SCALING LAND-BASED MITIGATION SOLUTIONS IN VENEZUELA

LAND-BASED MITIGATION NARRATIVES

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2. Introduction

Venezuela is one of 17 megadiverse countries worldwide. It comprises four biogeographic regions: Amazonian, Andean, Caribbean, and Guiana (Figure 1), and it ranks fourth in amphibian diversity, sixth in bird diversity, eighth in mammal and vascular plant diversity, and ninth in reptile diversity. The number of dicotyledonous plant species is estimated to be half the world total, with 14,292 species of angiosperms and an estimated 100,000 species of Coleoptera. Levels of endemism are high, particularly in plants, birds, mammals, and invertebrates (INPARQUES, 2007; FAO, 2020).

This variety of bioregions also involves a high diversity of ecosystems, which present a great variety of warm tropical climates in lowland areas, to temperate and cold in altitudinal floors that reach 5000 m, with very high to very low average annual rainfall (350 mm to > 6000 mm), diverse geological types (from the oldest >3000 million years in the Guiana region to active sedimentary plains such as the Llanos western) and topographies, with mountain ranges (Andean Cordillera and Cordillera de la Costa), with sea fronts (Caribbean Sea), and proximity to Ecuador (Amazon Basin). Among the dominant vegetation types, Venezuela possesses 46.2 million hectares of forest (51% of total country land cover), with tropical rainforests having the highest coverage (> 25,000,000 ha).

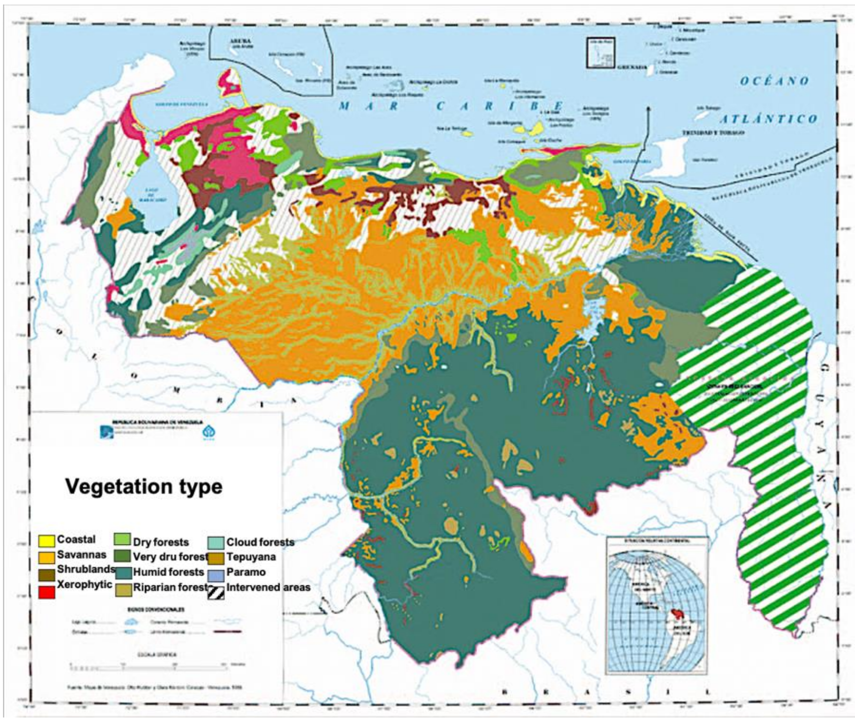

Figure 1. Vegetation map of Venezuela (adapted from Huber and Alarcón, 1988).

In this sense, climate change mitigation policies in the country have focused on the conservation and sustainable management of forests to protect carbon sinks and increase their capture of CO_2 (Bolivarian Republic of Venezuela, 2017a; FAO, 2020). However, various threats and uses expose these ecosystems to deforestation. It is important to mention that in Venezuela, protected areas are inhabited, so it represents a real challenge to develop policies that guarantee the sustainability of local communities and, at the same time, the conservation of natural ecosystems.

In this report, we will address the analysis of LMTs in three of the most relevant bioregions of the country:

1) Integrated fire management in the tropical humid forest of Amazon Basin (see section 3.2)

2) Agroforestry of arid and semiarid lands (very dry and xerophytic forests) (see section 3.3)

3) Agroforestry in dry forest lands (see section 3.4)

The first LMT corresponds to integrated fire management with an intercultural vision, in the tropical humid forest of Amazon basin. This LMT is based on Indigenous traditional knowledge of fire, as a promising LMT as a strategy for mitigating GHG emissions and the effective reduction of wildfires both in these ecosystems, as well as the challenges and advances to bring this experience to the national level. It is based on the extensive experience of the working group and addresses the analysis of fire management strategies based mainly on ancient Indigenous knowledge and traditional practices north of the Amazon region, in the heart of the Guianese shield. The initial experiences were focused on Canaima National Park, but within the framework of the LANDMARC Project, a national escalation is being carried out to implement policies that are based on fire prevention and fire management, rather than on the suppression and fighting of fires, which have been the dominant policies historically in the country and at the regional level in Latin America. The effective implementation of this LMT acquires great particular relevance due to the growing number of fires that occur and affect the natural areas of the country (Fire Management Report, 2020; Luziola et al., 2020; Finner and Mamani, 2022), degrading and reducing the carbon stock of natural systems (especially the most vulnerable such as tropical rainforests) with a strong impact on local populations, their productive activities, as well as the conservation and management of protected areas.

The second case we addressed is agroforestry in arid and semiarid lands. Although this region, which is located along the northern Caribbean coastline and islands (Figure 1), covers an area significantly smaller than that of tropical humid forests (4,102,300 ha that represents 4.5% of the national territory; Matteucci, 1986), it concentrates a third of Venezuela's population and are under high urbanization, agricultural, and industrial pressures. Additionally, erosion of these lands is a serious environmental problem and is considered the most determining factor in the degradation of productive soils. According to future scenarios of seasonal dryness (Medina et al., 2016), by 2050 semiarid lands will expand about 106,000 Km^2 into regions that currently belong to subhumid provinces, representing 10.08% of the national territory. Considering this situation, in this report we present and analyse the potential of LMT, of several projects of mixed agroforestry systems that mimic natural ecosystems and have been developed by public agencies, academics, and NGO´s working closely with local farmers, goat peasants and aloe or agave (i.e., cocuy, a tequila – like beverage) producers, with very promising results (Díaz, 2001; Miriam Diaz, pers. comm.).

Finally, we included the analysis of agroforestry in dry forest lands. Dry forest is the second most important ecosystem in the country with respect to extension and carbon accumulation capacity (Table 1). They are mainly localised in the Eastern, Central and Western Region of the "Llanos Venezolanos" (figure 1). The progress of physical and biological environmental degradation is highly dangerous, even leading to the disappearance of almost 70 % of the dry tropical forests.

Table 1. *Forest biomass and potential of C capture (Source: prepared by the authors)*

No.	Forest type	Area (ha)	Aboveground biomass (Tn/ha) (1)	Carbon Stock Tn C/ha (1)	Potential of C capture (Tn CO_2/ha) (2)
1	Tropical xerophytic forest	933,300 (2,3)	24	12	44.0 (2, 3)
2	Very dry tropical forest	2,663,000 (2,3)	75	37.5	137.6 (2,3)
3	Tropical dry forest	15,860,600	162	81	297.3
4	Humid tropical forest (evergreen)	25,058,000	277.2	138.6	508.7
5	Premontane Humid Forest	1,202,000	240	120	440.4
6	Lower montane humid forest	369,000	180	90	330.3
7	Montane Cloud Forest	18,000	180	90	330.3
8	Subalpine Forest	127,000	30	15	55.1

1 FAO, 2020; 2 Veillon, 1985; 3 Díaz, 2021

Dry forests have been disappearing rapidly due to logging associated with encroachment, burning and destruction for agricultural and livestock purposes. It is estimated that laminar erosion has caused the loss of more than 40% of the region's arable soils and the extinction of tree and wildlife species (Pacheco-Angulo and Silva, 2020). Agroforestry systems (AFS), which include silvopastoral systems (SPS), are considered as key alternatives in the current trend to promote the transformation of conventional agriculture into "climate-smart agriculture". This concept integrates the three dimensions of sustainable development (economic, social and environmental), jointly addressing food security and climate challenges (Montagnini 2015). In this report we present interesting initiatives with a great potential for scaling this LMT to other areas characterized by dry forests.

In summary this report will provide new information obtained from the literature review and testimonies gathering in interviews with relevant experts from a selected and representative LMTs of these three selected Venezuelan systems, considering the criteria and rationale used in the previous report (see D2.1 report). This report's present aim was to provide NETP quality narrative of these selected LMT's and analyse the techniques for further studies (through the help of model simulations) to scale up at local, regional, national, and global levels and meet the objectives of the LANDMARC project.

2.1. Integrated fire management

2.1.1. Introduction

Fire occurs naturally on terrestrial ecosystems from all continents of our planet, except on areas which lack vegetation such as deserts or those permanently covered by snow in Polar Regions (Bowman *et al*., 2011; Bilbao *et al.* 2020; FIRMS, 2021). The area affected by fires annually ranges between 300 and 450 Mha with maximums of 600 Mha (GFMC, 2019; IUFRO, 2018), with an average of 341 Mha (1997-2011), equivalent to 2.6 of the entire global land area (Chatenoux & Peduzzi, 2013; van Lierop *et al.*, 2015; Giglio *et al*., 2018). Fire is a landscape modelling agent that promotes fire-dependent ecosystems such as savannas and pine forests with fire-adapted plant species, while fire-sensitive vegetation such as tropical humid forests, have evolved in the absence of fire.

According to the recent IPCC Sixth Assessment Report (IPCC, 2021) many regions of the planet show, with a high level of confidence, a significant rise of "*fire-prone weather*" conditions: such as higher temperatures, extended dry seasons and increased heat waves, all of which favor wildfire occurrence and propagation, and greenhouse gas emissions. All fires, especially large wildfires (defined as uncontrolled fire in combustible vegetation that occurs in the countryside), have a significant impact on the production of carbon dioxide and other greenhouse gases (CH_4 and N_2O) that contribute to climate change (Randerson *et al.*, 2012). From 1997 to 2016, biomass burning from different ecosystems produced CO2 e emissions (2.2 10^{15} g C y-1), equivalent to 23% of global fossil-fuel$_{CO2}$ e emissions in 2014 (FAO, 2014; Boden *et al.*, 2015; Van der Werf *et al.,* 2017). Approximately 84% of global carbon emissions originate in the tropics, while 62% originate from tropical savannas, underlining the importance of fire as a driver of biogeochemical cycles and ecosystem processes in tropical ecosystems, particularly in savanna areas (Van der Werf *et al.,* 2017). NASA (2010) predicts that wildfire could increase by as much as 35% by 2100 and that most of these increases will take place in these fire dependent landscapes. Put the UNEP.

At present and according to Venezuela's second national communication (República Bolivariana de Venezuela, 2017a), wildfires and biomass burning during the year 2010 represented a critical factor in the C sink conversion of the AFOLU (acronym for Agriculture, Forestry and Land Use) sector to a source of emissions (Figure 1). Thus, the aggregate sources of CO_2 emissions and sources of emissions other than CO_2 on land emitted 0.5 Mt CO_2, 0.3 Mt CH_4 and 0.035 Mt N_2O, reaching an equivalent of 18 Mt CO_2eq. The burning of biomass contributed just over half of this emission (54%), either by burning forests (89%), savannas (9%) or crops (2%). Furthermore, considering that Venezuela has registered the highest historical fire incidence record during the last decade (Bilbao et al. 2020; Lizundia-Loiola et al. 2020; Finner and Manuni, 2022; Figure 2 and Figure 3), implementing a new paradigm concerning fire management as a mitigation strategy in Venezuela is needed.

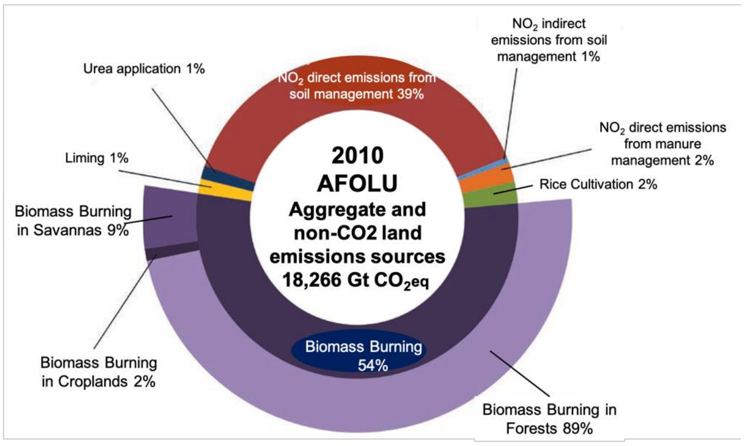

Figure 2. Emissions from the sub-sector aggregate sources of CO_2 emissions and AFOLU-sources of non-CO_2 emissions (adapted from República Bolivariana de Venezuela, 2017a).

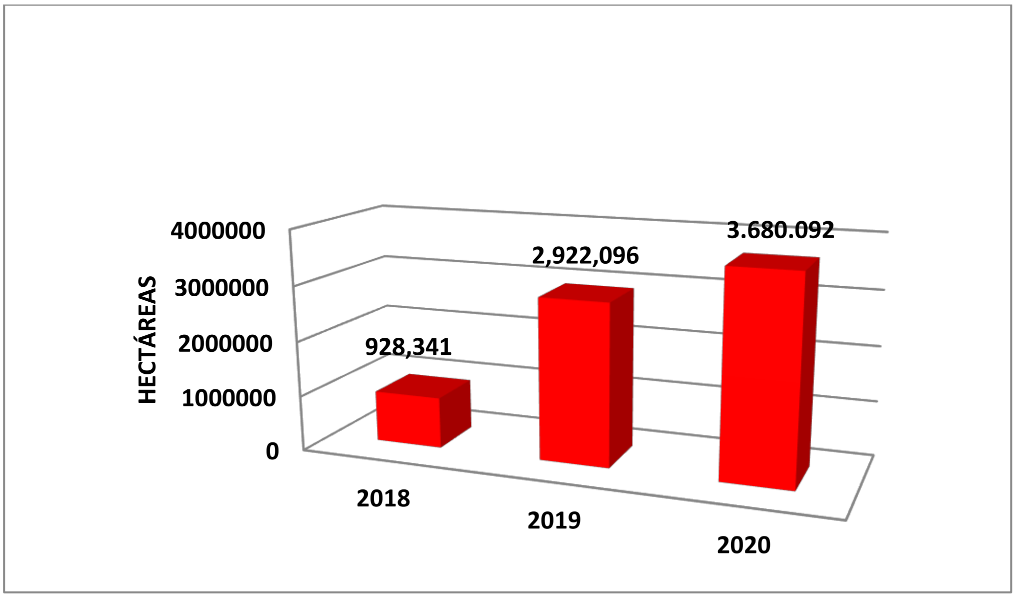

Figure 3. Area affected by fire (ha) estimated by remote sensors nationwide during the periods of drought (January-May) of the years 2018-2020 in Venezuela.

Historically, wildfire control around the world relies heavily on reactive practices of suppression and fire-fighting expert techniques such as fire brigades, the use of especial technical aerial and terrestrial support (e.g., helicopters and trucks), besides satellite monitoring. For instance, USA invest five billion dollars annually in fire-fighting control activities, equipment, and tools. However, wildfires and mega-fires incidence keeps on rising, as the mega-fire event in California during 2020 demonstrated. Besides their high costs, major criticisms of fire suppression policies indicate that they are not effective at reducing area burnt statistics, and that they do not consider the ecological and cultural role of fire in many ecosystems of the world (Eloy *et al.*, 2019, Mistry *et al.*, 2019, Ponce *et al.*, 2020; Bilbao *et al.*, 2020; Durigan, 2020). Despite these criticisms, most countries still rely on 'zero-fire' policies to ban and control virtually any fire type. These policies stigmatize all kinds of fire, promote ecological imbalances in zones with fire-adapted vegetation and create social conflicts with Indigenous peoples and local communities that depend on controlled burnings for their subsistence activities.

On the contrary, evidence has been provided on the benefits of Indigenous fire usage practices, not only for daily livelihood of Indigenous peoples, but also in reducing the risk of large fires, maintaining the reservoirs of carbon in soil and vegetation, and increasing the diversity of ecosystems (Crisostomo et al., 2015; Walter et al., 2021). There are positive experiences, such as the one presented in this report, that have tried to incorporate Indigenous fire management practices and knowledge in their territory in a new paradigm of fire management, called Integral Fire Management (IFM), which incorporates and recognizes the positive aspects of fire, as well as the knowledge of fire ecology and the cultural practices of local populations.

There are several definitions of the concept of integrated fire management, and especially of its application. The origin of the definition, Integrated Fire Management policy, comes from Myers (2006) who points out the importance of promoting inter-institutional coordination to reduce damages caused by wildfires and restoring the importance of fire as an ecological and cultural agent. This approach includes the three components of fire management: prevention, control, use of fire; along with its ecological character, as well as the socioeconomic and cultural needs of its use and integration of knowledge and capacities of institutions and fire managers, scientists, and local communities. His book "Living with fire" presents integrated fire management (IFM) as a management approach that links ecological, socio-economic, and technical aspects of fire in a holistic manner to address social and conservation problems and issues resulting from burning of to achieve goals of ecosystem sustainability as well as human livelihoods in fire-prone environments by integrating multiple scales - from local needs to global pacts on gas emissions, for example. However, usually researchers, the communities and environmental technicians are often using the term IFM, to refer exclusively to the implementation of prescribed burns. Thus, Barradas and Ribeiro (2021) consider the importance to be aware the intercultural approach, as suggested by Bilbao et al. (2019), for the integrated fire management, avoiding the regress to a technocratic understanding of fire management, disconnected from the ecological and social components.

In this sense, integrated fire management (MIF) with an intercultural vision, presents an important potential as LMT, which will be discussed and updated in this section, including the experiences at the local level in the Canaima National Park (CNP) in Venezuela, and the escalation process at the national level, which occurred in recent years.

Controlled application of fire by Indigenous people takes into account the place, time of the year, atmospheric conditions, as well as frequency, extension, duration and intensity of the burnings, for social, cultural and economic reasons (i.e. agricultural and cattle raising, ashes and charcoal application to improve soil fertility, boost grasses and pasture re-sprout, among others) (Mistry et al., 2005; Bilbao et al., 2010; Ziegler et al., 2011; Huffman, 2013; Welch, 2014; Trauernicht et al., 2015, Archibald, 2016; Eloy et al., 2018; Nikolakis & Roberts, 2020).

Integrated Fire Management based on Indigenous fire management practices as a LMT has the potential to reduce overall emissions from massive wildfires. Since controlled burnings used by Indigenous people in their territories are of low intensity and limited extension, and consider local ecological conditions, they prevent the occurrence of large wildfires. Alike Indigenous burnings, *prescribed burnings* are also controlled fire treatments applied by firefighters under the IFM policies, for the reduction of fuel material to prevent the occurrence and reduce the severity and extension of wildfires.

Fire also has been used from prehistorical times by South American Indigenous communities. The main uses are as fertilising agents for agricultural purposes and the protection of forests by reducing combustible accumulation material and thus preventing the spread of fire and its conversion into a wildfire. Thus, fire has a vital role in soil preparation before crop planting in shifting cultivation practices in small patches inside forests. The burning of plant material is required to release nutrients contained in the biomass. It increases soil fertility, reducing soil acidity (pH) and aluminium toxicity of the characteristic ancient and impoverished and washed tropical soils. These are very controlled burns that the Indigenous do against the wind (backfires) in the early morning hours, preventing the fire from spreading. Very different from uncontrolled and damaging wildfires that spread without control.

These Indigenous traditional practices were disrupted after Europeans arrived in South America. Indigenous acculturation processes and implementation of fire suppression policies lead to changes in fire practices, which currently are mainly used for deforestation, waste burning or without a functional purpose. This situation, combined with increasing drought periods promoted by climate change, has prompted mega-fires (defined as wildfires of great severity impossible to control with existing firefighting mechanisms) across the region.

2.1.2. Experiences of the CNP

In 1999 a long-term fire experiment was established to study the meteorological and fuel drivers of fire behaviour and its impact on vegetation, soil and atmosphere in a savanna – tropical humid forest gradient in Gran Sabana, Canaima National Park (CNP, 30.000 km2) (Fig. 2, Bilbao et al. 2009, Bilbao et al. 2010). Canaima National Park (CNP) is a region of great value due both to its biological and cultural uniqueness and its strategic importance, both politically and economically. The Park is a protected area located in the south-east of the country, in northern Amazonia, declared a World Heritage Site in 1994 by UNESCO because of its high biodiversity and endemism. Although humid tropical forest represents the dominant ecosystem in the CNP, it also contains a region characterised by a mosaic of savanna and forest ecosystems (Fig. 3) called the Gran Sabana (Huber 1990; Huber and Febres 2000; Huber 2006; Delgado et al. 2009). It also represents a strategic area because it includes the upper basin of the Caroní River. This hydrological source provides more than 70% of the country's energy.

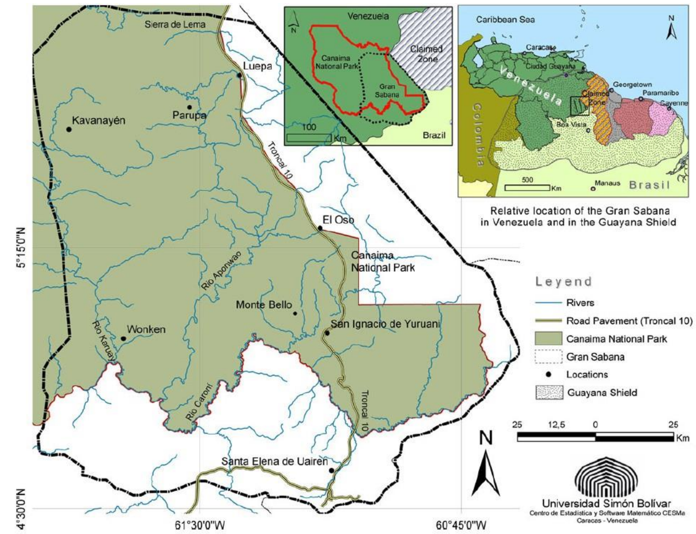

Figure 4. Gran Sabana and Canaima National Park location.

The use of fire by the Pemón Indigenous communities, natural inhabitants of the park, has been the hydroelectric company's concern because it could reduce the forest cover and affect the region's hydrological regime. Park administrators (INPARQUES) have been shared this concern, as the presence of "fire" was incompatible with the Park's conservation practices. In consequence, the institutional response was the creation, in 1981, of the Control of Wildfire Programme (PCIV), implemented by the Initial Attack Brigade Carlos Todd of CORPOELEC (the regional hydroelectricity company) to prevent, detect and fight wildfires in order to protect the headwaters of the Caroní. 21 000 km2 of this highly protected area is located in the Gran Sabana and includes the eastern sector of Canaima National Park (Gómez et al. 2000, Fig. 2). However, despite carrying out expensive and enormous fire suppression efforts, on average, only 13% of total fires are combated owing to the high number of fires over a large area (EDELCA-CORPOELEC. 2008).

Under this context, the results of the long-term fire experiment were critical to providing information and knowledge not only about fire ecology but also tools to inform the park administrators to make decisions about more appropriate policies.

The main discovery of this study was the characterisation of the ecological basis of the PMB (patch-mosaic burning technique). This technique, used by the Pemón for millennia, produces a savanna landscape in different stages of succession, which acts as natural firebreaks when wildfires reach the border of a previous burned patch (Bilbao et al., 2010). This strategy promotes the reduction of catastrophic wildfires, particularly in the most vulnerable areas of ecotones and tropical humid forest edges (Fig. 2). At the same time, fire exclusion resulted in the risky accumulation of dead combustible material that can promote wildfires of considerable magnitude and extension (Bilbao et al., 2009; Bilbao et al., 2010). The significance of this last result is that it promoted the reviewing of fire policies based only on fire suppression by firefighter bodies implemented in the CNP for decades.

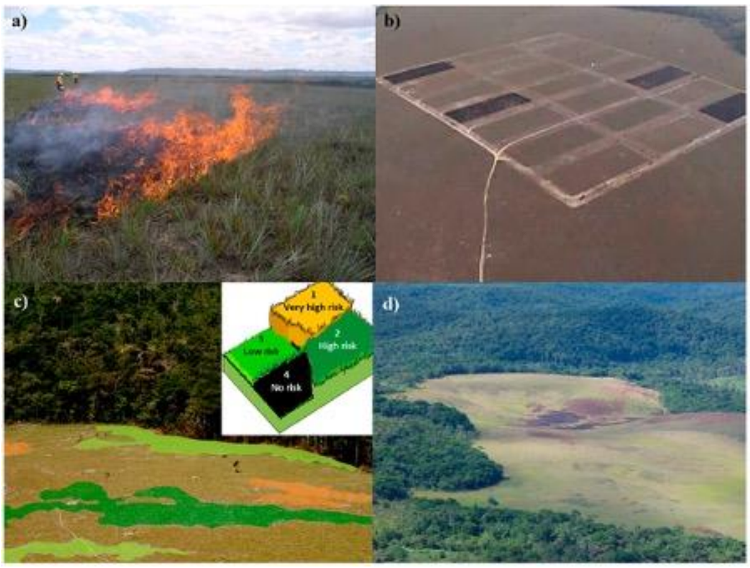

Figure 5. Experimental burns initiated by Indigenous Pemón firefighters (Photography by Bibiana Bilbao); b) Aerial view of the long-term fire collaborative long-term experiment plots (Photography by Rafael Salas); c) and d) Different views of Indigenous Patch mosaic burnings (PMB) (Photography by Ruth Salazar-Gascón).

Several initiatives, which evolved as a result of several participatory action-research projects coordinated by academics, and supported by firefighters, public officials (park administrators) and the inclusion of Pemón Indigenous communities, a paradigm change was finally enhanced to a more integrated fire management in CNP where Indigenous traditional practices of fire management were included (Bilbao et al. 2019; Mistry et al. 2019; Bilbao et al. 2020, Bilbao et al. 2021, Bilbao et al. 2022).

This experience was considered the case study (CS6) of the LANDMARC project to explore the LMT as NETP and to encompass the scaling up at the national level.

3. Policy context

In Venezuela, the Environmental Criminal Law enacted in 1992 and reformed in 2012 contains measures that prohibit fire and punish those who use fire in protected areas and limit the management by or inclusion of traditional practices of local populations (Government of Venezuela 2012). This Environmental Law respond to the fact that historically, Venezuela has had a national fire suppression policy based on the control and combat of all types of fires. This type of action has been extended to all national territory despite the great diversity of vegetation and climates along with the country. In 2013, the Forest National Law was enacted, creating the National System of Protection against Forest Wildfires (Chapter III), which operates under the Ministry's supervision with competence in environmental matters. It guides or regulates the creation of "unified commands" that operate at the national, regional, and local levels. Fires, in general, are considered in the forestry law as environmental risks or threats that must be addressed in terms of prevention, extinction and control of forest fires and the evaluation and recovery of areas affected by these events.

Likewise, within the framework of the same law, Chapter IV of Article 62 is dedicated to conserving the forest heritage by creating areas under a special administration regime (ABRAE). Thus, ABRAE is defined as those areas subject to special regulations destined for the conservation of ecosystems and the integral protection of natural resources according to their characteristics or location. Example of that is protective areas (PA), national parks, natural monuments, and biosphere reserves. Thus, particular legislation has been applied to protect natural areas (ABRAE zones) under the jurisdiction of INPARQUES (acronym in Spanish for Instituto Nacional de Parques) the highest administrative authority in charge of their management and conservation. INPARQUES, created in 1978, is an autonomous body ascribed to the Ministry of Power of the People for Eco-socialism (formerly Ministry of Power of the People for the Environment). In 1978, a Programme for Prevention and Protection Against Forests Fires was created to impart knowledge, experience, and skills for training forest rangers. In 2001, the Law of Fire-Fighters and Civil Emergency Management was enacted, promoting, some years later, the graduation of the first professional forest firefighters in the country. This law also gave rise to the Unified National Command against Forest Fires to coordinate the different entities—MINEA, INPARQUES, the Bolivarian National Guard and Civil Protection, regional and local bodies—during the dry season and mitigate fires in the country. Thus, the environmental authorities oversee the prevention and control of fires.

On the other hand, Venezuela has one of the most progressive Indigenous rights regimes in South America. For example, it officially recognizes, within its constitution, Indigenous peoples' rights to maintain their own production practices and protects the collective intellectual property of knowledge, technologies, and innovations (Constitución de la República Bolivariana de Venezuela, 1999). In addition, specific legislation focusing on Indigenous communities, such as the Organic Law of Indigenous Peoples and Communities (República Bolivariana de Venezuela, 2005), has also strengthened Indigenous rights to genetic resources and ancestral knowledge. However, despite the progressive constitution and regulations and the relative protection of Indigenous rights in national parks, the use of fire, in legal terms, has been heavily restricted and combated (Art. 65, Ley Penal del Ambiente, República Bolivariana de Venezuela. 2012).

Mainly within the framework of this body of laws protecting Indigenous rights and autonomy granted by the Forest National Law to INPARQUES, which was able to advance with initiatives coordinated by the Simón Bolívar University, financed by the Ministry of Science and Technology and supported by national and regional public development institutions, to the adoption of integrated and participatory fire management principles by the INPARQUES forest fire firefighters. Thus, the inclusion of Pemón Indigenous communities, firefighters, public officials, government institutional actors and academics in field research and joint experimentation on fire behaviour, as well as the debate and dialogue on socio-ecological issues of the CNP, led to the development of articulated knowledge and actions resulting in the foundation of a new paradigm of integrated fire management (IFM) and strategies for climate change mitigation and adaptation.

Since 2015, with the support and collaboration of the British Academy, Royal Holloway University and COBRA Collective, these activities and experiences were consolidated and spread to Brazil and Guyana north Amazonian countries. These activities resulted in the creation of the "Intercultural and Participatory Fire Management Network", whose fundamental principle is that "Indigenous fire management should be included in the management of territories in which Indigenous peoples live and develop their way of life, using ancestral, traditional and adaptive Indigenous knowledge of fire in conjunction with scientific/academic knowledge and the capacities of the institutions" (Bilbao et al., 2019).

In 2018, as a result of the agreements reached, implementation began of an intercultural mechanism for IFM in the east of the park (Gran Sabana). These pioneering activities involved two-way training, with the Pemón providing training in patch mosaic burning and other Indigenous fire prevention techniques to park authorities and forest firefighters, while also receiving technical training.

In 2019, following a presidential initiative, forest fire brigades throughout the country were expanded to 10,000 personnel, with training for 3,400 male and female firefighters; 1,800 of them are currently progressing toward university degrees as higher technicians and graduates in fire science and fire safety. This in-service education and training include elements of IFM in a new operational philosophy for firefighters. They do not just intervene in fire control, but also work as local managers who facilitate intercultural dialogue and replace the fire exclusion model with community fire management.

In the framework of LANDMARC project, a permanent working group for integrated fire management in Venezuela was formed in 2021, including researchers and academics, and officials from environmental, territorial management, public safety and emergency response agencies. They are committed to promoting the methodological development of IFM with an intercultural vision and disseminating this approach at the national level through webinars and workshops. The park's forest fire firefighters have now incorporated lessons learned throughout this process in their training programmes, applying IFM techniques in protected areas throughout the country and exchanging experiences in integrated and participatory fire management with national and international experts.

These experiences are now being included in a new national system of IFM that seeks to define the terms of reference and search for financing for a new integrated fire management policy at the national level. The objective is to replace the existing one (previously mentioned on wildfire risk reduction in the current Forest Law). It is promoted by an intersectoral team that includes public officials representing the INPARQUES forest fire firefighters, the Forest Fire Protection Directorate of the Ministry of Eco-socialism, the Vice-Chair of IPCC Working Group II on impacts, adaptation and vulnerability, and academics who have promoted these actions (see Bilbao et al. 2022, for details).

3.1.1. Current land use and potential land-use competition

The burning of biomass associated with land deforestation and degradation as a mechanism for the expansion of the agricultural and livestock frontier, the burning of crop residues and the elimination of weeds have become a trigger for large wildfires and important sources of GHG emissions in Venezuela (ACFIMAN-SACC, 2018; República Bolivariana de Venezuela, 2017a). Furthermore, under current climate change scenarios, the impact of these activities is promoting the turning of AFOLU sinking capacity (due to CO_2 fixation) to a net GHG source considering aggregate sources and non-CO_2 land emissions sources (República Bolivariana de Venezuela, 2017a, see Sections 3.2 and 3.3 for details). Although the forest policy and legislation plan in Venezuela envisage reducing forest wildfires by 50% for 2030 throughout the territory, (República Bolivariana de Venezuela, 2017a; República Bolivariana de Venezuela, 2019), new paradigms regarding the formulation of more effective fire policies based on the prevention instead of the suppression and combat of fire are necessary (Figure 5). The CS6 case of LANDMARC includes a fire management proposal based on 20 years of ecological studies and joint work with the Pemón Indigenous communities about fire management practices for agriculture and forest protection in Canaima National Park. The integration of scientific, Indigenous, and technical knowledge gained in this experience provided the basis for an integrated fire management in Canaima National Park, and other implementations at national level.

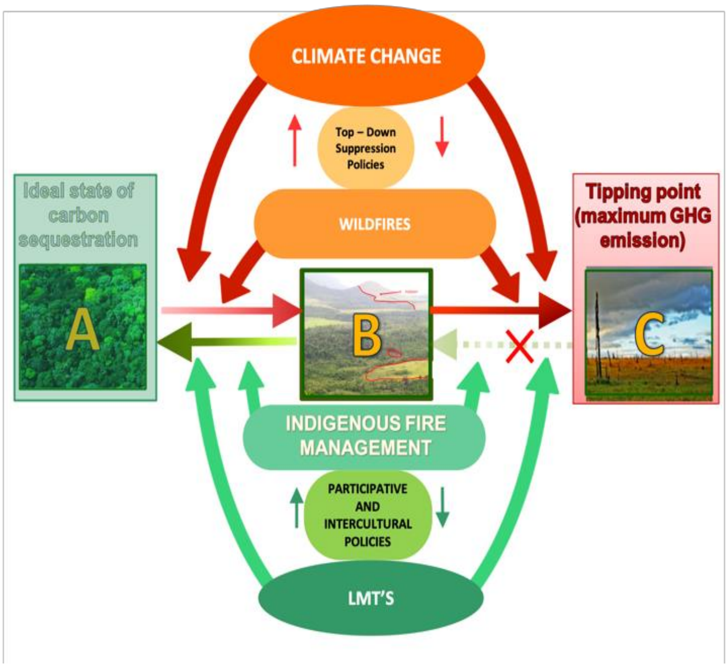

Figure 5. Conceptual framework of CS6 describing the transition states of CNP ecosystems affected by wildfires (under policies of fire suppression) and their interaction with climate change, as well as the effect of LMT's measures and comprehensive IFM policies based on Indigenous land management.

IFM-LMT actions in Canaima National Park (CNP)

Despite the limitations imposed by COVID-19 and the deep economic crisis in the country, important progress could be made in the realization of an intercultural articulation mechanism for Integral Fire Management in the Eastern Sector of Canaima National Park, in the Gran Sabana sector (ca. 18,000 km^2, figure 4) through the organization, comprehensive training and equipping of Community Forest Brigades, made up of members of the Indigenous people in the Pemón communities: Kavanayén (Arekuna), Paraitepuy del Roraima (Taurepan) and Mapauri (Taurepan) (Figure 4). These pioneering activities involved two-way training, with the Pemón providing training in patch mosaic burning and other Indigenous fire prevention techniques to park authorities and forest firefighters, while also receiving technical training.

In collaboration with other LANDMARC team members, diverse studies are being developed through EO and ALCES and DayCENT simulation models, to estimate the impact of the implementation of the LMT: Integrated fire management with an intercultural vision (based on Indigenous fire management techniques) and fire exclusion practices (based on fire suppression policies historically used by the Park's fire departments) (Figure 5). The EO studies are in the phase of data collection and identifying best places that describe the different types of management in the park and in the case of ALCES and DayCENT, are in the final stage of the definition of the landscape and carbon systems to be modelled (see Figure 6).

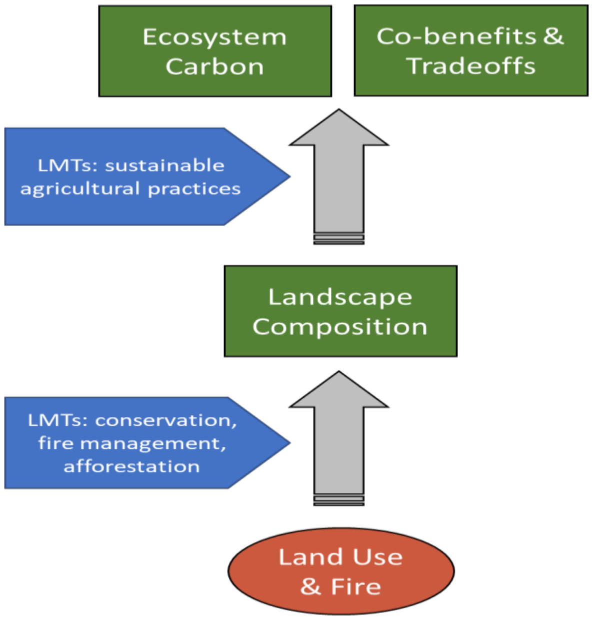

Figure 6. An overview of the landscape and carbon system that is being modelled by ALCES.

The abatement capacity of IFM-LMT in the CNP has not yet been estimated, but according to the revised literature, Indigenous fire management practices and prescribed burnings (based on effective EDS fire management) under the Integrated Fire Management could serve as a powerful natural climate solution to address climate change mitigation challenges facing countries within fire-prone savannas. The literature shows some evidence about the mitigation potential of this LMT in ecosystems similar to those of the Gran Sabana, in the CNP, particularly in the savannas of Australia and Brazil and several countries in Africa. These programmes have begun to be implemented at the local and regional levels during the last decades. The achievable abatement through savanna burning projects (based on Indigenous practices) reported in local experiences oscillates in the range of 0.12 Mt CO_2e y-1 (37%) in Western Arnhem Land (3 million hectares) and 1.38 Mt CO_2e y^{-1} across almost 40 million hectares of the savannas of northern Australia, to 0.29 Mt CO_2e y^{-1} (130 T CO_2e y^{-1} ha^{-1}) in Indigenous territories of the Cerrado Brazil.

National level

As part of the policies outlined in the plan for economic and social development at national level, Venezuela intends to implement a National Mitigation Plan to reduce its emissions by at least 20% by 2030 with respect to the baseline scenario (República Bolivariana de Venezuela, 2017a; República Bolivariana de Venezuela, 2019). From the mitigation options analysed for land-use change, it was established that the forest sector has a considerable potential for reducing CO_2 emissions (avoid or remove; Table 1) through the adoption of sustainable forest practices, especially by slowing the rate of forest loss and degradation. Due to the important extent of forest and other natural areas under different levels of protection (national parks, natural reserves), the maintenance of already existing biomass in natural forests should be the first priority to reduce the amount of carbon released to the atmosphere and potentially has the lowest carbon unit cost (Table 2, Figure 1). A good proportion of this Venezuelan forest heritage consists of Areas under Special Administration Regime (ABRAE, Spanish acronym), which represent 47% of the total country area. Over 37% of the ABRAE are devoted to the protection and conservation of biological diversity; 18%, to forestry production; and the remaining 19% are dedicated to multiple forestry uses (MPPEHV, 2014). However, in 2017, the Venezuelan national government changed El Caura Forest Reserve's figure to El Caura National Park (República Bolivariana de Venezuela, 2017b). This produced an increase in the forest areas destined for conservation (from 24.3 to 29.3 million hectares) and a reduction of the forest areas destined for sustainable forest resources management (from 16.3 to 11.18 million hectares). These data reveal that Venezuela is among the ten top nations with greatest extension of forests conserved for soil and water protection (República Bolivariana de Venezuela, 2017a; FAO, 2020).

Considering the potentiality of the total area under ABRAE system and the Forest Fire Brigade of INPARQUES has extended the IFM training process and the experience acquired in Gran Sabana, Canaima National Park, to Waraira Repano National Park (La Costa Mountain Range, Capital Region, 81,800 ha), Mochima National Park (Northeast coastal Region, 94,769 ha), El Guácharo National Park (La Costa Mountain Range, Eastern Chain, 62,700 ha). The bases of this intercultural strategy include rural communities as central characters in the formulation and development of Local Fire Management Plans in the whole country.

These plans comprehend the inclusion of community members, their traditional knowledge and practices about fire management, and scientific criteria, as to achieve an effective reduction of the area affected by fires. This strategy involved the promotion, organisation, training and equipment of Community Forest Brigades that integrate voluntarily to the National Risk Management System. This strategy has focused on the reduction of the forest area affected by fire while contributing to strengthening the culture of self-protection in remote rural communities.

There are no data on estimates of the abatement capacity of IFM-LMT techniques being implemented at the national level. However, estimates of the potential technical abatement capacity at a regional level in Brazil and at more global level, showed very promising values that ranged between 2.96 Mt CO 2 e y-1 (148 T CO 2 e y^{-1} ha^{-1}) for the entire area of the Cerrado Brazil (2,000,000 km 2) (Steil, 2020) and 89.3 Mt CO_2 e y-1 at a more global level, considering 37 countries, including Africa, South America and Australia (Lipsett-Moore et al., 2018). If results similar to those of Brazil are obtained, the abatement capacity of this MFI-LMT could contribute to offset the emissions corresponding to the loss of 32,140 ha/year of humid forests with a long dry season (emission of 3.82 Mt of$_{CO2}$eq). Not to mention, the conservation of the capacity of carbon sequestration that occurs mainly in the unburnt very humid and short dry season moist forests, with an annual aboveground biomass growth rate of 5-7 m3/ha (FAO, 2016; FAO, 2020).

Governmental authorities responsible for the creation and implementation of IFM showed a firm commitment to support this IFM-LMT initiatives. Return of fire suppression policies and impediments of the implementation of fire uses by Indigenous communities in CNP and other protected areas, due to changes in authorities or policies at governmental level, could represent, although unlikely, a significant limitation in the expansion of this LMT. However, in the case of this scenario, individual actions related to the IFM can still be implemented that would partially achieve similar objectives. Namely: implementation of prescribed and controlled burns, construction of firebreaks, participation of traditional communities' dwellers of protected areas and their surroundings in fire prevention activities, promotion, and compilation of Indigenous traditional knowledge of the use and management of fire, among others.

On a local and national scale, IFM could be replaced by other management practices for the implementation of crops at a more industrial scale (for example machinery for the elimination of plant cover, soil management and cleaning agricultural areas, fertilisers to increase the level of nutrients in the soil) instead of fire). However, these activities require high economic investments. Due to the country's current economic situation, it would not be possible to sustain and support these initiatives at the national level. Moreover, besides the socio-environmental benefits described above about IFM, its implementation is much less costly than intensive agriculture.

3.1.2. Climate risks & sensitivities

The LMT (IFM) is sensitive to the following climate-related changes:

Increase in the severity of "Fire-weather" conditions: including the increase of heatwaves frequency and air temperature, as well as the extension, duration, and intensity of dry seasons (IPCC, 2021). Heatwaves and intense droughts increase the flammability of fuel material, limiting the conduct of controlled burns. Drying fuel material, especially in savanna-forest edge areas, favours combustion and spreads fire into the forests.

Increased risk of accidents of occurrence of wildfires during controlled burning, preventing stopping the dangerous spread of fire to unwanted areas.

The alternation of extreme events of rainfall and drought stimulates the production of biomass of the fuel material during wet years, with the subsequent accumulation of dead and dry material during extreme drought periods favouring the spread of fires of greater severity and intensity.

Forest fires reduce carbon pools and the CO2 assimilation capacity of the remaining vegetation. Likewise, recurrent and severe wildfires limit the regeneration capacity of vegetation, especially forests, and it prevents the implementation of cultivation practices in forest areas. On the other hand, PMB (patch mosaic burning) practices in savanna areas are hindered by reducing the fuel material that resprouts after fires.

Increased or generally changed weather variability affects the burning regime (specific to each period of the year) and the timing of cropping practices that require particular conditions for planting and harvesting.

For most interviewees, the loss of diversity is one of the most worrying factors, which would make implementing this LMT more difficult. Species diversity allows greater resilience of ecosystems to climate change and wildfire occurrence and severity. Forests and savannas diversity maintain the supply of essential environmental services, such as water quality and availability, soil maintenance, and supply of natural resources, among others.

3.1.3. Economic implications

The introduction of the new paradigm of Integrated Fire Management (IFM) instead of fire exclusion policies, conveys important advantages in terms of costs reduction (and costs avoided) and economic benefits. IFM represents a viable alternative to the prohibitive costs and low efficiency of fire exclusion, especially for low-income countries (Mistry et al., 2019; Eloy et al. 2019). Fire prohibition and firefighting or extinction activities in the face of climate change scenarios, demand growing human, technical and financial resources that may surpass local and national capabilities and budgets as it occurs in many countries of Latin America and Africa (for example the US Forest Service employs US$ 5,000,000 annually to combat wildfires in the country).

The Federal Brigades Program implemented by Prevfogo/ Ibama in Brazil, is one successful example of how the implementation of IFM policies together with the involvement of Indigenous communities may become an efficient way to reduce wildfires and GHG emissions at low and affordable costs. Since 2016, fire brigades established in different settlements (Indigenous, rural communities, *quilombolas*) provided support to apply prescribed burnings to protect more than 600,000 km^2 located in federal, regional, and local public and private conservation areas (RPPNs), including settlement projects, Indigenous and *quilombolas* lands, with a public investment of R$ 1.5 (US$ 0.26) ha^{-1} (Ibama, 2020; Falleiro et al. 2021).

The low costs of the Federal Brigades Program were associated to the significant reduction of wildfire occurrence as well as the hiring of local and Indigenous peoples to handle prescribed burnings in those communities that manage fire in an autonomous way, instead of using external human resources. However, according to Brazilian technicians, this initiative should include funds to recognize the environmental services provided by local and Indigenous peoples, such as CO_2 sequestration, water resources and socio-biodiversity protection.

Indigenous Fire Management Programs may actually provide economic benefits, as it was the case of the Emissions Reduction Fund (ERF), established in 2014 by the Australian government, after the official approval of the use of savanna fire management to generate Australian Carbon Credit Units (ACCUs; Commonwealth of Australia 2015). The ERF offers a long-term public contract to landowners and managers for storing carbon or reducing GHG emissions. By 2018, a total of 75 savanna burning projects were registered under the ERF and 52 of these projects had secured contracts with the Australian Government to abate 13.8 $MtCO_2e$ over an average of 8.5 years. Savanna burning projects account for 7.2% (191.7 $MtCO_2e\ yr^{-1}$) of Australia's ERF contract portfolio, and 23 Indigenous projects account for 74% of the total potential savanna burning abatement. Considering the average ERF

Auction price of $11.97 (in June 2018), as a conservative value, the sales of 2 668 848 ACCUs reached by one of the most successful programs implemented in Australia (ALFA program) equates to well over AUD $31 million (Commonwealth of Australia, 2018). This is expected to provide significant incomes to Indigenous landowners over the next 7–10 year (Ansell et al. 2020).

Based on the Australian experience, Lipsett-Moore et al. (2018) made a global estimate for the least developed countries that have suitable environmental conditions to implement early fire management. These countries are eligible to receive the $5 USD t CO_2e results-based payments offered by the GCF2, since they could effectively deliver early savanna burning (EDS) in order to remove all late undesirable wildfires (LDS) in their territories. According to the authors estimations the fire managers that fit into these conditions could benefit of a total global market valued in USD $321 million per year.

3.1.4. Co-benefits and trade-offs

Integrated fire management is not only a possibility but an effective environmental management tool. It has been shown to have the potential to contribute to a range of positive environmental outcomes (as explained above), including biodiversity conservation. It also can enhance the capacity to support the sustainable livelihoods and pirobioculturality of savannas and tropical forest-based peoples (Ponce et al., 2022).

a) Among the main environmental benefits resulting from the application of the LMT are
b) the reduction in the number of forest fires and the absence of large fires (megafires),
c) reduction in GHG emissions increased carbon capture and storage,
d) improved air and water quality and other ecosystem services,

enhanced maintenance of ecosystems (savanna-forest mosaics), increased landscape diversity, enhanced landscape ecology (plants dependent on fire for their permanence), and increased plant and fauna diversity.

At the same time as mitigating climate change, supporting climate adaptation, and enhancing biodiversity conservation, the IFM-LMT approaches that are community-led and implemented can generate social, economic, and other benefits for local communities in these settings. Some of these benefits are: efficient management and conservation of forests and other ecosystems for conservation and/or support resources for subsistence activities, protecting public health (forest wildfires cause cardiovascular problems, respiratory failure and pneumonia), promote cultural heritage and aesthetic values. Other benefits point to the visibility and consolidation of local culture and practices.

Between the risks from applying the LMT, some actions contemplated in the MIF, such as prescribed or controlled burning, can cause forest fires due to the neglect or lack of human talent (forest firefighters and experimented members of local communities, among others), equipment and materials during their execution. Likewise, implementing prescribed or controlled burning techniques without adequate knowledge of how, where, when and for what can bring more significant inconveniences, which is to be solved in terms of damage to vegetation and soil and the respective GHG emissions. Another risk is the lack of adequate inclusion of all local, institutional, and academic stakeholders. Although the IFM in Venezuela merged from the interaction between academics, Indigenous people, and firefighting officials, it is essential to involve the private sector and rural companies that confront serious problems to cope with wildfires and their impacts.

It is also essential not to stop investing in previous programs of forest fire suppression, especially the big ones, while an effective IFM-LMT is implemented. Some of the stakeholders interviewed recommend the coexistence between the two policies.

3.1.5. Risks associated with scaling up

Scaling up the IFM-LMT from the sub-national level to the national level implies significant risks and new challenges that are important to address. Some of them are listed:

1) The consolidation of the LMT-IFM in Canaima National Park was possible thanks to research studies and actions to involve stakeholders systematically over several years. The socioeconomic realities of the local communities and the heterogeneity of actors involved require generating trust environments and stakeholder engagement activities, so it would be essential to cover the technical capacity of human resources to coordinate these activities, considering these complexities. It is also necessary to have facilitators that allow the integration of scientific, operational, and local community knowledge about IFM on a sustained basis.

2) Difficulties to adopt the new IFM-LMT paradigm and submit to the dominant historical discourse of the park administrators, firefighting institutions, some private landowners, the media, and other authorities, about the perception of the urgent and necessary implementation of fire exclusion strategies and continue criminalising local people as the starter of wildfires.

3) For practical reasons, diverse initiatives of IFM at regional and global levels are focused on prescribed burnings and not involving local communities' participation. Consequently, there is an increasing risk of losing operativity or even increasing wildfire risks for selecting erroneous conditions for prescribed burnings implementation.

4) Venezuela is a vast country with a high diversity of ecosystems, topographies, geographical accidents, and remote areas of difficult access. Implementing this LMT extensively and simultaneously in diverse regions will be a significant challenge. It would be advisable to reduce risks by starting with pilot studies, in which progress and learning are monitored on an ongoing basis to strengthen these IFM-LMT initiatives.

3.1.6. Research gaps

- There is not enough information and scientific research to properly understand the specific fire regimes and fire ecology from different vegetation types in order to design suitable and sustainable fire management programs (Bilbao et al., 2020).
- Currently, there is non-existent legislation on Integrated Fire Management.
- Limited or unavailable statistical data on the socio-environmental realities at the local level of Canaima National Park and the national level (vegetation maps, population distribution and density, land use types, and meteorological data, among others).
- Limited or absent nformation on different types of land use and their impacts on productivity, environmental aspects, cost-benefits and economic value.
- Need to update emission inventories and national communications (the last one was done in 2017, with data from 2010).
- Implementing remote sensing technologies for systematic and sustained fire occurrence monitoring over the country is necessary.
- Creation of national and international cooperation networks to exchange experiences and learn land-use strategies for climate change mitigation.
- Addressing IFM-LMT with an intercultural approach must recognise the relationship between fire and society and consider the complex interplay between the actors, factors, and fire.
- Addressing strategies for the co-production of knowledge and mechanisms promotes participatory platforms to reduce the intercultural deficit of institutions and close the gap between academics, local communities and the responsible of politics.

4. Agroforestry of arid and semiarid lands (very dry and xerophytic forests)

4.1.1. Introduction

The development of sustainable agro-silvopastoral systems together with the conservation of natural resources in the fragile arid and semiarid ecosystems in the north-west of Venezuela have been addressed in the past 50 years by several research institutions and development agencies, always focused on the improvement of living conditions and wellbeing of the poor rural inhabitants of these areas. The efforts have brought about the development of a solid corpus of knowledge and experiences on sustainable practices and technologies that have been slowly adopted in the region to reduce deforestation, forest resources extraction and extensive goat raising. Altogether, they appear as complement and compatible LMTs that take into account key socio-economic and environmental interconnections proper of arid and semiarid lands.

Looking at these experiences from an integral perspective, allowed us to present a coherent array of LMTs that jointly contribute to counterbalance land degradation caused by continuous extraction and overexploitation of resources. The alternative technological proposal includes:

a) Agroforestry systems that associate: (a) native legume tree species (to provide shadow, enhance local water balance, fix soil nitrogen, and serve as a protein source for human and animal consumption); (b) CAM local traditional crops of low-water demand, such as aloe, agave or cacti, planted under the trees cover (to avoid deforestation and soil degradation, reduce the irrigation requirements, and provide regular medium-term incomes to the farmers); (c) short-cycle vegetable crops planted in association with trees semi-shade (to provide food for family consumption and rapid economic returns from the sale of production exceeds); (d) establishment of plant nurseries and reforestation programs with native species.
b) Agro-silvopastoral goat and/or sheep systems based on semi-tabulated management (to replace extensive herd management). Grazing paddocks are established with grasses, maize, beans, moringa, and other native or naturalized fodder plant species to supplement food requirements. This involves the suppression or drastic reduction and strict control of animal charges on common foraging forested lands. Maintenance and protection of natural nearby forests.
c) Conservation, protection, and enhancement of forested areas remnants.
d) Afforestation and water surface runoff technologies to control soil erosion and promote vegetation recovery.

The application of water harvest techniques, the use of organic fertilization, and the adoption of sustainable energy sources and saving cooking devices are key for the success of the LMT.

Here, we will describe some of the alternative solutions developed by academic and institutional stakeholders jointly with communities from the arid and semiarid regions of Venezuela that have been adopted in this highly vulnerable region. Special attention will be paid to the experiences recorded in Falcón state and which have potential as LMTs.

Characteristics of Venezuelan arid and semi-arid lands

Venezuelan arid and semiarid lands cover 41,023 km^2 and represent 4.5% of the country. They are located along with the northern islands, the Caribbean Sea mainland coastland, the Falcón-Lara depression in the central-western area of the country, and in some slopes and valleys of the Andean west mountain range, below 600 (-800) masl (Figure 7).

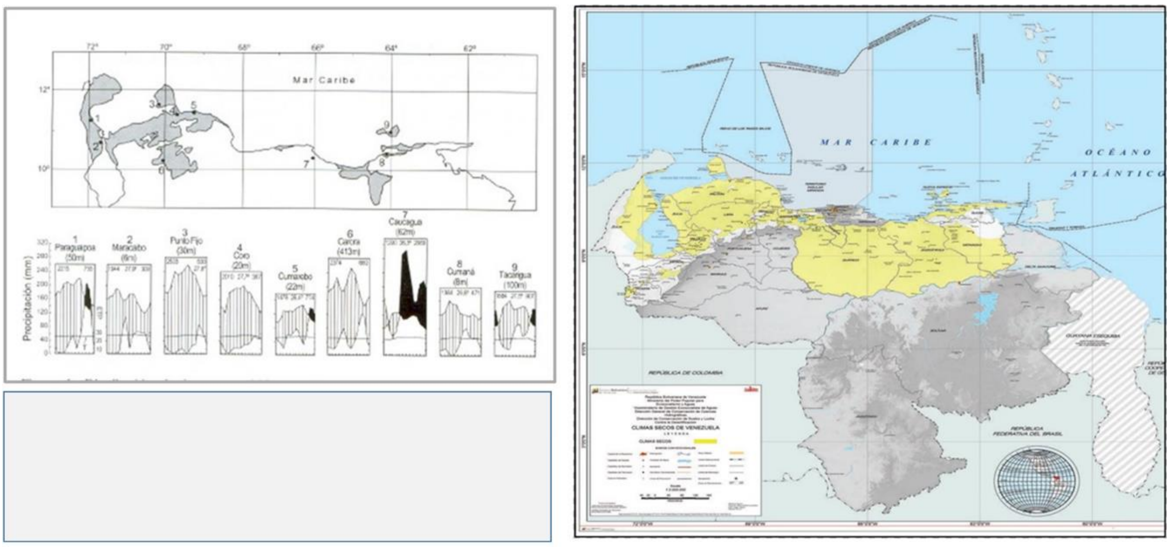

Figure 7. Location of arid, semiarid, and dry lands in Venezuela. Left: Map showing the current distribution of arid and semiarid lands in the country; at the bottom, the hydric climate balance of selected locations is presented (Medina et al. 1985). Right: Map of Venezuelan dry lands (MINEA, 2020). The areas shown in light yellow are at risk of desertification under climate change future scenarios.

Historically, these territories have been the location of important human settlements due to their vicinity to the coast and favourable conditions to establish land and sea communication and exchange routes. Archaeological evidence indicates that these areas have been inhabited since 14200 – 12980 years before the present, as Taima-Taima and many other archaeological sites excavated by Josep Cruxent in Falcón since 1960´s demonstrate (Darvill 2002). At the present, these areas concentrate nearly a third of Venezuela's population and are under high urbanization, agricultural, and industrial pressures.

This region shows a mega-thermic regime, with annual mean temperatures of 27° to 30° C, and mean annual rains of 250 to 500 (-800) mm. Precipitation tends to be erratic but usually concentrates in short periods of time causing torrential runoff, loss of soil and fast accumulation of sediments downstream, as well as the release of carbon to the atmosphere. Episodic brief rain events (5-10 mm) occur almost every month in some localities. High evapotranspiration rates (1600-2300 mm), constant wind currents (speeds of 4 to 8 m.s-1), and high daily radiation values (up to 6500 Kwatt) are stressful conditions for the local vegetation and fauna (Díaz 2001; Ewel & Madriz 1968, cited by Matteucci 1986). Soils are mostly alkaline and often with an argillic horizon between 40-60 cm deep, which explains the abundance of superficial tree roots (Díaz 2001).

High levels of hydric stress, together with soil characteristics shape the natural ecosystems found in these regions. Different types of vegetation are found in these lands, ranging from littoral herbaceous formations, thorny shrubby vegetation dominated by emergent cacti (<5 m tall), thorny shrubby vegetation dominated by legume Prosopis trees cover, and tall deciduous forest or a mixture of them (Matteucci 1986, Oliveira et al. 2010). Oliveira-Miranda et al. (2010) estimated that 25,172 Km2 of Venezuelan arid and semiarid lands were covered by thorny bush vegetation, while Díaz (in press) estimated that around 32,350 Km-2 of this region have some degree of xerophytic vegetation coverage.

Arid and semiarid ecosystems provide many resources exploited by rural inhabitants, such as firewood; wood for handcraft, furniture, and construction purposes; pastures and forages for goat raising; agave plants used for alcoholic beverage production, and as a source of food and fibre; and fruits for local consumption. Rabbits, iguanas, wild pigs (Tajassus sp.), and white-tailed deer (Odocoileus sp.) are appreciated hunts. Birds such as parrots, trupials, and cardinals (Carduellis cucculata), giant spiders (blue tarantula), as well as ornamental plants (i.e. bromeliads and orchids) are also extracted and sold illegally (Ángela Martino, pers. comm. 2021). The forest cover is usually removed in order to establish aloe plantations of various sizes as well as conucos where local families cultivate maize, legume grains, and pumpkins, among other short-lived crops. Intensive irrigated agriculture (onion, tomato, melon, maize, sugarcane, pineapple, sisal), cattle and goat, sheeps raising, and shrimp farming have been associated with vegetation degradation and soil loss.

Starting in the second half of the 20th century intensive exploitation of underground water's reservoirs for irrigation purposes has caused salinization of soils located in the vicinity of the seaside in sites such as El Cebollal, Paraguaná and Tocópero in Falcón state (Barros 2006, Torres et al. 2006).

Some authors (Torres et al. 2006) indicate that a continuous land degradation process has been observed in the semiarid zone of Falcón state, due to the prevalence of inappropriate conventional agricultural systems (i.e. honey dew melon or short cycle vegetable crops intensive production), under low rainfall and high evapotranspiration climatic conditions. Here, soil degradation has been accelerated by the application of high frequency localized irrigation systems that contribute to medium and long term soil salinization.

The intense human activity is responsible for a high degree of disturbance and loss of vegetation cover. Goat free ranging, wood extraction, urban wastes inadequate disposal, and sand mining have been reported also as some of the most degrading activities affecting these ecosystems (Matteucci 1986, Oliveira-Miranda 2010). On the coast, many touristic developments have been also established.

Oliveira-Miranda et al. (2010) reported a change of -19.37% (1988-2010), of shrubby thorny vegetation cover, while Díaz (2021) found a loss of -13.75% (1986-2019) of the total xerophytic forest vegetation (Table 2). Attending to the degree of disturbance and the risks of loss of their ecological functions, these ecosystems are included in the IUCN Endangered category (Oliveira-Miranda et al. 2010).

Table 2. Changes in xerophytic forest cover in some states of Venezuela were estimated from satellite analyses (Modified from Díaz, 2021).

Xerophytic forest cover in Venezuela				
State	Forest cover area (Km^2) in 2019	Forest cover area (Km^2) in 1986 [1]	Forest cover change (Km^2)	Forest cover change (%)
Falcón	8.939,42	10.000,04	-1.060,62	-10,61
Lara	6.668,83	10.710,70	-4.041,87	-37,74
Mérida [2] .	13.540,83	13.540,83		
Zulia	2.679,72	2.661,70	18,02	0,68
TOTAL	**32.348,98**	**37.506,86**	**-5.157,88**	**-13,75**

Source: Díaz, Miriam. Manual de restauración del bosque xerofítico. FAO. In press.

[1] Zulia state cover estimated from 2001 data

Inadequate management of these lands increases the vulnerability of desertification, as shown by Mogollón et al. (2016) in Paraguaná region. Shrubby and herbaceous thorny vegetation types that cover the 3% of this peninsula are the most vulnerable ones to degradation processes. Bush vegetation covers 11.4% of this territory and is the least vulnerable vegetation type thanks to the presence of plant species adapted to dryness. The remaining 85.6% of the lands have a moderate vegetation cover but are vulnerable to desertification caused by free or extensive goat cattle raising, and the application of intensive conventional horticultural practices leading to soil salinization and erosion.

CO2 fixation potential of Venezuelan arid and semiarid lands

Semiarid tropical lands can be highly productive under adequate management, and efficient soil and water use (Díaz, 2001). In Falcón state, natural undisturbed xerophytic forest ecosystems show a significant diversity and stratification, including trees, shrubs, erect cacti, vines, epiphytes and dense mats of succulent CAM species growing in the forest undercover, such as *Bromelia humilis*, *Agave* spp., several cacti species, and the naturalized *Aloe vera* plants. Under adequate conservation and management conditions, these systems have a significant biomass CO_2 fixation potential of up to 8.236,39 Kg ha^{-1} year (including photorespiration and respiration losses) as shown in Table 3.

Table 3. CO_2 fixation potential of evergreen and deciduous tree species from Paraguaná, Falcón state, estimated from instant photosynthetic rate measures.

Estimated CO2 fixation potential of a xerophytic forest from Paraguaná Península, Falcón state, Venezuela											
	Instant photosynthetic rate						CO_2 weight	CO_2 annual exchange rate per tree		Tree mean density (1)	CO_2 fixation potential (2)
Tree species	µm.m^{-2}.sec^{-1}	µm.m^{-2}.hour^{-1}	µm.m^{-2}.day^{-1}	µm.m^{-2}.year^{-1}	mm.m^{-2}.year^{-1}	m.m^{-2}.year^{-1}	g.mol^{-1}	g. year^{-1}	Kg. year^{-1}	N° trees.ha^{-1}	Kg.ha^{-1}.year^{-1}
Evergreens	150	540.000	4.320.000	1.576.800.000	1.576.800	1.577	44	69.379	69	82	5.654,47
Deciduos & semi-deciduos	250	900.000	7.200.000	720.000.000	720.000	720	44	31.680	32	82	2.581,92
										TOTAL	**8.236,39**

(1) A ratio of 1:1 evergreen to deciduos trees was estimated of a total count of 164 trees per ha

(2) Results nclude photorespiration and respiration values

Sources: a) Díaz M. 1988. Las zonas áridas al norte de Venezuela: Hacia el aprovechamiento racional de sus recursos naturales renovables. En: Caliman A. & Paredes L. Zonas áridas. Fundacite Zulia, Maracaibo. pp 33-54. b) Díaz M. 1994. Caracterización ecofisiológica de las especies arbóreas predominantes en las zonas áridas y semiáridas. Trabajo de ascenso para optar a la categoría de Profesor Asociado. UNEFM, Coro. 105 pp. c) Díaz M. & Granadillo E. 2005. The significance of episodic rains for reproductive phenology and productivity in trees in semiarid regions of northwestern Venezuela. Trees 19: 336- 348.

According to Mogollón et al. (2015), soil organic carbon (SOC) reserves in Paraguaná arid areas are highly variable, due to differences in soil, climate, and vegetation along altitudinal gradients. The SOC reserves increase with altitude (7.8 t ha-1 at 1 masl vs. 101.5 t ha-1 at 400 masl) and mean annual precipitation while decreasing at higher average annual temperatures conditions. Soil carbon content levels are also higher under dry and deciduous forest cover (63-92 ton C.ha-1), in comparison to cacti or thorny-shrubby vegetation (36.7-47 ton C.ha-1), and herbaceous or sparse shrubby vegetation types (10.3-21.9 ton.ha-1). The highest values of SOC in Paraguaná correspond to the understory of forest vegetation in Cerro Santa Ana Natural Monument (Mogollón et al. 2015). In contrast to conventional agricultural systems, in situ analyses performed in lands with similar climatic conditions but under aloe organic farming cultivation showed that soil carbon content and ion exchange capacity were similar to those of surrounding secondary forests and much higher than the values obtained from lands with conventional agricultural systems (Torres 2006, Mogollón 2015).

Mitigation and adaptation measures in Venezuelan arid and semiarid lands

Traditional farmers from the arid and semiarid regions of Falcón state have small subsistence production units based on free-ranging goats (to obtain meat and its derivatives, as well as milk, cheese, cream and traditional sweets), aloe or sábila plantations (to obtain aloin latex, sold to national intermediaries of a long international commercial chain), and maize and frijol rainfed plantations. Some of them also produce artisan liquors. These units provide food for family consumption and income from the sale of exceeds. Usually, trees are removed to establish the plantations. Farmers also extract wood for cooking and artisan fabrication of furniture and handcrafts.

Several mixed alternative agroforestry systems that mimic local ecosystems compartmentalization have been tested in Falcón state by academics and researchers from the Research Center in Ecology and Arid Zones of Francisco de Miranda University (Centro de Investigaciones en Ecología y Zonas Áridas - Universidad Nacional Experimental Francisco de Miranda, CIEZA-UNEFM).

Over more than four decades, CIEZA professionals have led research on ecological and physiological adaptive features of potential alternative crops, adapted to the harsh conditions that prevail in Falcón state, in order to offer local communities sustainable alternative agricultural solutions to their needs.

The results of their studies and practical experiences allowed the definition of an agroforestry semiarid system depicted as a combination of natural resources investments that include a) a tree coverage of legume and other woody species used by the farmers (analogous to a trust fund), b) succulent CAM crops production in forest understory (analogous to a saving account), and c) short-cycle crops (analogous to a current account). The farming potentiality of some local fauna resources such as rabbits, iguanas, or wild pigs, have also been assessed.

These systems are intended to provide local rural families alternatives to the extractive traditional land management practices that contribute to deforestation and land degradation while being economically attractive.

Aloe vera - Prosopis juliflora agroforestry systems

Prosopis juliflora, known locally as "cují", is a native legume tree species that contribute to soil nitrogen fixation while protecting the soil from erosion; its nutritive fruits are used to feed goats. Under the partial shade of cují trees, bromeliads plants such as teco (Bromelia humilis) and maya (Bromelia karatas, B. pinguin), as well as agave grow spontaneously forming dense mats. These species have a distinct CAM photosynthesis metabolism, proper of succulent plants adapted to dry and desert conditions. This observation gave insights to test the behaviour and productivity of sábila (Aloe vera), a local traditional rainfed crop introduced at least 400 years ago in the region when planted under cují trees partial shade. The results from various assays showed that sábila plants actually grow healthy and vigorous under partial shade conditions, increasing the gel production volume since they avoid the excess loss of water from their tissues. Similar results were obtained with agave plants (Díaz 2001), showing that carbohydrate accumulation is higher under partial tree shade. These findings suggest that tree coverage reduces crop irrigation requirements and protect plants from excess radiation levels. Similar effects have been observed with other tree species. In short, the incorporation of sábila CAM crops that grow well under partial tree shading, in association to mature legume trees and short cycle crops, are sustainable agricultural practices that prevent deforestation, reduce soil loss, and help in the restoration of already degraded dry lands (Figure 8 and 9).

Figure 8. Left: Cultivated Aloe vera plant. Right: Aloe vera plantation under the partial shade of Bursera sp. tree in Paraguaná. (Photos: Herbario Coro & Rosalba Gómez Martínez).

Agave cocui agroforestry systems. Towards the domestication of a traditionally multipurpose plant.

In the Falcón-Lara semiarid mountain range, there is a long tradition of harvesting Agave cocui plants for several purposes. This native species grows abundantly on dry calcareous soils and is tolerant to harsh climate conditions. Local inhabitants cook and eat the highly nutritive and tasty growing apex as well as the flowers during scarcity periods. The plant is used to treat several ailments (i.e., joint pains, menstrual and fertility disorders in women). They obtain soft fibres from the leaves to make hammocks, sandals, and handcrafts. The leaves and the inflorescence stalks are used as building materials. Finally, they prepare a traditional and highly appreciated alcoholic distilled beverage, the "cocuy", which is similar to the Mexican mescal and tequila. All these products are harvested from wild populations. Traditionally, cocuy spirit production, together with goat extensive production and aloe and maize cultivation has been a source of income for poor local farmers in the dry mountain range area of Falcón and Lara states. However, due to the influence of industrial competitors, the cocuy artisan spirit was banned and excluded from the Alcoholic Beverages National Law during the '70s of the past century, leading to persecution of local producers.

Figure 9. Agave cocui plants growing in natural conditions in Falcón state. Photographs: Miriam Díaz.

Attending the request of cocuy artisans and Falcón Government, Fundacite Falcón (Fundación para el Desarrollo de la Ciencia y la Tecnología del estado Falcón), a public institution affiliated to the Science and Technology Minister in charge of the promotion and support of research and innovation in the region, started in 1995 the research and innovation Agave cocui program, involving academics from UNEFM, NGOs and local farmers from Pecaya parish (Sucre municipality, Falcón state), in order to study the biological, environmental, sociological and technological implications of cocuy traditional production (Díaz 2002). A multidisciplinary team gathered information about the ecology, physiology, reproduction, propagation, and biochemistry of the plant; the analysis of the quality of the cocuy spirit as well as fermentation and distilling process; historical and sociological studies of the people from Pecaya parish were also undertaken. The productivity and benefits of several agroforestry systems based on promising genotypes of Agave cocui, Aloe vera, and short cycle vegetable crops (i.e., beans, coriander, tomato) planted under cují (Prosopis juliflora) trees shadow, were evaluated in the field. Agave plants and native tree species nurseries were established and promoted among local producers in order to reforest the areas and assure long-term supplies of agave and wood to sustain cocuy beverages production.

Semi-tabulated goat management

Degradation of the vegetation and desertification have been associated with extensive goat farming in the arid and semi-arid regions of Venezuela, similarly to what has been described in other countries of the world (Matteucci 1986, Matteucci & Colma 1997, Mogollón 2016). These processes usually occur when high occupation animal rates are maintained in a limited area during drought periods, resulting in overgrazing of vulnerable plants under hydric stress.

Extensive goat farming is one of the traditional subsistence activities that has been developed over the past 400 years in the arid and semiarid of Falcón – Lara states (Armas et al. 2006). Although the importance of goat farming has been underestimated in the rest of the country, it has great socio-productive relevance in this area, since this is the most important source of proteins for the inhabitants of these lands (Delgado et al. 2010).

These animal systems have been thoroughly studied by academics and researchers from Universidad Centro Occidental Lisandro Alvarado (UCLA-Lara), Universidad Nacional Experimental Francisco de Miranda (UNEFM-Falcón), Universidad Politécnica Territorial Alonso Gamero (UPTAG), and Instituto Nacional de Investigaciones Agrícolas (INIA-Lara and INIA-Falcón), among others.

Several initiatives have been implemented in this region in order to improve the technologies applied for goat production, reduce the environmental impact of the activity, and offer socio-economic assistance to the poor families that depend on this resource (Table 4). Semi-tabulated systems based on paddocks and protein banks that include native and naturalized herbaceous, shrubby and tree plant species as fodder resources, together with water harvest techniques, as well as reproductive control and sanitation herd management, help to lower the pressure over the xerophytic forests and promote the environmental and socio-economic sustainability of this activity. The many promotion efforts have contributed so far to an increase of awareness in relation to natural resources conservation and protection among some segments of the producers, although these practices have not been generally adopted yet (CIARA, 2014).

Table 4: Research and development public initiatives promoted to improve the sustainability of goat farming in the arid and semi-arid region of Venezuela.

NATIONAL RESEARCH AND DEVELOPMENT PROGRAMS FOR THE SUSTAINABILITY OF GOAT CATTLE PRODUCTION				
Initiative	***Date***	***Aim***	***Stakeholders involved***	***Funding***
PIDZAR Project of Research & Development on Arid and semiarid zones in central-western Venezuelan region (Proyecto de Investigación-Desarrollo de Zonas Áridas y Semiáridas en la Región Centro Occidental de Venezuela)	1980's	Design, implementation and evaluation of initiatives for the rational use of the natural resources of this zone, in harmony with the environmental conditions and the integral development of the area (Improvement of goat traditional farming and optimization of water and energy)	FONAIAP (currently INIA), UCLA, UNEFM, CORPOCCIDENTE& FUDECO. Pilot communities in Lara and Falcón states.	France International Technical Cooperation Program. Institutional participants contributions.
National Research Agenda on Goat Cattle	2000's	Research to advance national goat productive capabilities	MCTI. Fundacite Falcón. Fundacite Lara. Fundacite Zulia. UNEFM, UCLA, LUZ, UDO	FONACIT
Project for the sustainable rural development of the SemiArid zones of Lara and Falcón estates (PROSALAFA, by its Spanish acronym). PROSALAFA I, II & III	1993-2004 / 2006-2013 / 2014-	Capacitation and technology transfer to diminish the levels of extreme poverty and poverty of the rural communities of the semiarid region of Lara and Falcón states	CIARA Foundation	International Fund for Agricultural Development of the United Nations and the Corporación Andina de Fomento (CAF)
Program: Networks of Productive Innovation ("Redes de Innovación Productiva" or RIP)	2000-2016	Technology transfer program to increase capabilities of rural productive organizations	MCTI. Fundacite Falcón. Fundacite Lara. Fundacite Zulia. Rural productive organizations	FONACIT, LOCTI Funds & Misión Ciencia

References: CIARA 2014, Fundacite Falcón et al. 20009, IICA 1983, Matteucci & Colma 1997.

CIARA: Fundación para la Capacitación y la Innovación para el Desarrollo Rural Development)
CORPOCCIDENTE Corporación para el Desarrollo del Occidente de Venezuela
FONAIAP: Fondo Nacional de Investigación Agrícola y Pecuaria
FONACIT: Fondo Nacional de Ciencia y Tecnología
FUDECO Fundación para el Desarrollo del Centro Occidente de Venezuela
Fundacite Falcón: Fundación para el Desarrollo de la Ciencia y la Tecnología del Edo. Falcón
Fundacite Lara: Fundación para el Desarrollo de la Ciencia y la Tecnología del Edo. Lara
Fundacite Zulia: Fundación para el Desarrollo de la Ciencia y la Tecnología del Edo.Zulia
INIA Instituto Nacional de Investigaciones Agrícolas
MCTI: Ministerio de Ciencia y Tecnología
UCLA Universidad Centro Occidental Lisandro Alvarado
UNEFM Universidad Nacional Experimental Francisco de Miranda

Conservation of forested lands. The experience of Montecano communal lands in Paraguaná.

According to Jongwon et al. (2011) "traditional rural forests exist within the area of influence of village communities, having historical and cultural significance, and for this reason, they are forests that play a special role in clan communities or village communities." This concept can be applied to Montecano forests, located on communal Indigenous lands legally recognized as such since the XVII century. The members of the San José de Cocodite community have long used these lands mainly as shared foraging places for their goats. However, they started to have concerns about the sustainability of the forest decades ago when neighbouring communities pressed also for the use of these foraging lands, and new private urbanisms started to appear in their surroundings, among other threats.

In order to protect Montecano, a long cooperative effort was established in 1985 between the Community of San José de Cocodite from Paraguaná (Pueblo Nuevo Parish, Falcón municipality), Universidad Nacional Experimental Francisco de Miranda (UNEFM), and the private NGO BIOMA Foundation. After BIOMA's closure in 1996, INFALCOSTA NGO got into the cooperative agreement. In spite of various threats and external pressures over Montecano, this joint effort allowed to conserve this forested area and to develop research, conservation and educational programs, including the establishment of eco-touristic routes, about the value and importance of its natural resources and biodiversity (Infalcosta, n/d, Martino 2012).

Montecano is a low range of irregular topography that captures the air humidity carried by the northeastern-southeastern trade winds. During late-night hours when air temperatures drop, water condensates over the plant leaves enhancing plant productivity, especially of CAM species such as epiphytic and terrestrial bromeliads, orchids and cacti (i.e., pitahaya), and trees such as *Pereskia guamacho* (Edwards & Díaz 2006, Martino 2012). Recent studies have shown that some tree species present in Monte Cano (i.e., *Quadrella odoratissima*) can absorb water through the leaves and depend on atmospheric humidity rather than on direct precipitation; for that reason, they survive in these areas (Losada et al. 2021).

Attending the request of San José de Cocodite Community and its allies, Montecano was declared as a Natural Monument on April 22, 2019, by Presidential Decree N° 3825 published in the Gaceta Oficial de la República Bolivariana de Venezuela n° 41.617 and was officially included in the list of National Protected Areas administered by INPARQUES. The biological and ecological evidence to support this decree was gathered by CIEZA-UNEFM (Martino, 2012). Montecano Natural Monument covers 2,599 ha of xerophytic forest and shrubby vegetation and serves as a refuge for many animal and plant species that are not found in the rest of Paraguaná. It is an important CO_2 reservoir in this largely environmentally disturbed region (Figure 10).

Figure 10: Montecano Natural Monument covers 2995 ha of hills located in the northeast of Paraguaná Peninsula, Falcón state, in the Venezuelan arid and semi-arid region. Upper row, from left to right: a) the epiphyte Tillandsia usneoides captures air humidity and grows abundantly in the understory; b) hill landscape covered by bush and shrubby vegetation; c) San José de Cocodite community together with UNEFM and INFALCOSTA have guarded Montecano for almost 40 years. Lower row: d) Montecano faces eastward to the Caribbean Sea, so the hills trap humidity brought by north trade wind; e) Members of the San José de Cocodite community listen to the presentation of the proposal to declare Monte Cano as a National Monument in August 2016; f) columnar cacti and terrestrial bromeliads are common in Montecano.

Afforestation and water surface runoff technologies to control soil erosion and promote vegetation recovery.

Soils are a major CO_2 reservoir in arid and semi-arid lands in Venezuela. However, inadequate vegetable agricultural and irrigation practices, extensive goat farming, cattle raising introduction, native tree species overexploitation (to obtain firewood and handcrafts), and deforestation lead to loss of the reserves of soil organic carbon and microbial biomass carbon (Mogollón et al. 2015). Dry environmental conditions, high wind speeds, torrential rains in short spans of time, and wildfire occurrence, increase the risks of salinization, soil loss and desertification. The Paraguaná peninsula, El Cebollal, and Matícora river basin, are some of the areas that show evidence of degradation and loss of soil caused by inadequate agricultural and goat raising management in Falcón state.

Some local producers apply traditional "*torobas*" technologies in order to avoid soil loss during rainy season and manage rain overflow. *Torobas* are trappings made from stones or logs that are set on the terrain in a perpendicular way to the slopes, in order to conduct and slow down the speed of superficial runoff. *Torobas* function as sediment traps while increasing local soil water infiltration. These processes enhance the establishment of new plants that, in turn, attract herbivores which release their urine and feces in these feeding sites and contribute to enrich soil nutrients availability, thus creating a positive vegetation recovery cycle. *Torobas* are also used to improve irrigation water distribution in plantations.

In the past decade, Venezuela´s national environmental authority (MINEC) promoted several projects and actions in Falcón state to mitigate and recover the severely degraded basin of Matícora river including its tributaries sub-basins. Due to the severe erosion degree, native trees used in reforestation campaigns showed low rates of survival. In contrast, according to Falcón state MINEC environmental technicians the establishment of rural ditches undertaken by the local communities of Tupurito, in Dabajuro municipality was a successful experience (Josefa Morles, personal communication, 2022). Starting in 2014, the national environmental authorities from MINEC (Ministerio del Poder Popular para el Ecosocialismo) initiated a project based on a formal agreement with members of the local community organized as the "Consejo Comunal of Tupurito", by which MINEC technicians offered a basic preparation on local hydrology control principles and field advisory and supervision on how to build rural ditches using materials locally available (i.e., stones and logs). MINEC national officers transferred financial resources to the Consejo Comunal to hire members of the community to build several rural ditches. The community selected the area to establish the ditches, considering the recurrence of torrential floods that carried large amounts of sediments and debris that tended to interrupt an important rural road during the short rainy season. A battery of 6 rural ditches built by the community members under the supervision of MINEC technicians was ready before the next rainy

season. The results were evident: no flood occurred and the transit on the road was open during the whole rainy season. The ditches trapped large sized sediments and allowed the passage of smaller ones carried by the slowly flowing water. One of the local producers took advantage of the sediments trapped in the ditches to establish forages to feed their cattle. Runoff water remained in ponds for weeks after the end of the rainy season offering the cattle a source of drinking water. A group of women from Tupurito village that took part of this experience, decided to implement by themselves new rural ditches in their own lands to take advantage of this technology for their agricultural and cattle raising activities. They also shared their knowledge and helped other producers from nearby localities to build their own ditches. This is an example of how local communities can adopt sustainable technologies when the benefits are evident and compatible with their socio-economic rationale.

Figure 11: National Environmental authorities from MINEC provided technical and financial support to rural communities to develop artisanal ditches in Tupure river basin, one of the tributaries of Matícora river, in north-western Venezuelan Falcón state, in order to stop erosion and promote soil and vegetation recovery.

4.1.2. Which national policies exist that address the LMT?

In general, Venezuela has a comprehensive law system in the environmental area that provides support to agroforestry and conservation LMTs. Starting with the Constitución de la República Bolivariana de Venezuela approved in 1999, a varied set of organic laws and general laws have been approved such as: Ley Orgánica de Planificación y Ordenamiento Territorial; Ley Orgánica del Ambiente; Ley Orgánica para la Conservación Ambiental; Ley Penal del Ambiente; Ley de Meteorología e Hidrología; Ley sobre Manejo Integral de Riesgos; Ley de Áreas Naturales Protegidas, Ley de Seguridad y Soberanía Alimentaria. A thorough review of the legal instruments related to arid and semi-arid land management and development has been recently produced by Durán (2018)

United Nations Convention to Combat Desertification and mitigate the effects of drought (UNCCD)

Venezuela presented in 2004 a national report indicating its commitment to implement prevention and mitigation, or compensation actions related to the effects of desertification and drought in the country, according to national environmental policies and environmental agreements already signed.

In 2019, Venezuelan authorities officially informed the UNCCD about the national voluntary goals fixed by the country to accomplish Neutrality in Land Degradation (NLD) by 2030 (República Bolivariana de Venezuela 2019). The more relevant goals for arid and semiarid land sustainable management are the following ones:

- Goal n° 1: By 2030, to increase 262,361 ha (0.53%) of forest lands based on year 2010.
  This goal explicitly includes the reforestation of Hueque, Mitare and Matícora river basins, all of them located in Falcón state, as well as Tocuyo river in Lara state.
- Goal n° 3: By 2030, to recover and maintain an agricultural cultivated surface of 100,000 ha per year.
  This goal refers to the contribution of the Lands and Agriculture Ministry to the NLD that will be implemented in arid and semiarid zones of Lara and Falcón states, through (a) the Integral Crops and Goats Management strategies based on environmental sanitation and education in 3000 production units covering around 15000 ha; (b) Irrigation water-saving techniques implementation (sprinkler and drip irrigation); (c) tabulated and semi-tabulated goat herds management, with genetic improvement, fodder banks, multi-family rural cisterns, and comprehensive management of crops and vegetables, with technical and financial support. All these actions are oriented towards the establishment of a sustainable production quality certification program.
- Goal n° 6: By 2030 integration of Neutrality in Land Degradation (NLD) into territorial planning has been promoted, especially in those zones with critical levels of land degradation.
  This goal includes the obligation to produce and put into action the Management and Conservation Plans of the river basins Hueque, Mitare and Matícora in Falcón state, and of the Tocuyo river in Lara. It also refers to the consolidation of the territorial management of Coastal Zones to prioritize present and future actions to promote the sustainable development of these spaces.

These goals provide key orientations to all stakeholders involved in arid and semiarid sustainable development in Venezuela for immediate action. The experiences and models here presented may now find an opportunity to be extended, improved, and adapted under this official scheme of Neutrality in Land Degradation (NLD).

Forest National Law

Agroforestry systems are acknowledged in the Venezuelan Law corpus. The "Ley de Bosques" (Forest National Law), officially enforced in 2013, declares that one of its purposes is the promotion of agroforestry systems along multiple-use forest plantations as one way of assuring sustainable forest management and use (Article 7). The law acknowledges organizations, and Indigenous peoples and communities, the right of being consulted and of participating in the promotion and development of diverse initiatives oriented towards the conservation, and management of forests and forest patrimony including the conformation and management of socio-productive forms integrated into the productive forestry chain (Article 27). This legal instrument clearly points that is the duty of the State (at national, regional and local levels) to promote and encourage the increase of forest cover with responsibilities through programs, plans and actions aimed at the afforestation of lands devoid of vegetation for protective or productive purposes, and the promotion and conservation of forests as carbon sinks, among other initiatives.

Policies related to exploitation of local fauna species

According to Venezuelan Law of Protection of Wild Local Fauna (Gaceta Oficial 29.289, August 11, 1970), local fauna conservation and rational exploitation are considered activities of public interest under the direct supervision of the environmental authority. This legal instrument does not explicitly support fauna domestication programs; therefore, the establishment of private initiatives to exploit fauna species faces many restrictions. Starting in the '70s through the beginning of XXI century, some emblematic research programs promoted by Universidad Central de Venezuela and Universidad de Los Llanos Ezequiel Zamora, with the support of Ministerio del Ambiente, produced information on raising activities of some endangered fauna species (i.e., caiman del Orinoco, Arrau turtles) and some hunting preys (i.e. capybara), in order to improve the status of their natural populations. However, these initiatives have not been exploited at a commercial level. The establishment of commercial fauna species production systems could improve agroforestry systems economic impact and provide a sustainable source of food for the rural communities in semi-arid zones. An updated legal frame to promote sustainable fauna species domestication and exploitation is required.

Policies that regulate sustainable artisan beverages manufacturing and its impact on the environment

The results of the Program on Agave cocui, described in a previous section, supported the official acknowledgement of Agave cocui and its traditional usages as a natural and cultural Indigenous heritage in 2000, together with the approval of a quality standard (COVENIN) to produce the beverage, and the granting of a national appellation of origin to artisan cocuy pecayero spirit in 2001. This experience provided evidence to change the Alcoholic National Beverage Law in 2005, and to approve a special providence by the national tax authority (SENIAT) in 2008. These legal instruments set limits to the maximum volume of cocuy each artisan can produce per year, limiting thereof the number of plants that can be harvested to obtain this spirit. They also set the obligation of the artisans to establish agave nurseries for reforestation.

Starting from the request of Pecaya communities, followed by the involvement of academics and regional institutions, this bottom-up process led to the approval and modification of national legal instruments that finally allowed the artisans to produce and sell cocuy, improve their living conditions, and receive the recognition they deserve while setting sustainability environmental standards (Miriam Díaz pers. comm., Sánchez et al. 2008).

Cocuy artisans are allowed to produce up to a limited amount of cocuy spirit per year (2.000 litres per year); they also have the obligation to establish agave and tree species nurseries and are legally enforced to plant agave and trees (used as a source of wood for fuel) in the exploited areas. In 2022, a new law project intended to protect and promote Agave cocui production has been proposed and is currently under public consultation and discussion.


REPUBLICA BOLIVARIANA DE VENEZUELA.- MINISTERIO DEL PODER POPULAR PARA LA INDUSTRIA Y COMERCIO. SERVICIO AUTONOMO DE LA PROPIEDAD INDUSTRIAL Caracas, 10 de noviembre de 2016

AÑOS 206°, 157° Y 17°

RESOLUCIÓN N°: 238

I.- ANTECEDENTES

Visto: La Resolución N° 287 de fecha 22 de mayo de 2001, publicada en el Boletín Oficial de la Propiedad Industrial, N° 445, de fecha 01 de junio del 2001, Tomo VI, página 208 a la 210, mediante el cual se declara la denominación de origen de **COCUY PECAYERO** en los términos siguientes:

"Primero: DECLARAR que la denominación COCUY PECAYERO es una denominación de origen del Estado Venezolano para los productos obtenidos del Agave cocui "cocuy" de Pecaya, Municipio Sucre del Estado Falcón. Segundo: DISPONER la inscripción de la Denominación del COCUY PECAYERO en el libro de Denominación de Origen del Servicio Autónomo de la Propiedad Intelectual. Tercero: En virtud del anterior Reconocimiento al COCUY PECAYERO como Denominación de Origen del Estado Venezolano y por cuanto la misma puede ser utilizada por aquellas personas que cuenten con la Autorización de Uso correspondientes, otorgada por el Servicio Autónomo de la Propiedad Intelectual. Se hace de la Comisión de la Comunidad Andina "La autorización de uso de una denominación de origen protegida deberá ser solicitada por las personas que: a) directamente se dediquen a la extracción, producción o elaboración de los productos distinguidos por la denominación de origen b) realicen dicha actividad dentro de la zona geográfica delimitada según la declaración de la protección (...)".

Figure 12: National laws that regulate artisan cocuy alcoholic beverages production remark the obligation of producers to develop sustainable agave plantations.

Which actors are currently applying the LMT (e.g., land users, forest owners, farmers)?

In the past 20 years, several research-innovation projects have been developed by public organisms in Falcón and Lara states (i.e. Fundacite Falcón, Fundacite Lara, CIARA-PROSALAFA, Instituto Nacional de Investigaciones Agrícolas –INIA-), academics from Universidad Nacional Experimental Francisco de Miranda –UNEFM-, Universidad Politécnica Alonso Gamero –UPTAG-, Universidad Centro Occidental Lisandro Alvarado –UCLA-, NGO´s such as INFALCOSTA, working closely with local goat farmers, peasants and cocuy beverage producers, with varying results. Funds for this kind of projects used to come from grants provided by Ministerio de Ciencia y Tecnología including funds obtained by the Ley Orgánica de Ciencia y Tecología (LOCTI, but they are not currently operative).

Some private initiatives of small and medium producers and local entrepreneurs are already incorporating sustainable practices of goat herds management (i.e., Granja Agroecológica Virgen de la Guadalupe and others in Guzmán Guillermo Parish close to Coro), as well as pilot projects to raise local fauna species.

Figure 13: Semi-tabulated goat raising systems offer a sustainable alternative to extensive or free ranging environmental degrading practices, increasing the quality of the products obtained as well as the economic returns of small producers in semi-arid lands. Credits: Photos from Granja Agroecológica Virgen de la Guadalupe Instagram account @gvguadalupe.

Recently, a new generation of entrepreneurs have begun to implement agave beverages production projects in other localities of Falcón state, based on sustainable management of natural populations, as well as the establishment of their own nurseries for the propagation of promising agave clones to start large scale plantations (@cocuypecayero Instagram account, Figure 14). One promising private enterprise, Magno label, has recently been distinguished with two silver and one bronze medals in the International 2021 Liquor Contest in New York (https://observadorlatino.com/noticias/el-cocuy-venezolano-es-premiado-en-nueva-york/) (Figure 14). Artisans from Lara state have followed this example and recently received a medal in the London Spirits Competition 2022 for the quality of Cocuy 7 Primos Gota a Gota (https://elestimulo.com/gastronomia/2022-04-18/cocuy-7-primos-gana-medalla-en-london-spirits-competition/) (Figure 14).

Figure 14: Artisan and young entrepreneurs are adopting sustainable practices to produces cocuy alcoholic beverages in Pecaya and other semiarid Venezuelan regions. A) Establishment of agave

plantations under native trees shadow avoid deforestation. B & C) These new trademarks of cocuy have received international recognition in 2021 (Magno cocuy from Falcón state) and 2022 (Cocuy 7 Primos - Gota a gota from Lara state).

Which funds are available for the LMT?

Currently, financial sources to promote or support the adoption of agroforestry LMT in Venezuela, are very limited. During the past seven years due to the drop in Venezuela´s national income, the hyper-inflation economic cycle, and the international sanctions that affect country´s economy, public investment in this sector has stopped. Restrictions associated to the COVID19 pandemic during 2019-2020, brought about additional financial restrictions. Public and private banks that used to offer credits to producers and entrepreneurs, reduced drastically or even closed their credit offer in the past years due to the constant loss of value of the national currency.

However, small and medium established enterprises have managed to resist through these hard times, and continue to offer their production to national or even international markets (i.e.: BIOALOE, Barunú, Naturaven, Granja Agroecológica Virgen de la Guadalupe, among others)

Some private entrepreneurs are already evaluating and investing in the future development of environmentally friendly and sustainable agro-productive projects, such as intelligent or precise crop farming in Paraguaná (*Finca Ictiotecnológica El Chuchuve*), establishment of cocuy organic plantations in Lara and Falcón states (Chumaceiro Liquors company), and aloe farm agroforestry plantations in western areas of Falcón (CORPRISMA), to supply national and international markets demands of specific products.

International cooperation funds provided through FAO and the PNUD as well as some private international foundations, have granted some financial resources to rural communities and NGOs to develop technology transfer and family enterprises projects, and to support scientific research.

With the support of the Small Donations Program of PNUD in Venezuela, INFALCOSTA, a local NGO, develops a project (2021-2022) working closely with local communities from Monte Cano in Paraguaná, north of Falcón state. The project aims to transfer appropriate technologies (improved artisan ovens, solar dehydrators, capture of rainwater, establishment of family orchards and local trees nurseries, food processing techniques), offering poor rural family's new opportunities and means to improve their ways of living based on locally sustainable practices. One of the expected results of this project is to produce plants to implement a reforestation program in degraded areas of Monte Cano Natural Monument.

PNUD and Impact Hub Caracas NGO are sponsoring the program "Innovation Eco" aimed at community and private enterprises that promote sustainable productive projects in Venezuela. In 2022, the project "Eco-desarrollo del Agave cocui y sus derivados" was one out of 10 selected projects to receive technical and financial advisory to escalate their family business in Falcón (Instagram account @impacthubcaracas).

With the support of FAO and the participation of the Ministry of Ecosocialism, Dr Miriam Díaz and INFALCOSTA produced a Manual for the restoration of the xerophytic forest in Venezuela that was published in 2022.

Misión Árbol is a national reforestation program established by the Venezuelan national environmental authority (MINEC). This program has managed to establish nurseries of native tree species, adapted to arid conditions, to supply trees at low cost for reforestation campaigns and for private reforestation initiatives.

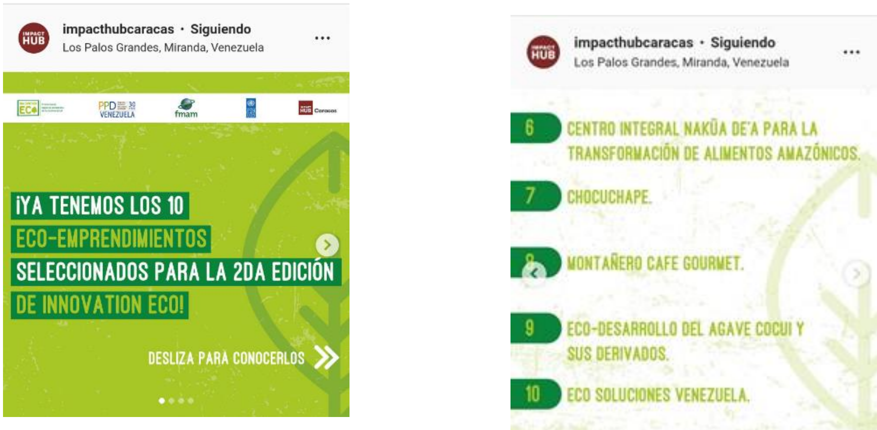

Figure 15: Innovation Eco Program was started in 2021 by Impact Hub Caracas to provide support to Venezuelan small entrepreneurs' initiatives, oriented toward sustainability production.

4.1.3. Current land use and potential land-use competition

Agroforestry as a way to conserve xerophytic lands and biodiversity has been used in the region for the past 30-40 years. It started as isolated initiatives undertaken by a few private landowners as a way to improve crop and goat farming results, while making efficient use of scarce local resources, such as water and plant fodder for cattle raising.

Unfortunately, under the current socioeconomic circumstances, mitigation through forest conservation or reforestation in the arid zones does not seem to be very effective at the present time. One particular difficulty is related to gas and oil scarcity conditions that affect the population in rural and urban contexts all over the country, the extraction of forest wood has increased. In the arid zones, people are extracting wood as a source of fuel to cook food and also as a way of living (i.e., sell of wood).

In spite of these circumstances, the recent establishment of the 2030 NDL national goals and the approval of tax incentives might help revert this scenario. Future expansion of these sustainable initiatives seems to be closely tied to private investment.

Due to local soil fertility conditions, the productivity, and economic returns of short cycle vegetable crops such as onion, chives, coriander, pepper, chilli, tomato, and melon are very attractive for farmers in semiarid lands. In the short term, these vegetable crops are more profitable than agroforestry systems, despite the implicit risks of underground water over-exploitation for irrigation with the subsequent soil salinization and aridisation effects.

It is important to assess if currently the incentives granted by the government to plant and export specific food crops are competing with this LMT. This should be assessed by agronomic professionals, considering the carbon balance of each crop.

Economic incentive schemes to promote agroforestry sustainable food production systems while discouraging traditional vegetable agriculture should be designed and carefully implemented.

4.1.4. Climate risks & sensitivities

Studies based on the analysis of precipitation and evaporation ratios have concluded that dry territories all over the world have extended in the past 60 years and they will continue to do so under a high greenhouse gas emissions scenario during the XXI century. This global dry land expansion will increase the population affected by water scarcity and land degradation. At present time, dry lands cover 41% of land world surface and are home to 1/3 of its population (Feng & Fu, 2013). South America will be one of the regions with the highest expansion of semiarid lands.

According to previous studies (Martelo 2012, Ovalles et al. 2008), the most plausible future climate scenarios for Venezuela in 2060 will be dryer and warmer than the current conditions. Some expected impacts include increased risk of drought and wildfires, an increase in the frequencies and impacts of ENSO events in its warm and cold phases (El Niño and La Niña), and an 8% increase of areas under desertification risk (from 39% to near 47%), among others. Since in Venezuela drought periods are usually modulated by a complex interaction system between atmospheric-oceanic ENSO and superficial water temperatures in the North Tropical Atlantic Ocean, it is expected that climate change increases the frequency, severity, and extension of drought events in the country (Paredes-Trejo & Olivares, 2018). In 2015, Medina et al. explored future tendencies of seasonal dryness in Venezuela. Their results showed a clear expansion of areas with a negative hydric balance in 2050. Accordingly, arid areas will expand in 7,904 Km2, and the greatest increase will occur in Falcón, Zulia and Lara states which are already the largest states in terms of aridity. These authors also found that semiarid lands will expand about 106,000 Km2 into regions that currently belong to subhumid provinces (Medina et al. 2015).

In spite of hydric resources abundance in Venezuela, barely 5.7% of agricultural lands have irrigation systems (Ovalles et al., 2008, cited by Paredes-Trejo & Olivares, 2018); therefore agricultural production is very vulnerable to extreme drought events, with negative socio-economic consequences (i.e. food scarcity, health problems, economic losses) that affect rural communities and small producers with limited recovery capacities (Olivares et al., 2016a, 2016b, 2017, 2018; Hernández, 2008; Paredes et al. 2014; all cited by Paredes-Trejo & Olivares, 2018).

The future expected climate scenarios of increased dryness will affect plants and the associated fauna species in different ways. Some dry-tolerant bird or bat species may experience an expansion of their niches and geographical distribution while others with very specific niche requirements will be totally excluded or severely restricted in their distribution, hence affecting the survival and distribution patterns of those plants species that depend on them for their pollination or dispersal (Angela Martino, pers. comm).

Stakeholders agreed that the agroforestry LMT practices are sensitive to climate change, in particular to extreme drought and high temperatures. They also mentioned that although in these dry areas the occurrence of wildfires is not so frequent, certain specific localities may be sensitive to forest fires increase. Biodiversity loss, diminishing soil fertility, and increased soil salinization and desertification were the major foreseen negative effects. The loss of insects, birds, bats and small mammals' populations that act as pollinators or fruit dispersal agents, as well as natural pest control agents, was a major concern pointed out by stakeholders, since these animals provide essential ecosystem services in semi-arid regions of the country. Soil degradation and loss due to inappropriate agricultural management, cattle introduction and deforestation are expected to worsen under climate change scenarios.

Increased weather variability is perhaps the most negative climate change effect on agroforestry LMT in arid and semiarid territories in the country. The effect and consequences of the El Niño-La Niña cycles are evident on Venezuelan arid and semi-arid lands. For instance, the heavy rains that occurred during the La Niña phase in 2010-2011 affected Aloe vera crops and many cultivated lands were lost due to fungi and bacterial diseases; goat herds also suffered serious diseases. Floods in the lowlands affected urban and rural infrastructure, causing the loss of many roads and homes. The 2011 rainy year was followed by an intense three-year drought period that limited water availability for agricultural, industrial, and urban uses. Currently in 2022, an extended La Niña phase has increased the intensity and frequency of rainy events leading to the proliferation of African snails' populations, an invader species that affects crops and bring about health risks to rural communities.

In order to increase the success and resilience of the proposed LMTs in arid and semi-arid lands, special efforts must be done to apply efficient technologies to store excess rain during La Niña ENSO phase, increase water percolation rates to recharge underground reservoirs, reduce drainage speed and soil loss, and protect the degraded river basins to diminish the risks of lowland flooding. These activities contribute to a better endurance of rural communities during the inevitable drought periods that will follow during El Niño ENSO phase.

4.1.5. Economic implications

Careful planning and implementation of agroforestry systems may bring along more benefits than risks, in terms of economic, social, and environmental impacts. The appearance of new private entrepreneurs that are incorporating sustainability concepts and LMT in their businesses is a favourable sign in this regard. Some interviewed stakeholders expressed their concerns in relation to larger initial investment costs and longer periods of time to start receiving economic returns. To overcome in part this handicap, early financial support and incentives are needed. However, these concerns only apply when establishing productive units in previously deforested or severely degraded lands. In those cases where there is a vegetation cover, a careful analysis of the land and soil conditions prior to the intervention will allow the design and implementation of a sustainable and diversified agro-productive plan that takes into account the local reality. This means that a new approach and economic rationale is required to assure the success of the LMT.

Stakeholders also pointed out that loan schemes applied to agricultural projects by national funding agencies and banks should be revised to incorporate agroforestry LMT budget items instead of those applied in intensive traditional non-sustainable agricultural activities (i.e. deforestation, agro-chemicals application, and soil cover removal). This means that there is a gap to be overcome between the financial institutions and producers who are willing to adopt sustainable agroforestry LMT.

Information on actual costs of implementing agroforestry at different scales is not readily available. Field assessment of the costs and on the GHG emissions reductions are still pending.

4.1.6. Co-benefits and trade-offs

Agroforestry systems contribute to preserving the landscape since these systems mimic natural conditions and maintain the continuity of the vegetation cover. They improve the percolation of rainwater and reduce water surface runoffs, therefore avoiding soil erosion and contributing to improve surface and underground water quality. Biodiversity could also be enhanced as long as a careful selection of plant species is assured. In this sense, the incorporation of legume tree species could also contribute to improving soil nitrogen fixation.

The success of agroforestry LMT solutions in arid and semiarid lands will highly depend on their capacity to provide food and useful resources to the farmers and the inhabitants of rural areas.

Therefore, the species selected to establish a particular agroforestry system are a key factor. Plant species should be tolerant and resilient to harsh climate conditions (i.e., increasing temperatures and water stress), and provide resources for the local population (i.e., fodder for goats and sheep, wood as fuel and building materials source, nutritive food and beverage sources, products demanded by local agroindustry with economic competitive value). These combined criteria have been used to design systems including cují legume trees (Prosopis juliflora), aloe and/or agave perennial herbs

According to some consulted experts, economic value and ecological criteria should be both taken into account for the design and implementation of these agroforestry systems. Selected plant species should also offer resources to support animal biodiversity. For instance, cardones (a type of columnar cacti) should be included in agroforestry systems in Falcón semiarid regions (as living fences, for instance), to assure the continuity of bat species corridors and migratory routes that feed on them and contribute, in turn, to the reproduction of these cacti species and other important groups of plants. So, plant species associations in the agroforestry systems are key for the success of this mitigation strategy. It is important to mimic natural vegetation composition when designing and establishing new agroforestry systems.

Beyond the economic value, other biological and ecological considerations must be considered. Slow-growing plant species, such as cardones (columnar cacti), might not be such an attractive candidate for an economically sustainable agroforestry system when compared to aloe vera crop, for instance, but aloe cannot provide the same ecological services and support to the trophic web that cacti do. In brief, ecological, and economic benefits should be carefully assessed when designing and implementing agroforestry systems in semiarid lands.

Are there any other risks / co-benefits as part of the LMT implementation?

1) At small scales of development, agroforestry systems may not represent high-income levels, but they can provide food and resources to farmers and rural populations The dynamics of human migrations could be improved, helping to keep the population in their original lands and offering them the adequate sustainable quality of living conditions, while reducing rural migration into impoverished urban centres, and preserving the continuity of rural systems.
2) Adoption of agroforestry systems by isolated small producers may not be successful nor generate the expected benefits when neighbouring production units still rely on conventional unsustainable agricultural practices. Under these circumstances conflicts of interest among producers in a region are prone to occur (i.e., organic aloe or watermelon cultivation may be affected by agro-chemicals application in surrounding areas; careless fire management in adjacent production units may affect forest barriers). Therefore, it is important to create conditions by offering incentives and/or imposing certain legal restrictions to producers located in larger areas (i.e., a complete river basin), so they feel akin to adopt agroforestry LMT practices.
3) The inclusion of foreign species in the agroforestry systems should be avoided.

Maintaining the original natural landscape conditions should be preferred instead of promoting drastic changes in the vegetation type and landscape, which could lead to unforeseen consequences.

Under climate change scenarios, agroforestry LMT can be considered as a promising option of preserving biodiversity and ecosystem services in a very fragile territory, such as the arid and semiarid lands of Venezuela. Agroforestry practices offers alternative and sustainable ways of living to local rural communities; besides, they are also novel agri-business opportunities to provide national and international markets interested in innovative products (i.e., nutriceuticals, cosmetics, food and beverages, and natural products economic sectors). Although traditional agricultural short-cycle vegetable products, such as onions, peppers, or tomatoes offer high and fast economic returns, the increasing temperatures, drought intensification and climate variability represent growing risks for producers and therefore more resilient and water-efficient crops will be needed in the near future. At the same time, it is urgent to adopt environment-friendly practices to slow down and revert desertification processes in the rural areas, as a way of providing sustainable and dignified ways of living to rural inhabitants, while maintaining the environmental services required by urban populations (i.e., water for human consumption, extreme weather events mitigation, among others).

Decisive action and incentives from the government together with communication and education programs can provide the needed impulse for a wider adoption of agroforestry LMT.

4.1.7. Risks associated with scaling up

Although establishing agroforestry systems similar to those that have been previously promoted in Falcón state in other Venezuelan zones is a feasible LMT solution, a successful scaling up depends on the understanding, support and acceptance of the local communities, landowners and land managers.

Previous analyses and thorough studies of the local socio-economic and environmental conditions must be performed in advance to adapt and adequate previously identified agroforestry solutions or design new ones.

The possible impacts of establishing these systems (escalate) should be previously assessed, in particular, the impacts over the local biota must be considered.

4.1.8. Research gaps

a) The systematization, evaluation, and diffusion of results of previous experiences are necessary.
b) Detailed long term assessment and quantification of environmental impacts/benefits of agroforestry models at different scales could provide deep insights for the scaling up of this LMT.
c) Long term studies of economic flows and carbon balance of proposed agroforestry systems are lacking. Special efforts should be devoted to fulfilling these gaps.

5. Agroforestry in dry forest lands

5.1.1. Introduction

The contribution of the Bolivarian Republic of Venezuela to the global emission of 2010 was 0.49%, which places it within the category of low emission countries, both globally and regionally (Second National Communication on Climate Change, 2017). According to this communication, total GHG emissions reached 243,380 gigagrams of carbon dioxide equivalent (Gg CO2eq), shared as 124,979 Gg of CO2, 5,011 Gg of methane (CH4) and 43 Gg of nitrous oxide (N2O) (52%, 43% and 5% respectively if estimated as CO2eq). The contributions per economic sector to the total national emissions were: 84% (203,399 Gg CO2eq) in the Energy sector; 12% (26,921 Gg CO2eq) in the Industrial sector; 2% (6,664 Gg CO2eq) in the Agriculture, Forestry and Other Land Use sector, and finally, 2% (6,395 Gg CO2eq) in the Waste sector.

However, as part of the policies established in the country's economic and social development plan, Venezuela intends to implement a National Mitigation Plan in conjunction with a National Adaptation Plan. In this sense and on a voluntary basis since 1995, the DANAC Foundation has been implementing and operationally validating four of the seven strategies and/or practices (NETPS) that make up the LANDMARC mitigation activities matrix.

Agroforestry systems (AFS), which include silvopastoral systems (SPS), can be defined as dynamic and ecological systems of natural resource management, based on the spatial integration of trees with agricultural crops and/or pastures, in order to diversify and maintain a sustained production, providing social, economic and environmental benefits. They are viable forms of land use that are governed by the principle of sustained yield and at the same time allow production to increase progressively through the integration of forestry activities with agricultural and/or livestock activities Macdicken and Vergara (1990); Montagnini (1992); Nair (1993); (Couto and Pasos, 1995).

These kinds of productive systems are considered as key alternatives in the current trend to promote the transformation of conventional agriculture into "climate-smart agriculture". This concept integrates the three dimensions of sustainable development (economic, social, and environmental), jointly addressing food security and climate challenges. It is based on three fundamental pillars: a) sustainably increase agricultural productivity and income; b) adapt and build resilience to climate change; c) reduce and/or eliminate greenhouse gas emissions where possible (Montagnini 2015).

Agroforestry systems (AFSs) are nature-based technologies and good land-use practices that contribute to the reduction of greenhouse gas emissions through carbon capture and sequestration in, above, and below-ground biomass. Contreras (2019) using Emergy Analysis proved the ecological sustainability, financial viability, and higher energy efficiency of PBSs in the use of natural resources when compared to other forms of land use.

The most widespread agroforestry system in tropical regions is the "Taungya" system, a term that translates as "hill cultivation," in which annual agricultural crops were established in teak (Tectona grandis) forest plantations with the objective of providing food for the workers by using available space during the first two to four years of the development of the plantation. It was developed at the end of the 19th century in Burma, introduced in South Africa in 1887 and taken to India in 1890, expanding later to other regions of Asia, Africa, and Latin America (Mac-Dicken and Vergara 1990, Nair 1993).

In 1996, DANAC Foundation established the Agroforestry System Program. The project: "Establishment and Evaluation of a Multispecific Agroforestry Forest", undertaken from 1996 to 2006, helped to consolidate this Program through the development and study of agroforestry production systems applying a sustainable development approach (DANAC, 2021). The LMT is the Taungya Agroforestry System and SSP is known in DANAC as Multispecific agroforestry forests or MAF (Bosques Agroforestales Multiespecíficos or BAM), being its main objective of the project was the establishment of 100 ha of valuable timber trees, bamboo (*Bambusa vulgaris*) and guadua (*Guadua angustifolia*), in association with short-cycle crops.

DANAC is located in the San Javier sector, via Guarataro, San Felipe, Yaracuy State, 15 km from San Felipe, the state capital, at coordinates 10°41'45'' North and 68°49'00'' West. It is part of the Tropical Dry Forest (BST) life zone of the central-western region of Venezuela (Figure 16), however, Torres and Madero (1999, cited by Messa, 2009), consider that it belongs to a transition zone between the Tropical Dry Forest and the Tropical Humid Forest.

Figure 16. Location of the LMT, DANAC Foundation, San Javier, Estado Yaracuy, Venezuela.

San Javier is located at an altitude of 100 masl; it has a clear rainy season between May and November, that concentrates 76% of the waterfall, that reaches an average annual rainfall of approximately 1370 mm, with an average monthly temperature of 26º C, with annual maximum and minimum averages of 31 and 22ºC, respectively. evapotranspiration of 14 mm, maximum relative humidity of 90% and minimum relative humidity of 60%. The average annual evaporation is approximately 2070 mm, while the average annual relative humidity is 83% with a monthly variation of + 1.6%.

The LMT is located in the Cordillera de la Costa physiographic province in west-northern Venezuela, specifically in the natural region of the Yaracuy depression, which forms an elongated and dissymmetrical tectonic valley that presents relief in the form of a large, inclined plane or *glacís de explayamiento*, oriented towards the Yaracuy River, with a predominance of two types of landscapes (Messa, 2009).

The biogeographic context of the LMT is devoid of natural vegetation, except for some relicts and gallery forests in the Yaracuy River meadows, which were formerly exploited for banana cultivation. The vegetation in the upper and middle reaches of the Yaracuy depression consists of the natural vegetation of semi-deciduous and deciduous forests, while the lower reaches are dominated by natural vegetation of semi-deciduous and evergreen forests, alternating with deciduous forests (Messa 2009). Most of the depression's surface has been deforested to establish pastures, annual crops and irrigated semi-permanent crops (Messa 2009).

Tree species more frequently found are: Bambú (*Bambusa vulgaris*), Bucare (*Erythrina glauca*), Caña Brava (*Gynerium sagittatum*), Caoba (*Swietenia macrophylla*), Ceiba (*Ceiba pentandra*), Jabillo (*Hura crepitans*), Guácimo (*Guazuma ulmifolia*), Mata ratón (*Gliricidia sepium*), Yagrumo (*Cecropia sp*), Roble (*Platymiscium diadelphum*), Samán (*Samanea saman*), Mijao (*Anacardium exelsum*), Cedro (*Cedrela odorata*), Jobo (*Spondias mombin*), among others.

The DANAC Foundation for Agricultural Research (formerly known as Desarrollos Agrícolas Naranjal Asociación Civil), is a non-governmental non-profit organization (NGO), supported by Polar Enterprises Foundation (FEP). Since 1986, the DANAC Foundation has contributed to scientific and technological agricultural knowledge, food production, rural communities support and environmental protection in Venezuela (DANAC Foundation 2021). It has been mainly dedicated to research and development of technologies for the genetic improvement of rice, corn, and soy, building alliances with farmers, universities and public and private institutions related to the national science, technology, and innovation system of Venezuela.

With the agroforestry system known in DANAC as the Multispecies Agroforestry Forest (MAF, Figure 9, it was possible to optimize the spatial diversification of land use through the adoption of good agricultural, forestry and livestock management practices, with the permanent participation of the rural communities neighbouring its productive environment and in strict compliance with current legislation regarding the environment and natural resources, labour rights and sustainable human and rural development.

Figure 17. Image of the "sistema agroforestal multiestratificado", Fundación DANAC. San Javier, Yaracuy State, Venezuela (GoogleEarth, 2005).

According to the results reported by Messa (2009) for different types of land use, total soil organic carbon (COS) fluctuated between 39.04 and 79.24 Mg ha^{-1}. ha, with the highest values corresponding to primary forest and grasslands with scattered trees. The first 20 cm of soil depth concentrated 44% to 63% of the soil organic carbon. The total C stored varied between 63.79 and 233.20 Mg ha^{-1}. The C fixation rate of the agroforestry systems (wooded pasture and forage bank) was 3.90 and 2.56 T ha-1 respectively, these amounts represented three times the amount of carbon fixed by the sugarcane crop with 1.15 T ha-1.

The total C stock varied between 63.79 and 233.20 Mg ha^{-1}, being 3.2 times greater in the Primary Forest than the average value of intervened units. Pasture in alleys, fodder banks and sugar cane units stored between 27 to 29% of total C observed in the primary forest, whereas it reached 43% in the improved pasture with scattered trees unit. The rate of C fixation was 0.96; 2.56; 1.15 and 3.90 Mg ha-1 yr-1 for PAL, FB, SCC and PST units. The removals of CO2 from the studied units varied between 3.52 and 14.30 Mg ha-1 yr-1, corresponding the highest values to the pasture with scattered trees and primary forest units. These results show the potential of improved pastures with scattered trees in carbon storage in livestock systems. The overall GHG balance was influenced by the distribution and management of LUTs in the livestock production system. In this sense, the Grassland with Sparse Trees and Forage Storage units showed a net positive balance, which shows the importance of silvopastoral systems in their contribution to the removal of carbon from the atmosphere.

These results show that AFSs play an important role in mitigating CC by reducing the pressure on forests, which are the largest reservoir of C, in addition to contributing to the uptake of C in the tree component, in crops and soils (Montagnini and Nair 2004, cited by Montagnini 2015). The potential for the capture of C by the SAF is highly variable, depending on the site, type of SAF, species involved, age and management (Montagnini 2015).

In general, AFSs with perennials accumulate more C than AFSs with annuals due to the additional contribution of the trees or shrubs of the perennial crop. In conclusion, it can be said that AFSs with perennial crops can be important in the storage of C, while AFSs with annual crops and intensive management are more similar to conventional agriculture (Montagnini 2015).

According to Guerra & Messa-Arboleda (2017), the most relevant results obtained between 1997 and 2015, were: consolidation of the BAM as a biophysical unit of environmental conservation, experimental and demonstrative agroforestry production; increase of soil organic matter and reduction of losses of arable layer due to water erosion; increase of soil moisture retention and decrease of sediment and agrochemical loads in runoff waters; improved habitats and food supply for more than 114 species of fauna; protection of the natural forest and in situ conservation of 19 agroforestry genetic resources in seedling stands, arboretums, etc.; CO2 capture, improvement of the microclimate and rural landscape; 140,000 trees planted on farms and in communities; 16 graduate and postgraduate projects supported; transfer of products and results to 4,000 users through workshops, courses, guided tours, consulting, etc.; 20 presentations at technical-scientific meetings; and 100 publications in print, digital and audiovisual media.

5.1.2. Policy context

The planning system in force in Venezuela, applicable to the national, state, metropolitan and municipal levels, comprises two categories of processes: those oriented to territorial planning and management (long term) and those oriented to a specific management period (medium and short term). The first category, i.e., long-term processes or plans (20 years or more) are generated from the articles of the organic laws for Land Management (1983), Urban Planning (1987), Environment (2007), Municipal Public Power (2010), Water Law (2007), Biodiversity Management (2008), and the Law of Forests and Forest Management.

Thus, for example, in 1983 the Organic Law for Land Management was enacted, allowing the integration of the land management process with development strategies, i.e., regulating and locating socioeconomic activities with respect to the physical-spatial conditions for the exploitation and "rational" use of natural resources, incorporating the protection-valuation of the "environment", its self-regulation capacities, specific conditions and ecological limitations (LOOT, 1983).

The regulatory framework at the national and international levels has taken important steps to encourage the strengthening of inclusive governance for environmental conservation and management. Two important processes have opened opportunities for addressing the effects of climate change in rural and urban areas. First, changes in national regulations as a result of the 1999 constitution; and second, the approval and ratification of international agreements.

International agreements become important for the development of national and local regulations and instruments for environmental conservation, addressing the effects of climate change and guaranteeing the right to enjoy a healthy environment. Their importance lies in providing guidelines for the establishment of inclusive environmental governance by not limiting themselves to government action commitments, but rather in raising the importance and need for private, community and all stakeholders' participation as a mechanism for the management and solution of socio-environmental conflicts. The main international agreements approved by law that are related to climate change and its effects are presented in Annex 1.

In the Venezuelan legal context, in accordance with the Constitution and the International Legal Framework on Environment, Conservation and Climate Change subscribed by the country, a series of laws have been developed to address the existing conditions of vulnerability, such as Law of Coastal Zones, Law of Forests, Law of Integral Management of Socio-Natural and Technological Risks and Law of Management of Biological Diversity; as well as different laws have been promoted and approved that somehow face the issue of the affectation derived from Climate Change: Organic Law of the Environment, Criminal Law of the Environment, Law of Waters, Law of Integral Management of Garbage and Law of Rational and Efficient Use of Energy, among others.

The "Bosques Agroforestales Multiespecíficos" (BAM) of the DANAC Foundation, since its creation, has received the unconditional support of the Fundación Empresas Polar (FEP); this foundation has promoted and supported DANAC institutionally and financially through the Sustainable Tropical Agriculture Program. FEP is a non-profit social organization that is part of "Empresas Polar", a conglomerate of large and small private industries in the food production sector for human consumption. In Venezuela, Empresas Polar has established itself as a diversified, solid industry committed to the socio-economic development of the country. Products such as POLAR beer, PAN precooked corn flour, MAZEITE edible oil, PRIMOR rice and pasta, EFE ice cream, a subsidiary of Pepsi-Cola and other emblematic food and beverage brands make up the list of products consumed in the world food market.

Together, the two Foundations (DANAC and POLAR) have implemented research and extension programs in agroforestry and environmental matters to consolidate the LMT - "Multispecies Agroforestry Forests" in which the efficiency of the good use of natural resources and the contribution to climate change mitigation and compliance with the Sustainable Development Goals of the 2030 Agenda has been proven.

In addition, there has been technical and scientific support from another very important institutional actor, the Faculty of Agronomy (FAGRO) of the Central University of Venezuela (UCV), Messa (2009).

In the context of sustainable rurality, other actors have been incorporated as protagonists in the agro-productive processes. These actors and users of the LMT total 118 people who have the benefit of being directly employed. In addition, another 354 people benefit indirectly from the socio-productive relationships generated by the LMT.

The most important, both in terms of extension and of contributions or benefits generated, was the system of legume species intercropped in the plantations of timber trees. These crops were selected to improve degraded Class III soils according to the FAO classification, due to the presence of a conglomerate and rock horizon, salinisation, and frequent periods of waterlogging. In the period between 1997 and 2004, 150.5 ha of legume species, including 109.3 ha of quinchoncho and 41.2 ha of crotalaria were established. Cover crops remained in the field for a couple of years until they were incorporated into the soil with a harrow pass, after harvesting the grain to ensure the seed for the establishment of new areas the following year. This was particularly the case of the quinchoncho, which was harvested by hand by members of neighbouring communities for 5 years. In the period 1999 – 2004, a total of 7,322 kg of quinchoncho were harvested. The product obtained was distributed in three parts for the communities and one for DANAC Foundation as seeds for the next plantations.

The management of the LMT and the benefits it generates have strengthened the strategic alliances with the families of small farmers who live in harmony and solidarity with the Foundation in the vicinity of Hacienda El Naranjal in the San Javier sector in the State of Yaracuy. The aforementioned producers make up rural communities near the foundation, occupying an area of approximately 272 hectares, of which 67 are gallery forests and environmental protection areas or forest areas of the "Tropical Dry Forest" biome.

Which funds are available for the LMT?

Fundación Danac is a non-governmental, non-profit organization that develops projects and programs focused on research and technology transfer related to food security and sovereignty, good land use and sustainable agricultural development. The funds for its operation come from self-management, the contribution of capital from Empresas Polar and the competition in national and international calls for research, development, and technological innovation projects.

5.1.3. Current land use and potential land-use competition

For 24 years, the DANAC Foundation, through its organizational policy, has implemented specific actions to mitigate greenhouse gases using nature-based strategies. Since 1995 and at all levels of the organization, a corporate commitment was established to carry out activities in all contexts that, today, are aimed at meeting the Sustainable Development Goals. For the next decades 2030 - 2050, it is projected to be one of the main organizations of technological innovation for the development of agricultural production and agroforestry systems in the country, whose carbon balance tends to neutrality (Guerra, 2021). In order to achieve these goals, there is already a platform for the mitigation of emissions based on the good use of land, which is the LMT or "Multispecific Agroforestry Forests". Likewise, in the medium term, corporate actions will be undertaken to quantify emissions, including avoided emissions from the program to eradicate the use of fire and from agroindustrial decarbonization actions and strategies within the framework of Empresas Polar's environmental policies. These actions are carried out in order to contribute to the Nationally Determined Contributions (NDC's) of the agri-food sector, meeting the criteria of the Kyoto Protocol and the guidelines of the Paris Agreement and the Sustainable Development Goals.

Approximately 50% of Venezuelan territory is covered by forests, 90% of which are concentrated south of the Orinoco River in the Guayana Region. Most of these forests are located in the lowlands.

Based on satellite images, the country's forest cover was estimated at 427,000 km2 in 1996 (Bevilacqua and Miranda 2002). However, in the lands north of the Orinoco, which concentrate 85% of the national population, the forests have been subjected to strong pressures as a consequence of the development of different economic activities (MARN-UNDP-GEF 2005).

In Venezuela, agricultural lands are severely degraded due to excessive use of machinery and chemical inputs, among other aspects. Likewise, the growing need for land for urban and industrial development has often been covered at the cost of loss of land with high agricultural capacity, generating significant soil degradation problems (Guerra, 2021). According to the same author, for the year 1978, it was established that the areas that did not present limitations in soil characteristics for good agricultural development in Venezuela occupied barely 2 % of the territory, most of these areas have relief limitations (44 %) and low fertility (32 %), poor drainage (18 %) and aridity or scarcity of rainfall (4 %). Precisely, this general condition of the country means that agricultural activity, if not well managed under the precepts of sustainability, can generate or intensify soil degradation processes.

In the mid-2000s, as a result of socio-economic changes and government policies, there was a growing interest on the part of agricultural producers and landowners in adopting forestry and agroforestry systems. Although this meant an increase in the area occupied with FFS, it was determined that the maintenance and management of most of these systems are deficient, since producers have little knowledge on the subject, often do not have clear objectives of the forestry component in the production unit and do not use technical advice (Guerra, 2021).

In this context, Fundación Danac consolidated the LMT the "Multi-species Agroforestry Forest", which is a biophysical unit of environmental conservation and agroforestry production designed to recover agricultural soils with severe limitations, major restrictions for crops and conservation needs. In addition, the production unit socializes the knowledge generated on the management of small and medium agroforestry systems applying economic, environmental, and social criteria. Currently, the Multi-species Agroforestry Forest has 73 Agroforestry Validation and Productive Demonstration Plots and 10 Conservation Plots for soil, water, and agroforestry phylogenetic resources (Guerra, 2021).

Are there other land use developments that compete with the expansion of the LMT, and if so, how do those affect the scaling-up of the LMTs?

The region where the LMT is located in a rural territory designated for agricultural production in the national land-use plan. There is currently no population pressure or competition from other productive activities. According to Guerra, (2021) the LMT does not have and should not have problems maintaining its continuity in the short, medium, and long term. Consequently, the scaling up of LMT within the LANDMARC context is positive and without limitations, as long as balanced governance is maintained, and the bioethical and eco-sociological precepts of Sustainable Rural Development are preserved.

5.1.4. Climate risks & sensitivities

In the First National Communication on Climate Change in Venezuela, climate type patterns were estimated according to Thornthwaite for the temperature and precipitation variables. According to the estimates suggested by the models, it is predicted that the LMT will be most affected by the following climatic events: heat waves, pronounced droughts, forest fires and an increase, or change in climate variability. It is estimated that the most likely future climate for Venezuela will be drier and hotter than the current climate, although precipitation could increase locally. Figure 5 shows the territorial distribution of climate types in the future, according to the two models run for the Intermediate Climate Scenario. It can be observed that at present, practically all the northern area of the country (with some exceptions) presents the three dry climate types (arid, semi-arid and dry sub-humid), which the United Nations Convention to Combat Desertification and Drought considers as critical climates. Consequently, the future climate in the medium and long term will be drier; therefore, it is necessary to optimize food production strategies based on the intensive use of open field lands, being agroforestry systems the ones that will provide greater resilience to climate variability and change.

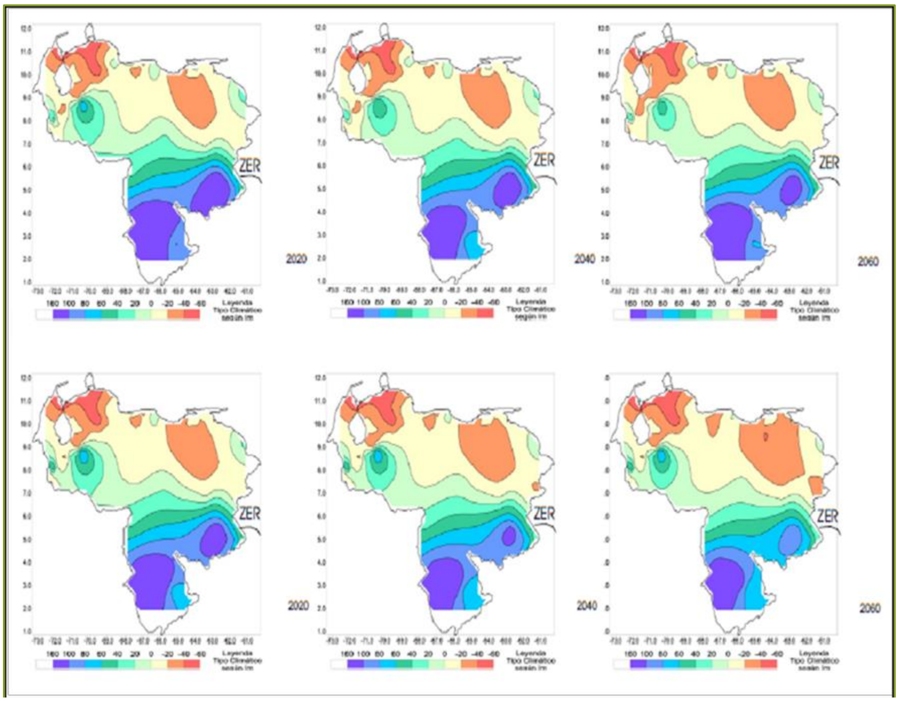

Figure 18. Territorial distribution of climate types in the future, according to the two models run for the Intermediate Climate Scenario

5.1.5. Economic implications

Venezuela's national accounts do not consider the environmental goods and services provided by nature. The sylvopastoril LMT *per se* is already economically competitive because it incorporates the environmental sustainability component in all activities. It is estimated that it will be even more competitive when the value of ecosystem benefits is included in the financial and/or economic analysis compared to other forms of land use. Nevertheless, the DANAC Foundation has been implementing technologies based on nature and good land use, such as agroforestry systems and agriculture, for more than twenty years.

In this context, in 2015, Escalante and Guerra presented a review of the successful agroforestry Taungya systems in DANAC Fundation Venezuela that include those in which short-cycle and semi-annual crops such as plantain (*Musa* spp.), quinchoncho (*Cajanus cajan*), and other species have been interspersed within high commercial value timber plantations during the first two years, in order to improve soil fertility, control weeds, produce food for the communities involved, and provide an additional income that makes up for the initial investment in forest plantations. Taungya systems significantly reduce the costs of establishing plantations in the first years and improve the financial performance of the investment in wood, since several years must pass before obtaining economic benefits. These avoided costs at the beginning of the forest plantation are very important for the financial performance of the system.

5.1.6. Co-benefits and trade-offs

What are the risks (negative side-effects) or co-benefits (positive side-effects) of the LMT:

Aspect	Negative effect	Positive effect
Agricultural production	In some cases, there will be a reduction in production and annual financial profit from monoculture.	Sustainable: Natural elements are maintained in the long term for future harvests (water, soil, biodiversity, soil carbon, soil macro and microbiota).
Landscape	None	With agroforestry diversification, the landscape will be more protected, more attractive and more pleasing to the eye.
Biodiversity	None	Increased plant biodiversity, resulting in a greater number of niches, livelihoods and refuges for wildlife.
Nitrogen emissions	Reduced	Very low or almost nil because there is no enteric fermentation or discharge of the livestock component.
Water quality	None	Water quality will be improved by substantially reducing erosion and eliminating leaching from polluting discharges.

Are there any other risks /co-benefits as part of the LMT implementation?

No other risks are foreseen for the moment, but there are many co-benefits associated with the sustainability of the productive systems due to the addition of carbon. Likewise, there will be new income from the commercialization of timber, as the trees will be reaching the cutting age.

Could you discuss the trade-offs of the LMT?

As the plantations are dedicated to carbon storage, the opportunity cost increases. As a consequence, as the decision is made to have less aggressive strategies for fuelwood production and, at the same time, the forest or plantation is maintained for carbon storage, a greater amount of income from the commercial timber activity is foregone and a greater amount of carbon storage is obtained, due to the tradeoff that exists between harvesting for carbon storage or fuelwood production (Merchán & De Freitas 2006).

The LMT will be prepared to exchange technical and scientific information, goods and services such as the sale of seeds and other inputs, consultancy, technologies and, in the medium term, it is expected to obtain income from the exchange of CO2 credits or bonuses as soon as the Venezuelan government incorporates into the national environmental policy the entry into the global carbon offset market.

5.1.7. Risks associated with scaling up

The main risks are socioeconomic, associated with changes in government public policies that may affect the operation of the DANAC Foundation. At the local level, there are no problems of scale due to the solid governance relationships of the LMT with the local actors, directly and indirectly, involved with it (since the beginning of its foundation), which has materialized in an excellent and harmonious community relationship - business.

5.1.8. Research gaps

This LMT has been a pioneer in setting the standard for the generation of the administrative, technological and methodological instruments necessary to be drafted to contribute to the design of a private enterprise approach to Agroforestry LMT in Venezuela. Comparative studies are required with other regions of the country to accomplish this goal.

6. Conclusions

Venezuela offers a rich range of opportunities for developing and implementing LMTs within the framework of NETP. Some of the major key points to achieve progress in the LMTs application in Venezuela are: a) the diversity of ecosystems, b) its status as a tropical country that favours the development of forests with a high capacity for carbon fixation and storage, c) the value of the traditional practices of local populations and human resources of the technical and academic sector. Additionally, the Venezuelan legal frame, starting with the National Constitution, indicates the state's obligation to promote public participation and consult the citizens regarding public policies. In spite of these good intentions, in most cases, these processes have historically, confronted significant barriers that limited relevant knowledge shared co-creation and solutions implementation. The analysis of several experiences revealed that top-down initiatives are prone to fail when public institutions lack efficient organisational mechanisms or continuity in their policies to lead and execute these processes until its completion. In contrast, bottom-up experiences or intercultural approaches conducted by local communities, supported by academics, collective organisations and official or private sectors showed promissory capabilities and positive results. This strategy provides more opportunities to build up safe spaces for the coproduction of knowledge by enhancing the inter-sectorial interactions required for the successful adoption of sustainable LMTs.

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8. ANNEX 1

INTERNATIONAL AGREEMENTS LEGALLY APPROVED IN VENEZUELA ON CLIMATE CHANGE

INSTRUMENTO JURÍDICO	OBJETIVO	FECHA Y LUGAR DE LA FIRMA	GACETA OFICIAL
Acuerdo de París Proyecto de resolución remitido a la cumbre de las Naciones Unidas para la aprobación de la agenda para el desarrollo después de 2015 por la Asamblea General en su sexagésimo noveno período de sesiones	Transformar nuestro mundo: la Agenda 2030 para el Desarrollo Sostenible Erradicar la pobreza Mantener el aumento de la temperatura media mundial muy por debajo de 2ºC con respecto a los niveles preindustriales	París 2015	30/12/2015 N° 40.819
Convenio de Estocolmo sobre Contaminantes Orgánicos Persistentes	Proteger integralmente la salud humana y el medio ambiente frente a los contaminantes orgánicos persistentes, de conformidad con el principio de precautoriedad estipulado en el principio 15 de la Declaración de Río	Estocolmo 23-05-2001	03-01-2005 N° 38.098 (Véase N° 5.754 Ext. misma fecha)
Ley Aprobatoria del **Protocolo de Kyoto** de la Convención Marco de las Naciones Unidas sobre el Cambio Climático	Comprometer a los Estados a implementar medidas tendentes a limitar y reducir las emisiones de Dióxido de Carbono y de gases de efecto invernadero a un nivel inferior al 5% del total de emisiones de esos gases para 1990, para el período comprendido entre el 2008-2012	Kyoto, Japón. 1997 del 22 JUL 2004	Asamblea Nacional 07-12-2004 N° 38.081
Convenio sobre el Procedimiento de Consentimiento Fundamentado Previo aplicable a ciertos Plaguicidas y Productos Químicos Peligrosos objeto de Comercio Internacional (Convenio de Rotterdam)	Promover la responsabilidad compartida y los esfuerzos conjuntos de las Partes Contratantes en la esfera del comercio internacional de ciertos productos químicos peligrosos, facilitando el intercambio de información acerca de sus características, estableciendo un proceso nacional de adopción de decisiones sobre su importación y exportación y difundiendo esas decisiones a las Partes		22-12-2004 N° 38.092
Enmienda de Montreal del Protocolo de Montreal	Establece la obligación de crear un sistema de licencias dirigido a reducir el tráfico ilegal de las sustancias que permita controlar el ingreso y egreso; así como el origen y destino de las mismas	Montreal 17-09-1997	12-06-2001 N° 32.217
Convención Internacional de Lucha contra la Desertificación	Prevención o reducción de la degradación de las tierras, rehabilitación y recuperación de las tierras degradadas.		N° 5.239 23-06-98
Enmienda de Copenhague del Protocolo de Montreal	Establece la ampliación de la lista de sustancias controladas y un nuevo calendario de eliminación para los países desarrollados y en vías de desarrollo	Copenhague 25-11-1992	04-11-1997 N° 5.180
Protocolo relativo a las áreas de flora y fauna silvestre especialmente protegidas (SPAW)	Conservación y preservación de especies raras, endémicas y en peligro de extinción		N° 36.110 18-12-1996
Convenio Marco de las Naciones Unidas sobre el Cambio Climático	Lograr la estabilización de las concentraciones de gases de efecto invernadero en la atmósfera a un nivel que impida la interferencia antropogénica peligrosa con el clima	Río de Janeiro 13-06-1992	27-12-1994 N° 4.825
Convenio Internacional de las Maderas Tropicales	Construir un marco eficaz de cooperación y consulta entre los países productores y consumidores de maderas tropicales; así como estimular la investigación y alentar el desarrollo de políticas de protección sostenible y conservación de los bosques tropicales y sus recursos genéticos	Ginebra 18-11-1983 Nueva York 26-01-1994	01-02-1994 N° 4.686 Ext. 05-12-1997 N° 5.187.
Convenio sobre la Diversidad Biológica	Conservar y preservar el máximo posible de diversidad biológica en beneficio de las generaciones presentes y futuras	Río de Janeiro 12-06-1992	12-09-1994 N° 4.780
Enmienda de Londres del Protocolo de Montreal	Establece el calendario de eliminación y crea el Fondo Multilateral del Protocolo de Montreal para cooperar con los países en desarrollo en la reconversión industrial y tecnológica	Londres 29-06-1990	21-05-1993 N° 4.580
Convención sobre la Protección del Patrimonio Mundial, Cultural y Natural de la UNESCO	Establecer un sistema eficaz de protección colectiva del patrimonio cultural y natural de valor excepcional organizado de una manera permanente y según sentido científico moderno	París 23-11-1972	06-07-1990 N° 4.191

INTERNATIONAL AGREEMENTS LEGALLY APPROVED IN VENEZUELA ON CLIMATE CHANGE

INSTRUMENTO JURÍDICO	OBJETIVO	FECHA Y LUGAR DE LA FIRMA	GACETA OFICIAL
Protocolo de Montreal relativo a las Sustancias Agotadoras de la Capa de Ozono	Proteger la capa de ozono adoptando medidas preventivas para controlar las emisiones mundiales de las sustancias que la agotan	Montreal 16-09-1987 Ajustes Londres 26-09-1990 07-03-1991	11-01-1989 N° 34.134
Convenio sobre el Comercio Internacional de Especies Amenazadas de la Fauna y Flora Silvestres (CITES)	Proteger ciertas especies de animales y vegetales que se encuentran en Peligro de Extinción Acordar medidas para proteger las especies mediante el control del comercio internacional	Washington 03-03-1973	29-06-1977 N° 2.053
Convención para la Protección de la Flora, la Fauna y de las Bellezas Escénicas Naturales de los Países de América	Establecer un sistema de protección en los países de América para la flora, fauna y medio ambiente de sus entornos	Washington 12-10-1940	13-11-1941 N° 20.643

ANNEX 2

LIST OF STAKEHOLDERS INTERVIEWED BY LANDMARC-VENEZUELA			
NAME	**POSITION**	**INSTITUTION**	**CONTACT INFORMATION**
Lic. Efrain Enrique León Cornivell	Director de Fiscalización y Control de Impactos Ambientales	Ministerio de Ecosocialismo (MINEC), Caracas, Venezuela	Phone: +58 424 2994667 eelcguitar6@gmail.com
Dr. Carlos Méndez	Jefe del Centro de Ecología y Ciencias Ambientales (IVIC) Jefe del Laboratorio de Ecosistema y Cambio Global (IVIC) Vice-Presidente del Grupo de Trabajo II del IPCC sobre Impactos, Adaptaciòn, Vulnerabilidad Miembro del Advisory Board del Proyecto LANDMARC Coordinador General del Capítulo II: Inventario Nacional de Gases Efecto Invernadero, de la II Comunicación Nacional de Venezuela ante la Convención Marco de las Naciones Unidas sobre Cambio Climático, Venezuela	Instituto Venezolano de Investigaciones Científicas (IVIC), Caracas, Venezuela	Phone: +58 416 2079763 / +58 212 504 1246 carlos.menvall@gmail.com
Dr. Roberto Rivera-Lombardi	Docente e Investigador activo del Instituto de Geografia de la UCV. Ex Director de Protección y Control de Incendios Forestales (2014-2015). Colabora desde el 2019 con el Núcleo de Investigación y Monitoreo de PREVFOGO Brazil. 20 años de experiencia en teledetección del fuego y estimación de las emisiones resultantes.	Universidad Central de Venezuela (UCV), Caracas, Venezuela Ministerio de Ecosocialismo (MINEC), Caracas, Venezuela Centro Nacional de Combate y Prevención de Incendios Forestales, Brasilia, Brazil	Phone: +55 84 9833 5441 robertoriveralombardi@gmail.com
Cnel (B) Miguel Matany Luque	Primer Comandante del Cuerpo de Bomberos Forestales (INPARQUES).	Instituto Nacional de Parques (INPARQUES)/ Ministerio de	

		Ecosocialismo (MINEC), Caracas, Venezuela	+58 424 1356063 / +58 426 3110496 mmatanyl172@gmail.com
Dra. Mirian Díaz de Arends	Presidenta de la ONG INFALCOSTA. Profesora Titular jubilada de la UNEFM.	ONG INFALCOSTA, Coro, Edo. Falcón, Venezuela Universidad Experimental Francisco de Miranda (UNEFM), Coro, Edo. Falcón, Venezuela	mdiaz541@gmail.com
Dra. Àngela Martino	Profesora Asociada activa de la UNEFM, Investigadora activa del CIEZA	Universidad Experimental Francisco de Miranda (UNEFM), Coro, Edo. Falcón, Venezuela Centro deInvestigaciones en Ecologìa y Zonas Âridas (Cieza), Coro, Edo. Falcón, Venezuela	amg.martino@gmail.com
Ing. Alvaro Guerra	Analista de procesos. Coordinador de sistemas de Gestión de calidad y sistemas Agroforestales de DANAC	Fundación DANAC, San Felipe, Edo. Yaracuy, Venezuela	alvaro.guerra@danac.org.ve

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ANNEX III

OVERVIEW OF INPUT TABLES FOR SIMULATION MODELLING PER COUNTRY

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13.Venezuela

13.1. Qualitative storylines by identifying measures and actions from interviews for each LMT scenario

Venezuela LMT 1: Integrated fire management (IFM) with an Intercultural vision (which considers local knowledge and participation of Indigenous populations and local communities).

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1: "IFM Policies at the National Level with an intercultural vision" (more optimistic) **Stakeholder representations:** Indigenous peoples, Local communities, Academia, environmental NGOs, INPARQUES (Acronym in Spanish for National Institute of Parks), Forest Fire Department, Ministry of Eco-socialism, Hydroelectric Company, private sector (forestry services)	1. Development of a plan and a new law about IFM Policies at the National Level with an intercultural vision by 2030 that replace the actual Fire Suppression Policies. 2. Training of new brigades from Forest Fire Department with and holistic formation integrating academic, technical, and local knowledge - cultural heritage, and considering human and ecological dimensions of fire in socio-ecological systems (SES). 3. Include indigenous local communities at all hierarchical levels of decision-making and implementation of these	• International funds for (1) and (2) (e.g., Green Fund), and the government pays for implementation (3). • Bottom-up IFM implementation (including Indigenous peoples and Local communities at all stages of the process)	• Permanent National Working Group on Integrated Fire Management in Venezuela (Grupo de Trabajo MIF-VEN, created under the LANDMARC project) conformed by academics, INPARQUES, Forest Fire Department Coordinators, the Director of Forest Fires of the Ministry of Ecosocialism, National Coordinator of Fire Specialties, National General Directorate of Firefighters (DGNB), Ministry of Interior Affairs, Justice and Peace. • Design and proposal development of a new plan and law about about IFM Policies at the National Level with an

	policies. Promote local governance.		intercultural vision (together with IP and LC) by 2030 that replace the actual Fire Suppression Policies.
Scenario 2: "IFM ghost policies" **Stakeholder representations**: Indigenous peoples, Local communities, Academia, environmental NGOs, INPARQUES (Acronym in Spanish for National Institute of Parks), Forest Fire Department, Ministry of Eco-socialism, Hydroelectric Company, private sector (forestry services)	1. Development of a plan and a new law about IFM Policies at the National Level with an intercultural vision by 2030 that replace the actual Fire Suppression Policies. 2. There are no implementation actions, nor monitoring of IFM plans. Weak relationship between IPs, LCs and government and academic members.	• International funds for (1) and (2) (e.g., Green Fund), but the government does not invest for implementation for the new policies (~~3~~). • Limited IFM implementation and participation of Indigenous peoples and Local communities at all stages of the process.	• Efforts of the National Working Group on Integrated Fire Management in Venezuela (MIF-VEN) unsuccessful for the acceptance of the proposal and implementation of the IFM law.
Scenario 3: "Exclusion - as usual - policies" **Stakeholder representations**: Indigenous peoples, Local communities, Academia, environmental NGOs, INPARQUES (Acronym in Spanish for National Institute of Parks), Forest Fire Department, Ministry of Eco-socialism, Hydroelectric Company, private sector (forestry services)	1. The design of new IFM policies is not achieved and fire suppression policies continue as yore. 2. The traditional practices of the use of fire by IP and LC continue to be prohibited (excluded), and large fires of great magnitude occur due to climate change (fire climate due to great drought, high temperatures and heat waves).	• There is no investment of international funds, and governments maintain fire exclusion policies (although without funds for combat or the implementation of new IFM programs), or • Government asks for loans to equip with high and expensive fire suppression technologies (and increases state indebtedness), or • Government diverts international funds granted to MFIs with local	• Dissolution of the National Working Group on Integrated Fire Management in Venezuela (MIF-VEN). • No formulations of new MFI policies are made. • Restrictions and implementation by the use of fire by IP and CL are accentuated.

		participation, for other programs (or the funds disappear).	

13.2. Quantitative storylines: pace of implementation for each LMT

	Current situation (baseline)	SCENE- 1"IFM Policies at the National Level with an intercultural vision" **SH perspective:** Indigenous peoples, Local communities, Academia. environmental NGOs, INPARQUES (Acronym in Spanish for National Institute of Parks), Forest Fire Department, Ministry of Eco-socialism, Hydroelectric Company, private sector (forestry services)		SCEN- 2"IFM ghost policies" **SH perspective:** Indigenous peoples, Local communities, Academia. environmental NGOs, INPARQUES (Acronym in Spanish for National Institute of Parks), Forest Fire Department, Ministry of Eco-socialism, Hydroelectric Company, private sector (forestry services)		SCEN- 3": "Exclusion - as usual - policies" **SH perspective:** Indigenous peoples, Local communities, Academia. environmental NGOs, INPARQUES (Acronym in Spanish for National Institute of Parks), Forest Fire Department, Ministry of Eco-socialism, Hydroelectric Company, private sector (forestry services)	
Year	Now (Provide sources)	2030 (Change relative to the current situation) (Provide sources)	2050 (Change relative to the current situation) (Provide sources)	2030 (Change relative to the current situation) (Provide sources)	2050 (Change relative to the current situation) (Provide sources)	2030 (Change relative to the current situation) (Provide sources)	2050 (Change relative to the current situation) (Provide sources)
LMT 1: Integrated fire management (IFM) with an Intercultural	Excluding Protected areas (PA) and Indigenous territories (IT) or areas where local	50% of wildfires [5]. The implementation of IFM programme, in savanna areas of Brazil, achieved	Lipsett-Moore et al. [10] estimated a 74% emission	Similar to the current situation, with increases in the trend of	Similar to the current situation, with higher increases in the	Increase of wildfire occurrence with respect to the current situation	Increase of wildfire occurrence with respect to the 2030 situation

vision (which considers local knowledge and participation of Indigenous populations and local communities).	management is allowed, Venezuela shows an increase in its trends of wildfire incidence due to the initial implementation of IFM policies, land use changes and an increase of fire weather (due to climate change). [1],[2], [3], [4]	a 17% reduction in total burned area (from 13766 km2 to 11449 km2), during 2013-2018, in comparison to the previous 5 years (2007-2012), and an estimated abatement potential of 1.71 $MtCO_2e$ of non-CO_2 GHG over six years (0.29 $MtCO_2e\ y^{-1}$) [6],[7]. According to Australian experience, shifting the fire regime from an average of 7.6% of area burned early and 32% of area burned late to an average of 20.9% burned early and 10.9% burned late, the fire managers achieved a mean annual emissions reduction of 37.7% (116,968 tCO_2e), relative to the baseline, over the first 7 years of operations [8],[9].	potential, 89.3 Mt $CO_2e\ y^{-1}$ global emissions reductions of the late dry season uncontrolled wildfires through early dry season burning considering 37 countries, including Africa, South America and Australia. .	wildfires, but with more reduced wildfire incidence in IT and PA, where local fire management is allowed) [1] [2] [3], [4]	trend of wildfires, but with more reduced wildfire incidence in IT and PA, where local fire management is allowed [1] [2] [3], [4].	(globally by a factor of 1.08 to 1.4 in the year 2030 [11]), promoted by more intense "fire weather" (under more severe climate change conditions than present), and suppression policies (that promotes fuel accumulation and limit or prohibit use local fire management, and loss of traditional local fire knowledge) [1] [3], [11], [12].	(globally by a factor of 1.21 to 1.27 in the year 2050, and by a factor of 1.3 to 1.57 in the year 2100 [11]), promoted by more intense "fire hazard weather" (under more severe climate change conditions than 2030*), and suppression policies (that promotes fuel accumulation, limit or prohibit use local fire management and loss of traditional local fire knowledge) [1] [3], [11], [12].

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