental issues. Conversations on topics such as nutrition, cost of livestock inputs, opportunities for producing these inputs on the farms, and the commercial value of farms with diversified production systems and protected streams, helped to motivate farmers to adopt silvopastoral and restoration practices (CALLE; MURGUEITIO, 2020).

Three levels of intervention were applied in the cattle farms of Riberas del San Juan:

- *Pilot farms*: The PVS provided technical assistance, supplies and labor to transform three conventional farms into pilot or demonstration farms, with silvopastoral practices such as scattered trees in paddocks, fodder hedges and mixed fodder banks. The transformation of the El Sinaí farm (30

hectares) began in 2016, during the initial phase of the PVS. As of 2019, the same process began at El Porvenir (65 hectares), Santa Marta (358 hectares) and Margaritas (20 hectares) farms. Participatory farm planning with the families was the first step in all cases. The result of each planning exercise was summarized in a map of the property with the changes desired by its owners. Based on this input, implementations were prioritized.

- *Advising farm owners*: The project provided technical assistance and inputs, but not labor, to the La Fortuna, La Cristalina and Canaán farms, where the process also began with participatory farm planning. Several activities in these properties focused on adequate water management. Forest fragments were fenced to prevent further degradation by livestock and ecological restoration processes were initiated in the hills, where cattle productivity is very low. Live fences and cattle rotation were also implemented to improve productivity.

- *Low-touch approach*: In the remaining farms, the Project supported some actions that the ranchers wanted to implement. Farm owners received seedlings, fencing materials and technical assistance to plant trees such as abarco (*Cariniana pyriformis* Miers) and cacao (*Theobroma cacao* L.). Relationships with these landowners began with their interest in the changes implemented in the pilot farms. For example, a rancher who transported supplies and equipment to the pilot farms, decided to adopt some ideas on his own farm, with minimal support, after observing the progress in the pilot farms.

The following question played a key role in supporting ranchers at Riberas del San Juan: Which trees do you like? To weaken cultural barriers towards integrating trees in farms, ranchers' preferences were prioritized over ecological criteria (CALLE-D, et al., 2014; TARBOX, et al., 2020). It is important to mention that four participating farms were managed by women.

Figure 2. Figure 2. El Porvenir farm in May 2019 and April 2021.

Source: Photos by Mauricio Carvajal (2019, 2021).

RESULTS AND DISCUSSION

The following silvopastoral and agroforestry systems were designed and tested with ranchers at Riberas del San Juan:

- *Mixed fodder bank* (MFB): Although the use of trees as a source of fodder is a very old practice, their systematic cultivation for this purpose is relatively recent (BENAVIDES, 1994).

MFBs have been investigated in the tropics for several decades (MURGUEITIO; IBRAHIM, 2001). Designs and applications evolved from monocultures of trees and shrubs such as *Morus alba* (HERNÁNDEZ, et al., 1999), *Gliricidia sepium* (Jacq.) Kunth ex Walp. (ESCOBAR; ROMERO; OJEDA, 1996), *Trichanthera gigantea* (Bonpl.) Nees (GÓMEZ, et al., 1999), *Cratylia argentea* (Desv.) Kuntze (ALGEL; LASCANO, 1999), *Moringa oleifera* Lam. (FOIDL.; MAYORGA; VÁSQUEZ, 1999) and others, to the integration of various forage plants, trees, palms and crops (GIRALDO; SINISTERRA; MURGUEITIO, 2011). This model has been adopted by ranchers in the project area and in larger-scale initiatives, such as the Colombian Sustainable Cattle Ranching project (THE WORLD BANK, 2021). At the beginning of CIPAV's work in Riberas del San Juan, a rancher expressed his desire to plant a cut-and-carry grass reserve for his livestock. An initial design was proposed for a MFB, which underwent several changes during the implementation process (MEJÍA; ZAPATA; SOLARTE, 2017). Initially, homogeneous blocks of species such as *G. sepium*, *Tithonia diversifolia* (Hemsl.) A. Gray, *T. gigantea* and food crops were planted. Later, farmers started managing the abundant regeneration of *Trema micrantha* (L.) Blume, a common pioneer tree whose shade facilitates the growth of fodder shrubs. The edges of the MFB were then planted with *Cecropia* sp. trees in order to create a partially shaded environment and protect the soil. The implementation of a continuous flow biodigester made it possible to take advantage of the effluent as liquid fertilizer in the MFB. Over time, it became clear that the success of MFB in the conditions of Riberas del San Juan relied on a readily available source of liquid organic fertilizer, the use of which required photovoltaic energy and a pump. The cost of the biodigester and the complementary equipment limited the adoption of the MFB in other farms.

- *Scattered trees in paddocks*: Paddocks with scattered trees are silvopastoral systems with great potential in the tropics (ESQUIVEL, et al., 2003) due to their low implementation cost and the local adaptation of native tree species. Tree selection and adequate management techniques largely determine the success of these systems. In the case of Magdalena Medio, a change of attitude was needed towards the trees that spontaneously regenerate in grazing areas, which were systematically eliminated by farmers (CALLE; MURGUEITIO, 2015). Shade availability in the paddocks is essential for farmers to be able to fence the forests in the Magdalena Medio region and stop using them as resting places for cattle. One of the first changes agreed with the ranchers was to stop spraying herbicides. This made it possible to increase shade rapidly by managing the natural regeneration of common pioneer trees such as *Xylopia aromatica* (Lam.) Mart. and *Vismia ferruginea* Kunth. A goal was agreed with each rancher in terms of tree density in grazing pastures. The initial plan required adjustments to increase light penetration and control the allelopathic effects of the leaf litter of regenerating *X. aromatica* trees. Trees were thinned several times to maintain an adequate canopy cover for grass growth (30 to 35%) and to take advantage of the wood. *X. aromatica* performed well because it allows light to reach the ground. However, *V. ferruginea* trees were gradually eliminated because ranchers associate this species with the presence of warts on cattle. However, it has not been possible to confirm a direct relationship between the trees and the presence of warts caused by viruses in cattle (probably a bovine papillomatosis). As a complement to the trees in the paddocks, an adequate rotation of the animals was promoted after analyzing with the farmers the factors enhance pasture growth. In one of the farms, an argument in favor of the trees was the observation of a group of monkeys trying to cross a

paddock. Other producers had the idea of integrating trees in the paddocks, but had not considered the possibility of obtaining them through natural regeneration.

- *Live fences*: Live fences are linear elements of agricultural landscapes that can include a wide variety of tree species in different contexts. Their contributions to biodiversity have also been studied mainly in the dry tropics, where they are frequently established to provide shade and forage, but also in moist tropical conditions comparable to those of in project area (MOLANO; QUICENO, 2000). Before the PVS, live fences were unknown in the region. All the fences in Riberas del San Juan were made of fine timber obtained from vulnerable or endangered trees such as: *Clathrotropis brunnea* Amshoff (Fabaceae), *Licania arborea* Seem. (Chrysobalanaceae), *Caryocar amygdaliferum* Mutis (Caryocaraceae), *Cariniana pyriformis* Miers (Lecythidaceae), *Minquartia guianensis* Aubl. (Olecaceae), *Terminalia amazonia* (J.F. Gmel.) Exell (Combretaceae), *Couratari guianensis* Aubl. and *Eschweilera pittieri* R. Knuth (Lecythidaceae). The scarcity of these trees and the high cost of timber and transport from distant sites, motivated ranchers to adopt live fences. Very soon, ranchers understood the advantages of this practice, such as lower maintenance cost of the fences and the production of timber for different needs in the farms (CALLE; MURGUEITIO, 2015): The following species were planted in the live fences of Riberas from San Juan: *Crescentia cujete* L., *Mimosa trianae* Benth., *Handroanthus chrysanthus* (Jacq.) S.O. Grose, *G. sepium*, *Samanea saman* (Jacq.) Merr., *Guazuma ulmifolia* Lam., *Citrus* spp., *X. aromatica* and *Mangifera indica* L.. Unfortunately, toward the end of the Project, the cost of fencing materials and their transportation, still limited the adoption of live fences to subdivide paddocks and increase grazing efficiency.

- *Fodder hedges:* The El Porvenir farm implemented the first fodder hedges in the Magdalena Medio region. The idea arose from a training that involved the entire family of owners, focused on ruminant nutrition and the importance of a diversified diet to meet the requirements of protein, energy, and minerals. By weighing grass biomass periodically to assess forage availability, the family understood the need to subdivide the paddocks and implement rotational grazing in order to guarantee grass consumption at the optimum moment. Fodder hedges are corridors with live fences on both sides, which integrate the production of forage and food such as cassava (*Manihot esculenta* Crantz), banana (*Musa* spp.), and citrus. During the establishment phase, the grass is cut very low before planting *T. diversifolia* and cassava at a 30 cm distance plants. This high-density planting develops a shady environment rapidly and helps control the regrowth of grasses. Larger plants (banana and trees such as *Mimosa trianae* Benth.) are planted on a line at the center of the hedge, and forage shrubs are planted in parallel lines every meter to facilitate handling. Some Tithonia plants are left to grow freely to provide flowers for beneficial insects. These multiple strips of forage shrubs mixed with trees and palms contribute to landscape connectivity by facilitating the movement of wildlife, attract beneficial birds and insects to the grazing systems, reduce wind speed and improve forage supply (AYALA, et al., 2017).
- *Agroforestry systems (AFS)*: The Covid-19 pandemic and the quarantine imposed by the Colombian government motivated several ranchers to reinforce food sovereignty on their farms with crops such as cocoa, banana, cassava, and chaya (*Cnidoscolus aconitifolius* (Mill.) I.M. Johnst.). The first AFS was established in a key site for ecological connectivity, located between two natural drainages and already surrounded by live fences. Different timber trees were planted inside the AFS.

- *Agroforestry for connectivity and food sovereignty*: In regions with a recent history of deforestation, connectivity corridors with a design based exclusively on biological criteria (without integrating the needs of ranchers) can be perceived as an imposition (authors' observations). Ranchers may be more open to the possibility of integrating trees on their farms when the benefits for the farming system are the starting point of the conversation (Carvajal, personal observation). At the beginning of the project, several ranchers expressed an interest in growing crops such as plantain (*Musa* spp.) and cassava (*Manihot esculenta*) so they would not have to buy them in the market. This expectation gave rise to the idea of planting agroforestry corridors between the paddocks. These corridors offer the same services as live fences, but also produce fodder for livestock and food for the family, while enhancing connectivity between forest fragments. After observing the multiple benefits of the first agroforestry corridor, several owners expressed their interest in expanding this strategy on their own farms.
- *Rehabilitation of land unsuitable for cattle ranching*: Hills in the Magdalena Medio region become degraded rapidly when used for grazing (Carvajal, personal observation). Unfortunately, there is a strong cultural barrier against the practice of allowing vegetation to grow spontaneously on these eroded lands. However, some ranchers understood the benefits of implementing agroforestry systems on degraded hills. The owners of the Las Margaritas and La Fortuna farms planted a combination of crops such as plantain, cassava, cocoa, and corn, with multipurpose trees of their choice such as *Mimosa trianae*, Parkia pendula (fast-growing, with tenuous shade and good effect on pastures), *Ceiba pentandra*, Cedrela odorata, *Guazuma ulmifolia* and *Crescentia cujete*.

Table 1. Species integrated in agroforestry and silvopastoral systems of Riberas del San Juan, Colombia.

Type of system	Species
Mixed fodder banks	Mexican sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray), cassava *(Manihot esculenta* Crantz*)*, sugarcane (*Saccharum officinarum* L.), white mulberry (*Morus alba* L.), *Trichanthera gigantea* (Bonpl.) Nees, maize (*Zea mays* L.), *Arracacia xanthorrhiza* Bancr., *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Trema micranta* (L.) Blume, *Artocarpus altilis* (Parkinson) Fosberg, *Cordia gerascanthus* L., *Xylopia aromática* (Lam.) Mart., *Cecropia membranácea* Trécul and grasses. Sinaí farm
Fodder hedges	*Handroanthus chrysanthus* (Jacq.) S.O. Grose, *Mimosa trianae* Benth., *Tithonia diversifolia (Hemsl.)* A. Gray, Citrus sp., calabash tree (*Crescentia cujete* L.*)*, *Guazuma ulmifolia* Lam., *G. sepium, Cordia gerascanthus* L., *Spondias purpurea* L., maize, *Byrsonima crassifolia* (L.) Kunth, chaya *(Cnidoscolus aconitifolius* (Mill.) I.M. Johnst.). El Porvenir and Margaritas farms
Live fences	*C, cujete*, *M. trianae*, *H. chrysanthus*, *G. sepium*, *G. ulmifolia*, *Citrus* spp., *X. aromatica* and mango *(Mangifera indica* L.). El Sinaí, El Porvenir, Margaritas, Santa Marta, La Fortuna and La Cristalina farms
Scattered trees in paddocks	*X. aromatica*. El Sinaí, El Porvenir, Margaritas, Santa Marta and La Fortuna farms
Agroforestry systems	*M. trianae*, *H. chrysanthus*, plantain (*Musa paradisiaca)*, cacao (*Theobroma cacao* L.), cassava, *(Manihot esculenta* Crantz*)* rain tree (*Samanea saman* (Jacq.) Merr.), *T. diversifolia*, *Citrus* spp., *C. cujete*, *G. ulmifolia*, *G. sepium*, *C. gerascanthus*, *S. purpurea*, maize, *B. crassifolia*, chaya *(C. chayamansa)*.

Source: Elaborated by the authors (2021).

Other practices adopted by ranchers at Riberas del San Juan include the following:

- *Biodigesters*: The implementation of continuous flow biodigesters had a great impact since the beginning of the Project because firewood for cooking was scarce in the region, and unauthorized firewood collection was a permanent source of conflict between neighbors. On the other hand, propane gas for cooking and its transportation to the farms were expensive. Families that implemented biodigesters recovered their investment

in a period of 8 months without buying gas.

- *Solar panels*: At the beginning of the Project, frequent and prolonged power cuts made it difficult to manage rotations in the paddocks. The implementation of solar panels and photovoltaic energy for electric fences and basic household needs, accelerated the transformation of farms. Photovoltaic energy allowed farmers to sustain fodder production and to implement adequate cattle rotations.
- *Forest fencing*: The use of forest fragments as resting places for cattle is a common practice in the Magdalena Medio region. Cattle trample the understory and destroy regenerating seedlings, thereby forming unproductive muddy clearings within the fragments (Carvajal, pers. obs.). Fencing prevents livestock from entering and accelerates the recovery of degraded forests.
- *Cattle aqueduct*: Permanent water supply in each paddock, which often depends on photovoltaic energy, avoids long walks of cattle to streams and drinking troughs. The implementation of several livestock aqueducts eliminated the common practice of offering stagnant and low-quality water to the animals.

During five years of exchange and work with the ranchers, it was useful to introduce new practices in terms of improving the farming system and avoiding debt with agricultural input suppliers, without focusing directly on the restoration and conservation benefits. To overcome the cultural rejection of trees, a set of multipurpose species that had already shown good results in the region was prioritized for planting (Table 1). Soil degradation and increasingly erratic weather limited the number of species planted on cattle farms. On the other hand, cultural barriers also made it difficult to integrate a high diversity of species since the beginning of the process. However, the objective of weakening this cultural barrier was achieved.

A total of 343 hectares were enhanced in the landscape of Riberas del San Juan, with land-use changes that

focused on sustainable livestock management (Figure 2). For example:

- 28 hectares of silvopastoral systems were established, including a mixed forage bank (0.5 ha on, one farm), scattered trees (21.35 ha on five farms), fodder hedges (1062 m on three farms) and live fences (7547 m on five farms).
- Three continuous flow biodigesters and a rainwater harvesting systems were implemented.
- Livestock aqueducts were built to bring water to the paddocks on five farms, with a combined length of 3.6 km. Additionally, five complete photovoltaic systems and two boosters were implemented. The orderly rotation of the animals as a result of these actions accelerated the recovery of the pastures. In turn, the enhanced grass cover visibly reduced erosion and sedimentation of water bodies.
- The adoption of some practices was followed by the arrival of butterflies, beetles, birds, and other organisms (Carvajal, personal observation). For example, fence posts, together with Mexican sunflower and cassava plants, accelerated the regeneration of native plants by providing perches for seed-dispersing birds.
- 57.76 ha were released for conservation and restoration on five farms and a total of 510 m of connectivity corridors were established on three farms. The fencing of forest fragments allowed natural regeneration of tree species of high conservation value. Natural seedling banks were formed, including species that had not been produced in the nursery due to the difficulty of harvesting or germinating the seeds.
- 2.17 ha of agroforestry systems were established on two farms.
- A total of 45,000 trees and shrubs were planted.
- Furthermore, the project prevented the loss of 78 hectares of forest that ranchers had set aside to expand their pastures in the future.

CONCLUSIONS

The CIPAV team did not mention forest conservation or restoration as

explicit objectives of the work with the ranchers of Riberas del San Juan. Paradoxically, the positive environmental effects achieved in the project were an indirect result of sustainable livestock practices. Throughout the project, the adoption of practices such as scattered trees, live fences, fodder hedges and mixed fodder banks to enhance land use efficiency in areas with the best agroecological conditions, allowed ranchers to protect forest fragments and release strategic areas for restoration.

The main lesson learned from this process is the importance of initiating forest landscape restoration processes with actions aimed at strengthening production systems and livelihoods. Although this route is slow and indirect, it makes more sense for farmers who are taking the first steps in the process of reconciling with forests.

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