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REPORT

CO

2014

Sustainability | Land Use | Bioenergy

Identifying Highly Biodiverse Savannas based on the European Union Renewable Energy Directive (SuLu Map)

Conceptual background and technical guidance

About this report

Publisher WWF Colombia
Publication date June 2014
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Supported by:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

4D Elements Consultores

Executive Summary

There is growing recognition that decisions about land use can have profound implications for climate change, biodiversity, and poverty. Increasing global demand for agricultural commodities of all sorts is driving conversion of natural habitats to agricultural production. This process, if adequately planned and implemented, can provide incomes and contribute to development and poverty reduction. However, when done badly, it can result in massive GHG emissions, loss of biodiversity, and social inequity. This issue has been central to the current debate about the production and use of biomass.

The main challenge is to achieve sustainable production. This means eliminating further loss of biodiversity, reducing GHG emissions, and minimising the negative impacts of direct and indirect land use changes. The pressures on land are high, therefore critical conservation priorities including biodiversity, ecosystems, and areas critical for rural livelihoods must be identified, and methods of preservation found. Consistent tools recognised by government and industry need to be used ahead of the transformation of existing landscapes for biofuel, food, and feed production. This is crucial for improving social conditions and reducing competition between food and biomass production.

In light of the above, a project was formed titled “Balancing Spatial Planning, Sustainable Biomass Production, and Conservation – A Practical Multi-Stakeholder Approach to Spatial Planning for Climate Mitigation” (shortened to Sustainable Land Use – SuLu). It is an initiative led by WWF with the support of the German Ministry of Environment (German: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMU), and has been implemented in three countries – Colombia, Brazil, and Indonesia. The main goal of the project is the reduction of both GHG emissions and loss of biodiversity due to land use change caused by biomass production.

This initiative incorporated, as a reference axis, the Directive 2009/28/EC of the European Parliament and Council (EU RED), which establishes a framework for the promotion of energy from renewable sources. It determined that for import and consumption of biofuels, only those would be considered that do not come from transformation of land with high biodiversity value or high carbon stocks. It is here that, besides forested areas, protected natural areas and peatlands, wetlands and highly biodiverse savannas, are also included.

In that sense, the implementation of the SuLu project in Colombia aims to develop or adapt methodologies and tools to identify highly biodiverse savannas[1] as ‘no-go’ areas according to EU RED.

1 *In this study, the term savannas is used as a synonym for tropical grasslands, because it is the predominant ecosystem in the Orinoco region, and it best characterises the ecological processes and dynamics between different land covers in the Llanos ecoregion also.*

Project Region

Located in the eastern part of the country, the total study area in the Colombian Orinoco is 17,903,559 ha (15.7 % of mainland Colombia). The limits are marked by the Arauca, Meta, and Orinoco rivers, which form natural boundaries with Venezuela. The southern part is delimited by the transition between the Amazon and savannas, and the eastern part is delimited by the 1,000-metre altitude line along the foothills of the eastern Andes.

The Orinoco basin has 71 % of the country's swamp water. It hosts the largest population of mammals in the country with 167 species (Alberico *et al.*, 2000), including 26 that are threatened. It is also home to 783 species of birds (McNish, 2007), 658 fish species (Maldonado–Ocampo *et al.*, 2008 in Maldonado *et al.* 2009), as well as 2,692 flowering plant species (Rangel-Ch. 2006).

In recent years the Orinoco region has become increasingly threatened by the disorderly expansion of agroindustry, cattle ranching, and the oil industry, and is now seen as a 'new agricultural frontier' for development. This is based on a drive to internationalise the economy and a common misunderstanding that the region is of low ecological importance (Correa *et al.* 2006).

The Orinoco basin represents an important opportunity for conservation. It currently has a comparatively low level of conservation land (4 %), holds significant biodiversity value, and has unique water and carbon dynamics. The region presently lacks an integrated sustainable development plan, where the trade-offs between economic developments are balanced with ecosystem services and functions.

Methodology

As part of measures to achieve sustainable agriculture in the Llanos region, the SuLu project aims to develop a framework combining the EU RED standards, the High Conservation Value concept, and the Systematic Conservation Planning approach, in order to guarantee that all datasets available are taken into consideration and that the precautionary principle can be applied in the most optimal way.

The construction of a sustainable land use map (Sulu Map) is based on a decision tree for the regional allocation of biodiversity and carbon levels (Figure 1). The methodological approach's entry point is article 17 of EU RED, where high biodiversity values and high carbon stocks are defined as the main criteria to identify areas for sustainable bioenergy production, so that primary forest, other forested areas, and designated protected areas are excluded from conversion. The land use categories were selected from the CORINE land cover map made using remote sensors in accordance with the EU RED baseline – January 2008.

The framework for the construction of the map consists of three categories. Firstly, there are those areas that are qualified as 'no-go', in which conversion to agricultural use for bioenergy is not acceptable at any time. Such use is also restricted by Colombian regulations and covers the land categories described in the EU RED. Within the 'no-go' areas other land uses are: forests, wetlands, and protected areas, as well as highly biodiverse grassland and those containing high carbon stocks (measured as GHG emission savings comparing biofuel to 'regular' fuel[2]).

2 *See EU RED Art. 17 (2)*

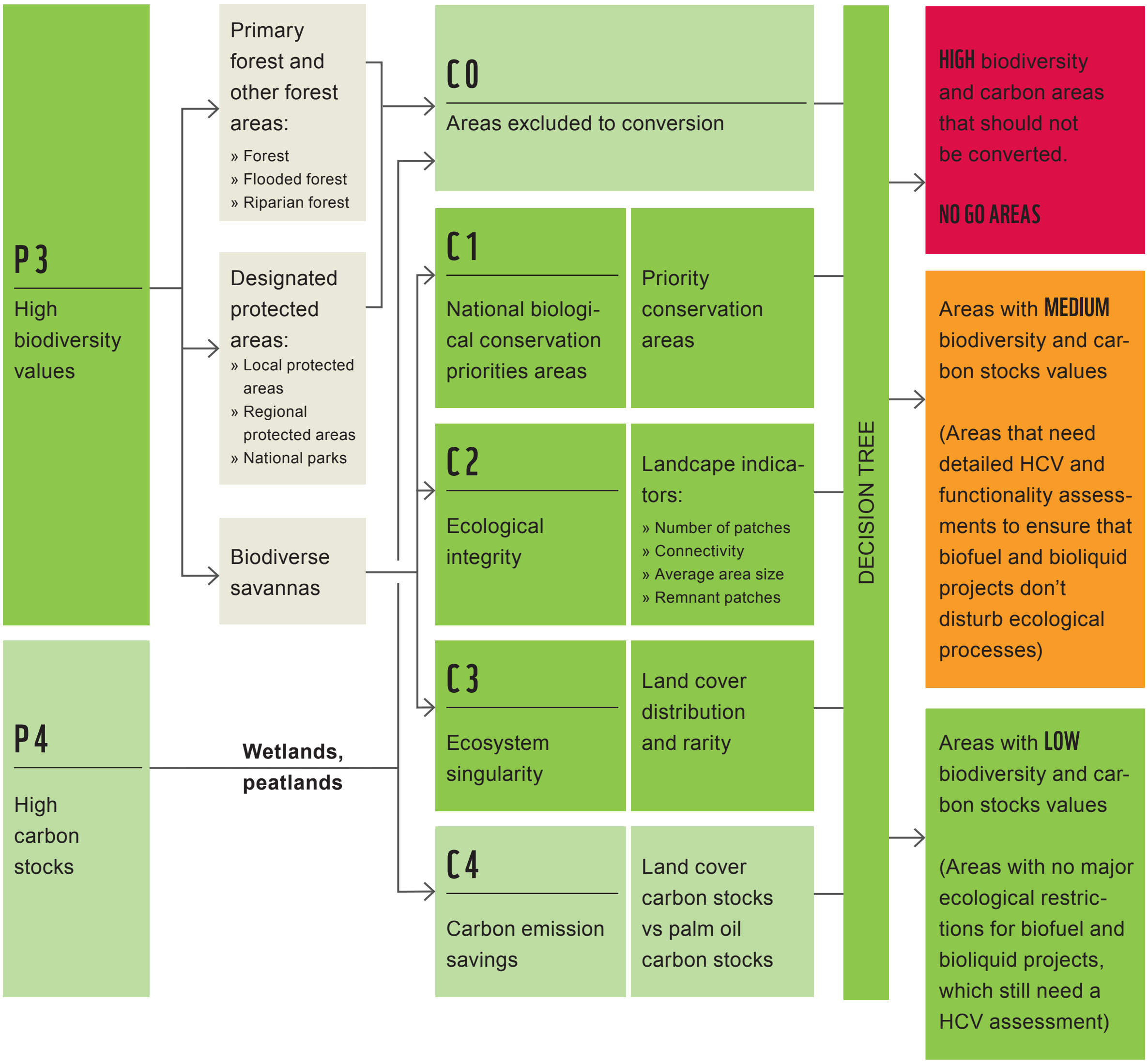

Figure 1.
Methodological flow chart

The second category in the framework concerns areas with good ecological integrity but with some signs of human intervention, and with evidence of significant conservation needs, in which special ecological considerations must be taken into account to keep processes functional. For this reason a detailed analysis of 'High Conservation Values' (HCV) are required as well as a connectivity assessment to guarantee the preservation of conservation objectives and natural processes.

The third class describes areas with an already high conversion rate, where most of the native biodiversity and carbon stocks have already been converted. A basic site assessment following the HCV method (or an equivalent one) needs to be applied to determine whether this land is an acceptable site for sustainable cultivation of agricultural production for biofuels/bioliquids. This is for two reasons. Firstly, mapping exercises can produce scenarios where biodiversity and carbon stock values are likely to be highest, but sometimes fail to identify smaller discontinuous areas of value. Secondly, cultural and social values of land are not identified through a mapping process, but through a canvassing of the area gathering information from the local inhabitants. Such values are currently not covered by existing EU RED sustainability criteria.

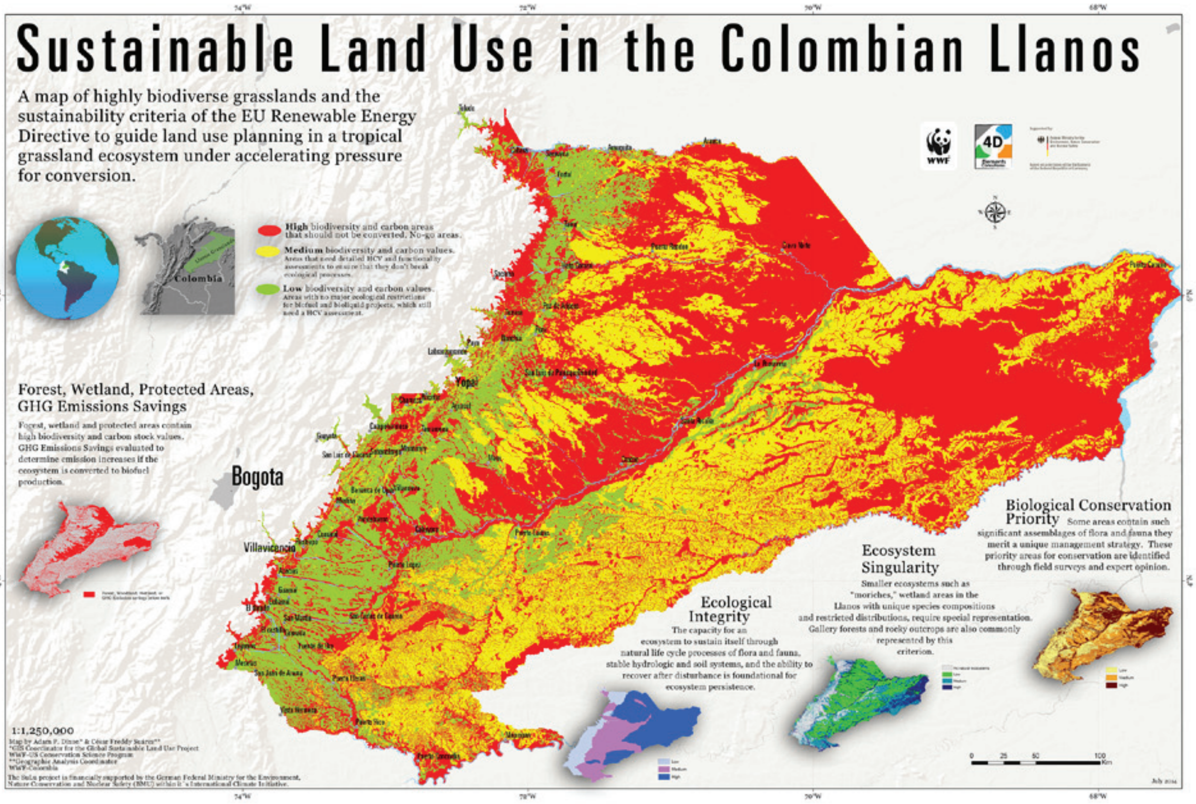

Figure 2.
Map of biodiversity and carbon values for the Llanos region based on EU RED (SuLu map).

In terms of biodiversity value the SuLu approach is based on different methods, developed for the identification of priority areas for conservation (Biocolombia – UAESPNN 1991; Fandiño & Van Wyngaarden 2005; Galindo *et al.* 2007; Corzo 2008; Lasso *et al.* 2010; Usma & Trujillo 2011; amongst others), and the concept of High Conservation Values (HCV) recently implemented in South America (WWF 2007; Santivanes & Mostacedo 2008; Martinez-Ortiz 2007) and Colombia (Usma & Trujillo 2011; Otero-Garcia 2010; Bustamante 2010). This methodology, which is based on the identification, management, and maintenance of the HCV at local scales, was created for the requirements of forest certification as a commercial alternative for forest products (Forest Stewardship Council – FSC and Proforest 2003).

However in Colombia, with the recognition of the implications of land use change issues on regional scales – effects on climate, biodiversity loss, poverty, and other negative effects due to improper use – the need is proven to develop methodologies for the management of other areas of conservation besides forests, like wetlands and savannas.

To this end, the Sustainable Land Use map (Figure 2) – created using spatial analysis methods based on conservation planning tools and concepts – includes three main criteria: biological significance, ecological integrity, and ecosystem uniqueness/singularity. To determine different levels of biodiverse savannas present in the Orinoco region they were reclassified in three levels – high, medium, and low. The highest level contains the 'no-go' areas.

Finally, after taking into account that biofuels can contribute to reducing carbon emissions, only if produced in a sustainable manner, land use categories such as wetlands and peatlands – well known as carbon sinks – are excluded from conversion. According to the parameters set forth in the EU RED regarding a minimum of at least 35 % emission savings compared to fossil fuel alternatives, the carbon stocks of the remaining areas were compared to their potential carbon stock if they were converted to oil palm (Lange, Suarez 2013, EU Biofuel Policies in Practice – A Carbon Map for the Llanos Orientales in Colombia).

After the integrated analysis, it was found that 50 % of the total area must be excluded from consideration for biofuel production, 34.3 % was identified as medium risk to sustainable land use, and 15.7 % was categorised as low risk to sustainable use.

Conclusions

The EU RED is one of the first policies recognising the importance of grassland conservation. The information obtained during the SuLu project shows significant progress in the methodology used to determine biodiverse savannas and high carbon stocks. While progress on carbon analysis has been successful in recent years, this has mostly only covered forest areas in Colombia. The method used for SuLu includes for the first time an approximation to the dynamics of carbon capture and storage for each identified land cover in the region and goes beyond this type of analysis, as it is also one of the first advances to incorporate more detailed variables, such as carbon in organic matter and soil. Nevertheless, further studies regarding carbon are strongly recommended.

We believe that the SuLu methodology can also be implemented in other areas. The indicators used have been implemented and verified and could easily be replicated in many studies worldwide. Flow charts associated with the mapping process explain the methodology in detail and can be adjusted when necessary (while maintaining the baseline without major modifications) to produce a final map of biodiverse savannas. Using it in other regions only requires setting the parameter values to locally applicable characteristics. The methodology developed to define biodiverse savannas can be used for all kinds of purposes and is not at all limited to bioenergy uses.

The sustainability criteria established by EU RED, and their interpretation in Colombia through the SuLu initiative, represent an opportunity to leverage national processes around Orinoco savannas and focus on the international market context. The Orinoco is a highly biodiverse, but highly threatened region due to increasing attention from the government and the private sector for the development of industrial agriculture, mining, and exploitation of hydrocarbons.

Sustainability criteria incorporated by EU RED regarding biomass production (bioenergy) will not be enough to conserve the biodiverse savannas. Most palm oil production in Colombia is still used for the domestic market and mainly for food (around 80 %), but it is also used for local bioenergy production that does not have the same sustainability criteria as the EU. However, the results of the SuLu initiative can help to enhance decision-making processes, with its inputs and results regarding land use planning disseminated not only within the oil palm sector, but also to key productive and extractive sectors, as well as to stakeholders involved in the land use planning process at various scales.

To promote sustainable land use planning, the technical products generated in the SuLu project were embedded into an outreach strategy with key institutional stakeholders[3] in charge of policy formulation, research, land planning, and productive sectors, as well as NGOs, universities, and civil society. This approach involved socialisation of the initiative, facilitation of information exchange, provision of technical support, continuous discussion throughout the whole project, and data sharing with decision makers as to how results might potentially be put to use. In addition, previous contextual analysis regarding legal land planning frameworks and drivers of land use change[4] at national and sub-regional level were developed.

Recommendations

Policy

It is important to disseminate these results in strategic institutional and policy contexts, in order to best encourage their use and adoption by competent authorities in relation to forming environmental and productive policy concerning land use planning processes. To this end, WWF will strengthen strategic alliances with research institutions and organisations such as the Humboldt Institute (National Biodiversity Institute), IDEAM, and others.

The Ministry of Environment and Sustainable Development as well as other relevant Ministries[5] need to discuss and agree on guidelines relating to export-oriented production planning. Given the infrastructure development stimulated by productive expansion in the region, it is also very important that the Ministry of Transportation incorporates these results as inputs in feasibility studies and subsequent infrastructure development planning in the region.

WWF recommends the SuLu results concerning biodiverse and carbon rich areas are included in the Conpes Document[6] for the High Plains Savannas 'Policy for inclusive and sustainable development of Colombian Altillanura', currently being formulated by the National Planning Department.[7]

The Biofuels Intersectoral Committee should also adopt sustainability criteria.

3 *Ministries of Environment and Sustainable Development, Agriculture and Rural Development, Mining and Energy, Infrastructure and transport, Commerce. Institute for Research on Biological Resources-Alexander von Humboldt, Geographic Institute – Agustín Codazzi, National Institute of Hydrology, Meteorology and Environmental Studies – Ideam-, National Natural Parks, Regional Environmental Authorities, Fedebiocombustibles (Colombian Federation of Biofuel Producers), Fedepalma, among others.*

4 *For more information see http://www.globallandusechange.org/mediacenter.html.*

5 *Ministry of Agriculture and Rural Development, Ministry of Mining and Energy, Ministry of Commerce, Industry and Tourism.*

6 *Policy Document formulated by the National Social and Political Economy Council of the National Planning Department of Colombia (Consejo Nacional de Política Económica y Social) lead by National Planning Department.*

7 *Política para el desarrollo incluyente y sostenible de la Altillanura colombiana.*

Land Use Planning Processes

The SuLu outputs provide different kinds of information applicable to different decision-making arenas. The results will be useful as technical inputs to Ministries, regional governments, regional environmental authorities (Corporinoquia and Cormacarena), as well as to municipalities, in order to strengthen policy formulation and the inclusion and adoption of key elements of biodiversity and carbon conservation in land use planning processes[8].

The Agricultural Planning Unit of the Ministry of Agriculture and Rural Development needs to agree on an action plan to disseminate the results and support its inclusion in the guidelines for credits and incentives. Furthermore, this strategy also applies to key instruments of Sector Planning Agencies (National Agency for Oil, National Agency for Mining, and National Agency for Infrastructure).

WWF will promote the inclusion of the SuLu results as sustainability criteria in the sector planning of Colombia to be incorporated by the National Federation of Biofuels Producers (Fedebiocombustibles), National Federation of Oil Palm Producers (Fedepalma), Association of Sugarcane Growers of Colombia (Asocaña), National Federation of Grains Growers (Fenalce), National Federation of Timber Industry (Fedemaderas), Productive Transformation Program, etc.

Technical considerations

To improve the identification of biodiverse savannas, WWF proposes to include the savannas ecosystem services as additional criteria, including their role in the carbon flux cycle, and regulation of fire dynamics.

Carbon stock data needs to be verified and validated through field work to better differentiate between land covers, as is the case for the calculation of above ground biomass or organic material in the soil.

Cartographic data should be processed in vector format rather than raster (although it increases the time required to process information), because it has a greater capacity for analysis, overlay operations are very simple, and data do not lose their characteristics when expanding the scale display or analysis. In addition, this format has greater compatibility in linking to external databases.

Based on these results it is necessary to continue working on a toolkit for the identification of High Conservation Values in savannas at the local scale. Local and site analysis results are more related to farm planning and certification schemes, and very often the direct decision maker is the owner of the land. It is both possible and feasible to promote the articulation between scales through the inclusion of technical results in the land planning instruments.

More information and details about the SuLu project can be found at www.globallandusechange.org

8 *Environmental Regional Authorities are responsible to determine environmental elements of the landscape that must be conserved or specially managed and establish them as key elements (determinantes ambientales in Spanish) that must be incorporated by Municipalities during Land planning instrument formulation (Planes de Ordenamiento Territorial – POT – in Spanish).*

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1 Introduction

The Llanos ecoregion and the foothills of the Colombian Orinoco as defined by Olson *et al.* (2001), are part of the great savanna biome, which covers about 15 million square kilometres worldwide and dominates half of the African continent, large parts of South America and Australia, and in smaller distributions in North America and Eurasia (Figure 3).

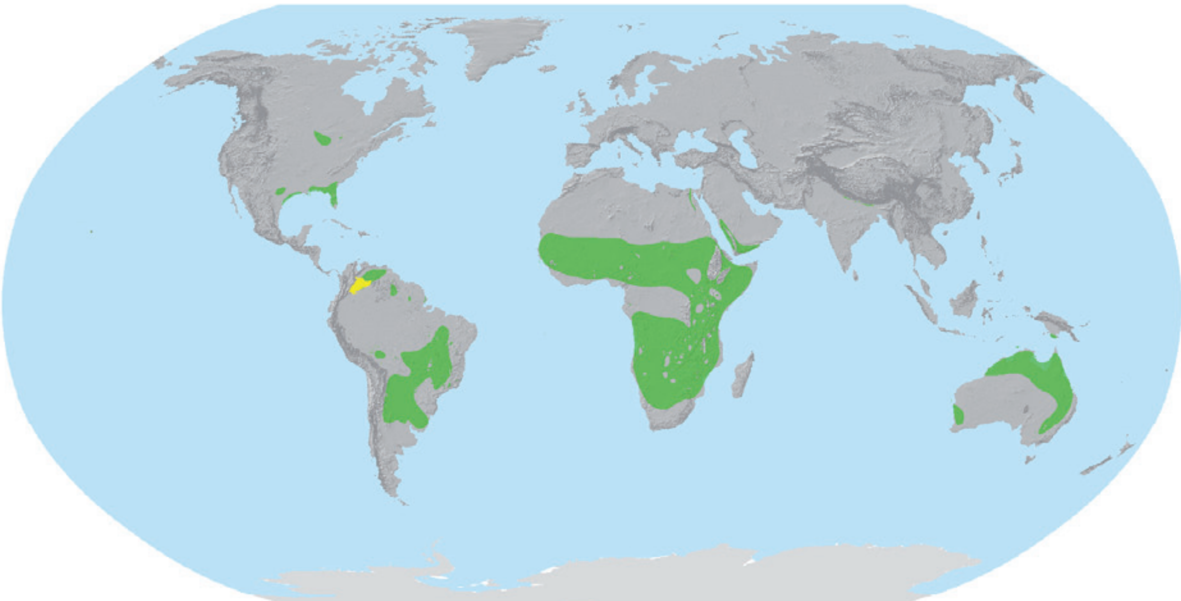


Figure 3.
Global distribution of savanna biome.

The Brazilian Cerrado ecoregion covers almost 76 % of the total area of savanna land in South America, the region of the Llanos between Colombia and Venezuela represents 11 %, the region of the Chaco between Bolivia and Paraguay covers 5 %, and the Guiana Shield the remaining 1.5 % (Sarmiento *et al.* 2002).

Savannas have been recognised globally as centres of high flora and fauna biodiversity (Scanlan 2002). In Colombia they are threatened by the intensification of agricultural production through the establishment of large-scale industrial agriculture and infrastructure projects – driven in the main by the internationalisation of the economy (Correa, Ruiz, & Arevalo 2006). Ecological impacts due to such land use change could result in soil degradation, loss of biodiversity, and impaired ecosystem functionality, thereby affecting the health of ecosystems and wildlife populations, which in turn impact the benefits humans receive from a healthy ecosystem. Degradation of the capacity of soils to sustain life is linked with climate change, increasing anthropogenic pressures, population growth, and the same activities due to land use changes (Critchley *et al.* 1992). Furthermore, authors like Goel & Norman (1992) have shown how the climate at different scales – from micro to global – becomes directly affected by land use change and inherent increases in greenhouse gas emissions. Over the last decade, the change in land use has been considered one of the main factors influencing global climate (Foley *et al.* 2005).

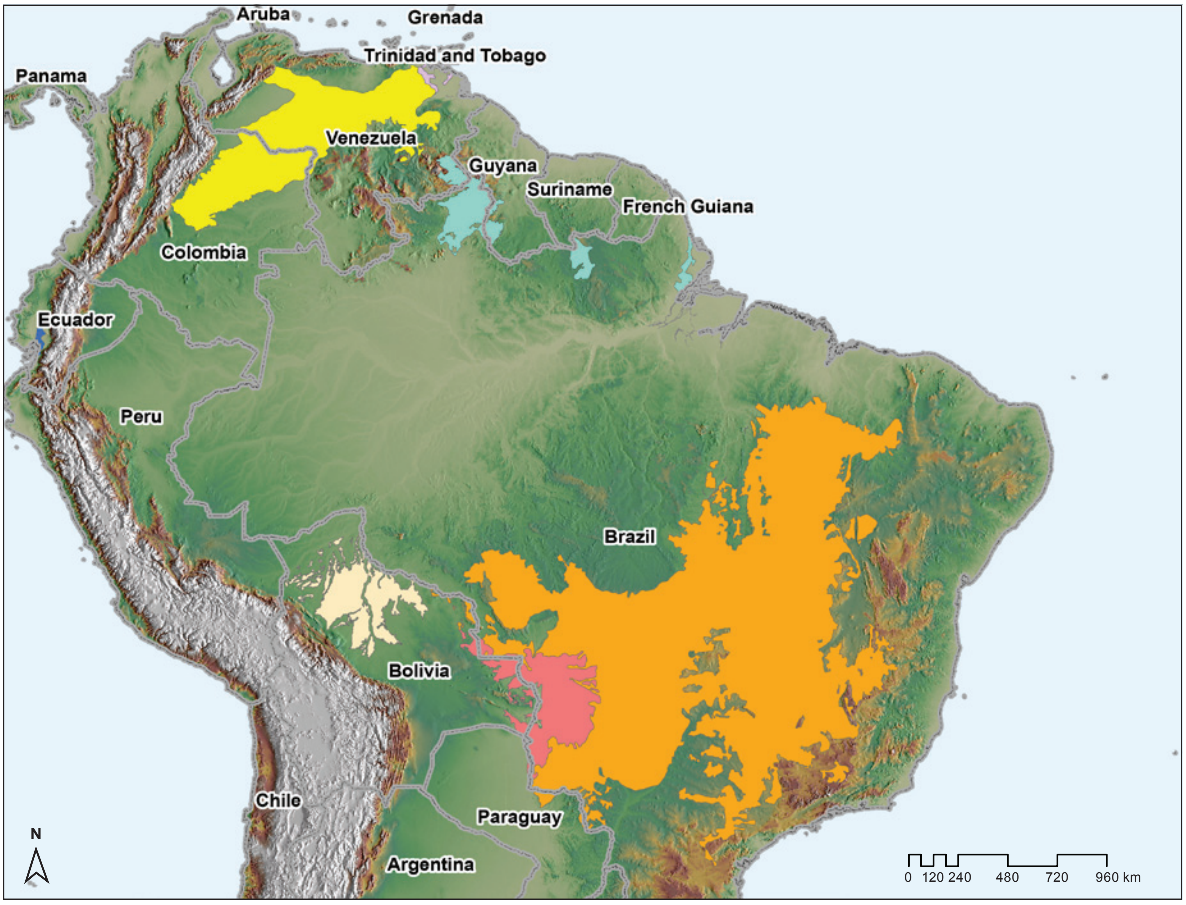


Figure 4.
Distribution of tropical, subtropical, flooded grasslands, savanna, and shrublands ecoregions in northern South America.

International Boundaries

Tropical, Subtropical, Flooded Grasslands, Savannas and Shrublands

- Beni Savanna
- Cerrado
- Guayaquil Flooded Grassland
- Guyanan Savanna
- Llanos
- Orinoco Wetland
- Pantanal

The change in land use due to deforestation has not only led to a serious loss of biodiversity and vital ecosystem services (such as soil and water integrity), but has also contributed substantially to increased emissions of greenhouse gases. Global deforestation and forest fires lead to the release of stored carbon into the atmosphere in the form of gas. It is currently estimated that in clearing tropical forests, between 90 and 160 tonnes of carbon per hectare is released (IPCC 1995; FAO 2007). Globally, the IPCC estimated in 2000 that deforestation is responsible for 20 % (2 billion tonnes) of CO_2 emissions into the atmosphere, while the Food and Agriculture Organisation estimated it to be 30 % (FAO 2007).

As part of efforts to reduce greenhouse gas emissions arising from land use changes, and to comply with the Kyoto Protocol of the United Nations Framework Convention on Climate Change, the European Union has been implementing a wide range of procedures to contribute to reducing emissions. Within these procedures, measurements have been developed that allow increased control of energy consumption in Europe, increased use of renewable energy sources, and improved energy savings and efficiency. For instance, the European Union Renewable Energy Directive (EU RED) requires that biofuels/bioliquids must be derived from sustainable agriculture. Although EU RED has provided standards to guarantee that those requirements be upheld, their application within the context of highly biodiverse grasslands have proven problematic and somewhat challenging to implement. Under this precept, the Colombian SuLu initiative proposes a definition of highly biodiverse savannas for use in planning in the Colombian Llanos.

To this end, the Sustainable Land Use (SuLu) initiative developed a map using spatial analysis to determine the different levels of risk changing land use presented to different levels of biodiversity and carbon stocks in the Orinoco region. The map was designed as a tool with which people can track and share evaluative information regarding whether agricultural production within a particular area is in compliance with the EU RED standards. The construction of a risk map is based on a decision tree for the regional allocation of risk (Figure 5).

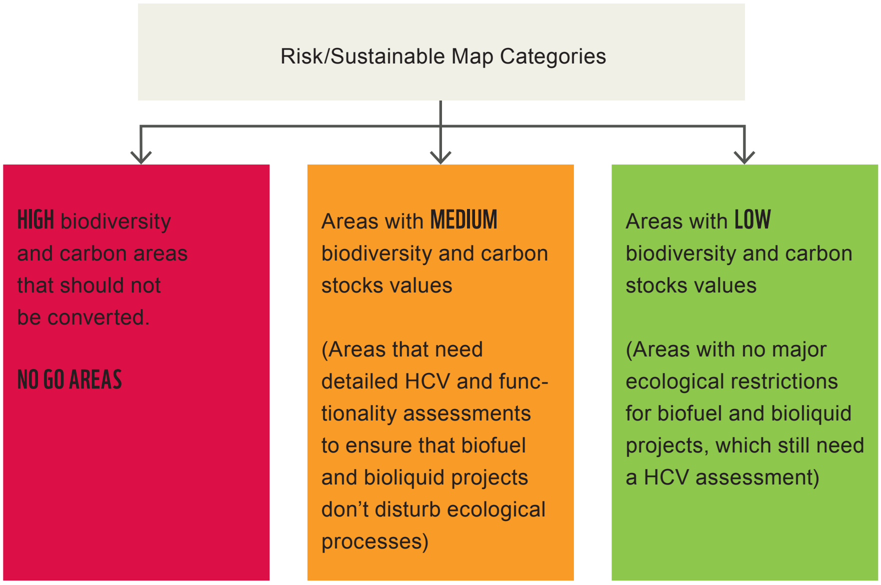


Figure 5.
Categories to determine the risk map of SuLu.

In this framework, there are three categories for the construction of the map. The first includes those areas that are qualified as 'no-go', considering that converting them to agricultural use for bioenergy is unacceptable at any time, on the grounds that use is restricted by regulations and covers the land categories described in the EU RED. Within these areas, forests, wetlands and protected areas, as well as highly biodiverse grasslands and carbon stocks (measured as GHG emission savings), are considered in the EU RED.

The second category corresponds to areas of medium biodiversity and carbon stock value, described as areas with good ecological integrity but with some signs of human intervention and with evidence of important conservation needs, in which special ecological considerations must be taken into account to keep ecosystem processes functional. For this reason a detailed analysis of 'High Conservation Value (HCV)' is required as well as a connectivity assessment to guarantee the preservation of conservation targets and natural processes.

The low biodiversity and carbon stock value category covers areas with low diversity and low carbon storage, as well as already converted landscapes. Determining if a site is acceptable for sustainable cultivation for the production of biofuels/bioliquids requires a basic assessment following the HCV method (or an equivalent one), and is necessary for two reasons. Firstly, mapping exercises can produce scenarios where biodiversity and carbon stock values are likely to be highest, but sometimes fail to identify smaller, more discrete areas of value.

The second reason is that cultural and social values of lands are not identified through a conventional mapping process, but can be through social mapping of the area, gathering information from the local inhabitants. This in itself poses a problem since social and cultural values are not covered by the EU RED sustainability criteria.

In the EU RED, primary forests and other wooded lands, protected areas, areas with rare, threatened or endangered species or ecosystems, or grasslands of high biodiversity, belong to the category of highly biodiverse areas (Article 17, EU RED). The category of high carbon stocks includes wetlands, continuous forests, areas with 10–30 % canopy cover, and peatlands (Article 17, EU RED). In this study, we use the term savannas as a synonym for tropical grasslands, because it is the predominant ecosystem in the Orinoco region and it best characterises the ecological processes and dynamics between different land covers in the Llanos ecoregion.

2 Study Area

Biodiverse savannas of the Colombian Orinoco are dominated by herbaceous vegetation with patches of shrubs and trees in floodplains forming a mosaic of mixed grasslands and riparian forests distributed amongst various climatic and edaphic conditions. These savannas are distinguished by having unique communities of plants, a large number of endemic and rare species, migratory and common species, as well as some particular soil types that play an important role in the water and carbon cycle. Additionally, these savannas have complex hydrological dynamics linked to flood and fire regimes.

In the Llanos, savannas are characterised by a tropical wet and dry climate, with annual rainfall between 400 and 2500 mm, and marked seasonality with most of the rain confined to one season. The average annual temperature is 26 °C to 27 °C and the dry season length may vary from three to six months, followed by the five to seven month long rainy season. Nevertheless much of the more than 1.5 million ha of oil palm that have been projected for the next 20 years (Productive Transformation Program, 2011) will be grown in the Orinoco region, which reveals the importance of proper planning, including ecosystem criteria, for this region.

The ecoregion of the savannas in the Colombian Orinoco covers an area of 17,903,559 ha (15.7 % of mainland Colombia) in the eastern part of the country between 2.5° to 7° N and 74° to 67° W, with an elevation range between 100 and 1,000 m. The northern boundary is marked by the Arauca River and in a northeast direction to the Rio Meta and towards the mouth of the Orinoco River. The latter forms part of the eastern boundary of the study area upstream of the Vichada River. The southern part is delimited by ecosystem transition between the Amazon and the savannas, and in the eastern part by the 1000 altitude limit along the entire eastern foothills of the eastern Andes mountain range.

The Orinoco basin has 71 % of the water of the swamps in the country, 36 % of Colombian rivers with a throughput greater than 10 m^3/s, and high species richness (CIPAV *et al.* 1998). It hosts the largest population concentrations of mammals in the country (167 species, Alberico *et al.* 2000), including 26 that are threatened. The Orinoco is also home to 783 species of birds (McNish 2007), 658 fish species (Maldonado–Ocampo *et al.* 2008; Maldonado *et al.* 2009), as well as 2692 flowering plant species (Rangel-Ch. 2006).

The Llanos region is mostly flat with minor undulations and some areas with tabular rocks. Nearly 19 % of these areas present a semi-undulating topography with slopes between 1 and 3 %, which are located mainly in the south between the Meta and Vichada rivers, while the region between the Yucao and the Manacacias rivers has slopes that reach 5 %. Only 4 % of the area has steeper slopes and are located around the Orinoco River and the foothill region where slopes can reach between 11 and 30 %. The basins of the rivers Meta, Arauca, Bita, and Vichada-Tuparro in the region are the major tributaries of the Orinoco River.

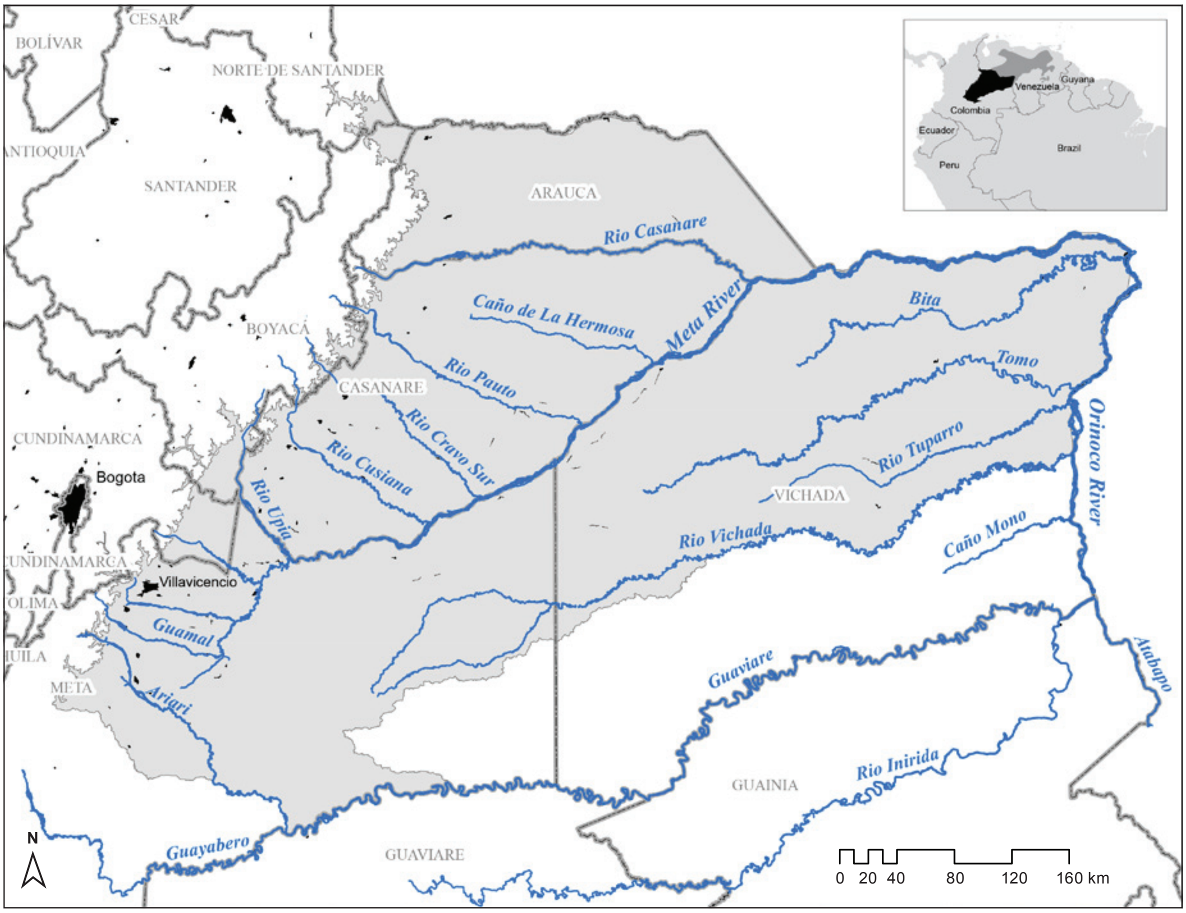


Figure 6.
Study area location.

Departments boundaries
Main rivers
Cities
Study area

In recent years the Orinoco region has become increasingly threatened by the disorderly expansion of agroindustry, cattle ranching, and the oil industry, and is now seen as a 'new agricultural frontier' for development. This is based on a drive to internationalise the economy and a common misunderstanding that the region is of low ecological importance (Correa *et al.* 2006). The Orinoco basin represents an important opportunity for conservation as it is one of the most intact river systems in the world with a relatively low population density (13 inhabitants per sq km). However, according to the National Parks Unit, there is a necessity to protect HVCs of the region that are currently least represented in the National Parks System. In addition, the region lacks an integrated sustainable development plan, even though there are rapid processes of ecosystem transformation currently taking place. The results of SuLu initiative will help to identify high conservation values in savannas, which could guide government institutions and sectors to enhance decision making processes related to policy, land use and environmental planning, and sector expansion.

3 Background: Implications of Land Use Changes

3.1 Worldwide

During the past five decades, humans have been largely responsible for major land cover changes in a rapid and extensive way in the different biomes of the planet (MA 2005). Based on their estimates of forest loss and dry areas in the world, Goldewijk and Ramankutty (2004) mapped the global changes of these land cover types.

Changes in land use affect the Earth's climate in two main ways: i) changing biogeochemical processes and ecosystem capacity to process carbon through gas exchange and photosynthetic processes; and ii) modifying the biophysical processes such as the albedo (reflection coefficient) of the soil surface, which creates an imbalance between the loss of sensible and latent heat (Foley *et al.* 2005). Moreover, land cover changes alter the regional climate by their effects on net radiation (the energy division due to sensible heat and latent heat) and the distribution of precipitation on soil water, evapotranspiration, and runoff (Foley *et al.* 2005).

Land cover changes in the tropics have primarily affected water balance, which in turn results in impairment in the quality of air emissions and altered atmospheric conditions due to changes in reaction rates, transportation, and disposal of atmospheric elements (Foley *et al.* 2005). Finally, changes in land use at the local level (deforestation, dam building, urbanisation, changing crop type, and different irrigation systems) change the behavioural patterns of the weather (extreme events such as storms, hail, fires, freezing, etc.) and climatic variables such as precipitation, temperature, humidity, and winds (atmospheric circulation at a meso-scale).

In the implementation of climate change policy, the National Research Council (NRC) of the United States recommended strengthening the relationship between land cover and the processes of alteration which affect global climate (Committee on Radiative Forcing Effects on Climate, Climate Research Committee 2005). However, these processes were not clearly incorporated into the last Intergovernmental Panel on Climate Change (IPCC). The NRC report also notes that beyond the increases in average composition of global atmospheric greenhouse gases, changes in the landscape can have important additional climatic implications at the local and regional levels.

According to Canadell *et al.* (2007), the global total net flux of carbon by land use change increased from 0.5 Pg[9] C in 1850 to a maximum of 1.7 Pg C in 1991, then dropped to 1.4 Pg C in 2000 and then increased again to 1.46 Pg C in 2005. The bulk flow during the period 1850–2000 was 148.6 Pg C, of which 55 % was in the tropics. During the period 1990–2005, the largest regional flow was in South and Central America, with a total of 11.3 Pg C.

During the last several decades, land cover changes have led to increased emissions of carbon in the Orinoco; for 2007, net emissions were estimated to be 13.91 Tg CO_2/yr[10] (Etter *et al.* 2010). The expansion of agricultural land increased emissions to 21.5 % compared with 1970 levels, equivalent to 2.46 Tg CO_2/yr.

9 Pg = petagramme; 1 Pg = 1.0 E12 kg

10 Tg = teragramme; 1 Tg = 1.0 E9 kg

3.2 The Tropics

In the tropics, the expansion of agriculture and ranching, logging, and road infrastructure development have been identified as direct drivers of land use change (Geist & Lambin 2002; Rudel 2007). In Latin America these drivers are defined by geographic, socio-economic, and biophysical parameters. The continent currently accounts for 4.3 % of global carbon emissions, of which 48.3 % is the result of deforestation and land use changes (UNEP 2000). According to FAO (2005), land cover changes are caused by expansion of crops and livestock production.

3.2.1 Land Use, Climate Change and Biodiversity

Changes in land use and climate are driven by multiple factors that also affect the actions and strategies of policy response to prevent and mitigate biodiversity loss (Figure 7). According to Dirmayer *et al.* (2010), changing land use is a major direct driver of biodiversity change (A) and is expected to have the greatest global impact over this century, followed by climate change. The effect of climate change is seen as an indirect driver of biodiversity loss (B), together with the effects of habitat loss and fragmentation of landscapes. These effects will cause changes in the composition of most ecosystems and geographical shifts of habitats of native species, which are translated into pressure (C) in the regime, increasing loss of these species and creating the opportunity for the introduction of exotic species (IPCC 2007). In other words, changes in community composition and distribution of ecosystems can cause reactions that affect global and regional climate (D). In addition, changes in the intensity and spatial patterns of land use and climate can lead to the loss of important ecosystem services they currently provide (E) (Quétier *et al.* 2009).

The impacts on biodiversity change are not a linear function of the magnitude and rate of climate change. For some species and ecosystems there may be thresholds of change of temperature, precipitation or other factors which, when exceeded, will result in discrete changes in viability, structure, or function.
At present, it is not possible to combine and assess all the impacts of ecosystem services at a global scale (F) due to uncertainties on regional climate change and regional-level responses, difficulties in assessing the impacts on the natural systems and human health (G), and various considerations of equity, both between regions and between generations (IPCC 2007). Therefore interventions and political strategies must address mitigation and adaptation to global, regional, and local dynamics that determine the drivers of biodiversity change (H).

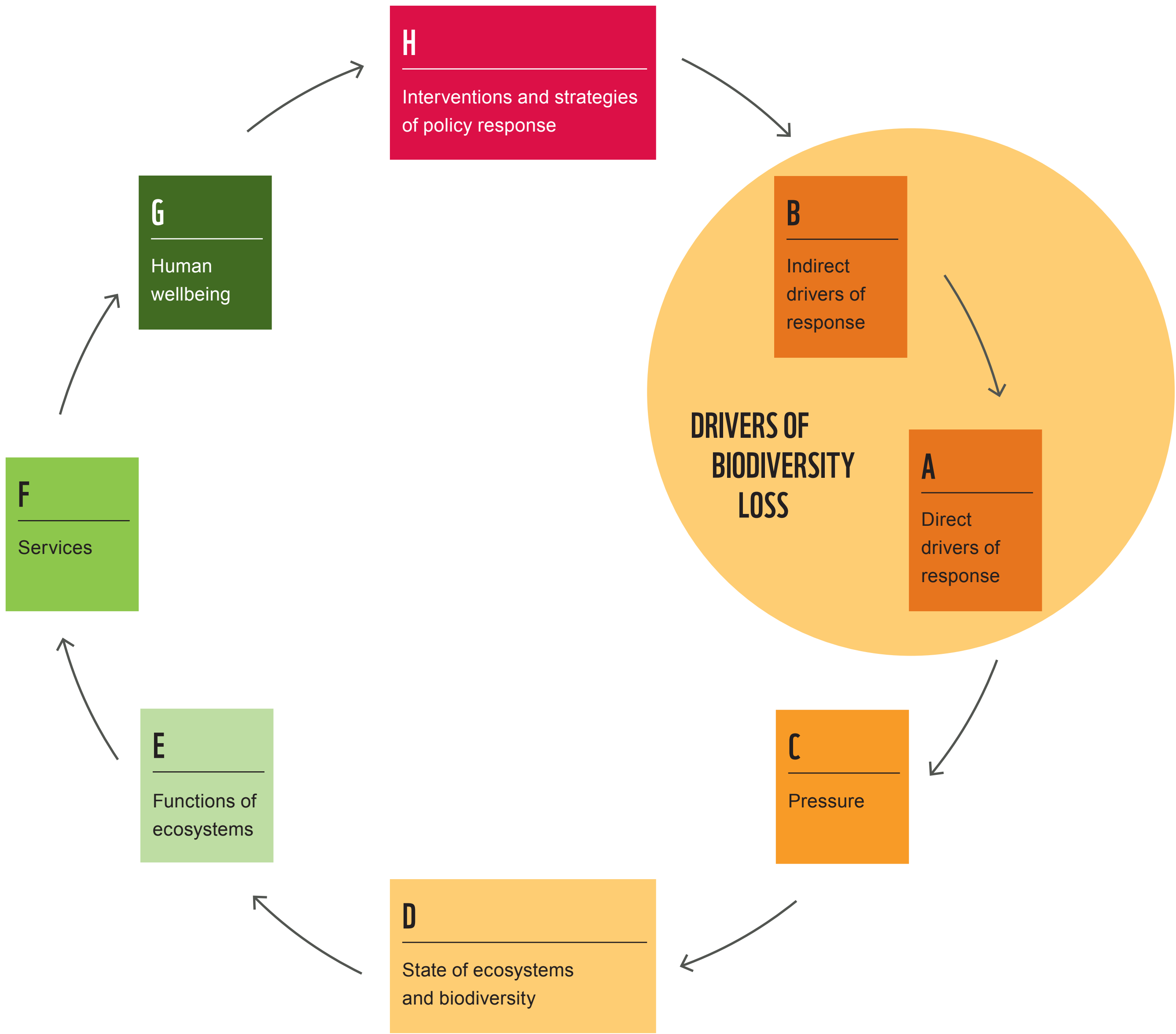


Figure 7.
Drivers of biodiversity change in terms of land use change and climate.

1	Structure and functioning of ecosystems
2	Distribution patterns of ecosystems
3	Changing size and structure of the population
4	Changes in the distribution of species
5	Changes in the composition of species (invasive species)
6	Changes in species interactions
7	Changes in phenology of plants and animals
8	Global extinction of endemic species or species with restricted distribution
9	Loss of genetic diversity
10	Changes in frequency and intensity of the disturbance regime
11	Provision of goods and ecosystem services to society
12	Social and economic impacts

Table 1: Impacts of changing land use and climate change on biodiversity.

In the framework of the Millennium Ecosystem Assessment, the future of biodiversity is examined by changes in three drivers: climate, land use, and nitrogen deposition. It is stated that the number of vascular plant species may decrease by 12–16 % of their relative abundance by 2050, as compared to the numbers reported in 1970. Nearly 80 % of the loss of species is due to changes in land use (mainly deforestation) in the tropical forests and savannas (Sala *et al.* 2000). Rodriguez-Erazo *et al.* (2010) describe the main impacts on biodiversity associated with land use and climate change (Table 1).

Climate controls the patterns and processes within ecosystems as well as the distribution, abundance, and regeneration of species, primary productivity, growth, and disturbance of vegetation, and the occurrence of pests and fires. Increases in temperature and precipitation changes, together with climate change, impact the structure and processes of ecosystems and their species. It is expected that climate change will directly affect individual organisms, populations, species distribution, and ecosystem functioning, as well as the increased occurrence of extreme events like droughts, floods, and fires (CBD 2009).

3.2.2 Land Use and Quality of Life

Increasing degradation of Latin American ecosystems, coupled with the decline in natural resource availability, requires the inclusion of environmental considerations into economic planning efforts. Natural resources are a main source of national wealth and can only be guaranteed for future use with sustainable utilisation. It is paradoxical that a country like Colombia with such enormous natural richness contains such a contrast in personal economic status, which can be observed in human development indices, poverty rates, and marginalisation (DANE 2011).

Soil degradation or desertification is one of the major contemporary environmental problems in developing countries like Colombia, and poverty positively correlates with it. This process has been defined in Colombia by the National Department of Statistics as "the diminution or destruction of biological potential of natural resources caused by their improper use and handling, which results in degenerative processes by the physical, economic and social development of the populations in their surroundings" (DANE 2011). The main processes are the degradation of vegetative cover, erosion by water and wind, excessive accumulation of salts, and physical and chemical degradation. Some factors associated with soil degradation in Colombia are: a) agriculture, b) deforestation (change of land use, logging, fire), c) over-exploitation of vegetation for consumption, d) overgrazing (excess cattle), e) industrial activities; and f) urbanisation.

Farmers could play an important role in reducing global emissions by planting trees, reducing tillage, increasing vegetative cover, improving grassland management, altering forage and animal varieties and more effective use of fertilisers, among other measurements. By keeping larger amounts of carbon in the soil – a process called 'soil carbon sequestration' – the farmers can help reduce carbon dioxide in the atmosphere, improve soil resilience, and boost crop yields.

Farmers, local communities, and fishermen have learnt throughout history to deal with climate variability and have often adapted crops, farming, and hunting practices to new conditions. But the intensity and rate of current climate change presents unprecedented new challenges. The poor in rural and urban areas will be hit hardest, since they depend on climate-sensitive activities and have low adaptive capacity. It is anticipated that the gradual change in temperature and rainfall and more frequent extreme weather events will result in crop failures, livestock fatalities, and other losses of assets, which represents a threat to food production and to access, constancy, and use of food resources. In some regions these changes may well exceed the adaptive capacity of the population.

Agriculture is a driver of climate change, as it is a major source of greenhouse gases. Agricultural production releases these gases into the atmosphere and produces emissions of methane (from cattle and wetlands, especially rice cultivation) and nitrous oxide (by the use of fertilisers). Changes in land use such as deforestation and soil degradation, two devastating effects of unsustainable agricultural practices, emit large amounts of carbon into the atmosphere and thus contribute to climate change.

3.3 Land Use Changes in Savannas

3.3.1 On a Global Scale and in South America

For many centuries, savannas have been used as a source of goods and services by humans, such as in the logging and burning of vegetation, and fishing, hunting and gathering activities. However, due to population growth and increasing density, patterns of natural resource use are changing rapidly, with the development of intensified agriculture, livestock, and infrastructure construction (Chacon 2007). These processes have been affecting ecological processes such as fire frequency and biomass accumulation, and thus altering the carbon cycle (Barbosa & Fearnside 2005; Grace et al. 2006). Today, savannas are increasingly important in the global food supply, especially in Latin America, and are therefore prone to increasing human impacts (Ayarza *et al.* 2007; Brannstrom *et al.* 2008). Goldewijk and Ramankutty (2004) estimate that at a global scale about half of the natural changes in land cover occurred in grasslands. Grace *et al.* (2006) estimate that globally the savannas are being transformed at a rate of 1 % per year, though more detailed data are still lacking. Savanna areas in different parts of South America are being affected by the expansion of soybean and oil palm plantations; as the study of Dros (2004) predicts, the Cerrado will be the area with the greatest loss of ecosystems due to the expansion of soybean cultivation (approximately 9.6 M ha by 2020).

Rudel *et al.* (2009) describes the first wave (1960–1985) of land cover change in other ecosystems in Latin America such as the Amazon as being caused by small farmers. The second wave (1985–present) on the other hand, is being driven by multinational companies. As globalisation and urbanisation increased in the 80s, the drivers of deforestation have changed in the two main tropical biomes. In these areas, the globalisation process began when well-capitalised farmers started to be more prominent, weakening the historically close relationship between local populations and natural processes (Rudel *et al.* 2009). Using increased consumer demand as positive justification, small and large-scale farmers – as well as pioneers – expanded into the global markets of palm, soybean, and sorghum, leading to a loss in natural ecosystems to meet the needs for food and biodiesel. These processes can be seen in Figure 8.

Currently, some countries have focused on increasing agricultural production through the establishment of large industrial projects and agricultural infrastructure, encouraged mainly by the internationalisation of the economy (Correa *et al.* 2006). Consequently it is considered that industrialisation is nowadays one of the main drivers of change in land cover, which is also the case in the Colombian savannas of the Orinoco region. Therefore local and regional changes are no longer a sum of local effects affecting an area; global effects can also now be used to determine the agents of change in an area. As such, the global affects the local and regional. Many of the drivers of change are long-distance connections involving flows of matter, energy, and information between countries, regions and continents, and socio-economic changes related to globalisation, promoting a rapid change of farming systems oriented to local, regional, and global markets.

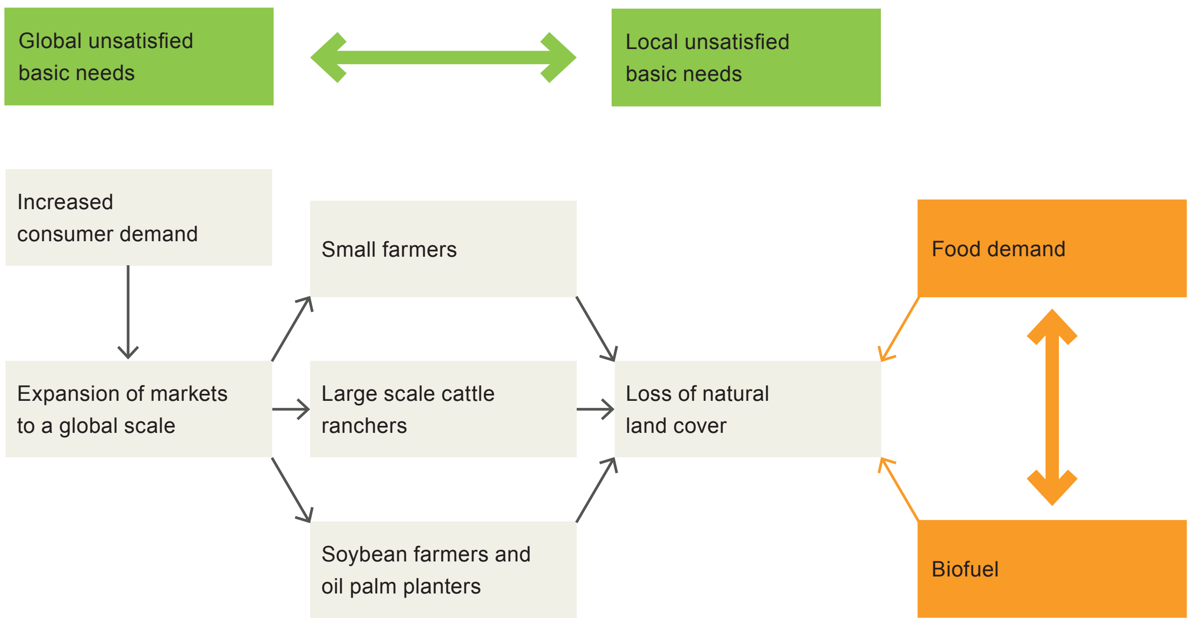
3.3.2 In the Orinoco's Savannas

3.3.2.1 Change of Use from the Early 60s

In the Orinoco's savannas, traditional indigenous use – hunting and gathering in gallery forests, savannas and rivers, and the use of small agricultural plots – gradually changed from the early 60s when the first farmers from the mountainous Andes region arrived, implementing extensive ranching and converting areas in the foothills into arable land. In the early 80s, a direct increase in the use of land originated from the establishment of agriculture. Changes included the introduction of fertilisers due to the physical and chemical limitations of this ecosystem and the climatic seasonality that reduces production yield.

Romero-Ruiz *et al.* (2012) present an analysis of spatial and quantitative changes in land cover and soil in the Orinoco by the process of colonisation over the past four decades. The changes were detected by using secondary data from the 70's and multitemporal assessments by Landsat and CBERS satellite images acquired from 1987–88, 2000–01 and 2006–07 (Table 2). Systematic transitions in the landscape were identified and put into context with data from population census and economic activities. The results showed that during the period between 1987–2007, 14 % of this region underwent some type of land use/cover change, most of which occurred mainly in the last decade. Systematic transitions were observed from flooded savannas, to crops and exotic grasses, and in turn to oil palm plantations. The observed changes are related to economic and market-oriented development that can be categorised into four historical periods: i) before 1970, use of land by indigenous and traditional ranching; ii) 1970 to 1987, agriculture and livestock intensification and economic development; iii) 1987 to 2000, the stimulation of oil palm and rice plantations and the beginning of petroleum exploitation; and iv) 2000 to 2007, oil palm expansion and the petroleum production boom.

Figure 8.
The new drivers of change in land use since the early 80s.



Between 1987 and 2007 the greatest loss of natural land cover in the Orinoco concerned flooded savannas – approximately 1,502 km² (Table 2). In contrast, the category with highest expansion is for crops with a total of 2,078 km².
On the other hand, the category with the largest relative growth (referring to the proportion of its initial area) has been oil palm plantations, which quadrupled during this period.

Category		1987		2007		1987–2007
		Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area of change (km^2)
Natural	Water	365	2.18	365	2.18	0
	Forest	3,158	18.89	3,046	18.21	- 112
	High savannas	6,500	38.87	5,885	35.19	- 614
	Flooded savannas	4,688	28.04	3,185	19.05	- 1,502
	Sandy savannas	213	1.28	213	1.28	0
	Rock outcrops	16	0.10	16	0.10	0
	Wetlands	70	0.42	70	0.42	0
	Secondary forests	139	0.84	139	0.84	0
Not natural	Infrastructure	170	1.02	190	1.14	19
	Oil palm	31	0.19	162	0.97	131
	Others crops	1,369	8.19	3,447	20.62	2,078
TOTAL		**16,722**	**100.00**	**16,722**	**100.00**	

Table 2. Changes in the Orinoco basin covering 1987 to 2007.

3.3.2.2 Changes Due to Oil Palm Plantations

In recent years the expansion of biofuels is stimulating land use change and loss of natural ecosystems in different parts of the world, and the Orinoco region is no exception. The expansion of oil palm cultivation in Colombia began in the mid 1960's when there were 18,000 ha in production. Nowadays, there are over 360,000 ha (as to 2010) in 73 municipalities in four production zones (Fedepalma 2012). Romero-Ruiz *et al.* (2012) showed palm expansion went from 31 km² to 162 km² between 1987 and 2007, especially in areas that were previously crops, though also forests and savannas. Changes began in the 1980's through the establishment of intensive agriculture and increasing human population.

3.4 The Carbon Cycle, Methane and Water in Savannas

Savanna ecosystems are commonly continuous and extensive areas, and are subject to a periodic fire regime that modifies regional and global energy levels, water and carbon balances, and the chemical composition of the atmosphere (Grace *et al.* 2006). Fires, in combination with natural disasters and anthropogenic influences including grazing and land use changes, result in an outflow of carbon into the atmosphere which is estimated to be up to 5–8 Gt C/yr (Seiler & Crutzen 1980). Available raw material combustion for fires may greatly increase during the next century as a result of climate change, especially of global warming and drying of the savannas, as well as savannas expected to be replaced by other anthropogenic cover. Grace *et al.* (2006) and Etter *et al.* (2010) made estimations on the magnitude of carbon fluxes between savanna and atmosphere, emphasising the importance of this ecosystem in the global carbon cycle, and concluded that their protection can contribute significantly to worldwide carbon sequestration.

At the same time, it has been globally recognised that aquatic ecosystems (including flooded savannas and wetlands) are of invaluable importance to an effectively functioning planet due to their role as social and economic ecosystems (Barbier & Thompson 1998). In ecological terms, they are notable for their role in regulating the water regime and climate. Wetlands limit the decomposition of organic matter and are an emergent element in global climate. Areas of flooded soils contain about 1/3 of all organic matter stored in the world and are therefore an important net sink of carbon, highlighting a requirement to better understand their specific distribution (Ordoyne & Friedl 2008). The total carbon dioxide and methane captured by these ecosystems are equivalent to the actual carbon content throughout the atmosphere. Though there is increasing evidence that some types of wetlands play important roles in carbon storage, it is still not fully recognised in national and international strategies, processes, and actions as a response to climate change (RAMSAR 2008).

Land cover changes, water systems, and the fire regime, all lead to a change in the dynamics of the Orinoco system. In these savannas there is a natural dynamic between carbon emission and sequestration: during the rainy season sequestration dominates, while during the dry season emissions dominate the cycle. Looking ahead to 2020, carbon emissions are predicted to increase by 31.5 % compared to the 1970s equivalent of 1.16 Tg CO_2/yr. Table 3 shows the carbon emissions coming from different processes involved in the carbon cycle in the Orinoco (Etter *et al.* 2010).

Intensification of land use is one of the main factors contributing to increased CO_2 emissions. During the period from 1970 to 2010, carbon sequestration has been favoured by the increase of oil palm plantations, while there has been a reduction in emissions due to burning, which is associated with the reduction of natural grasslands that have been now become cropland.

Year	Fire	Livestock	Crops	Rice	Plantations	Net emissions	Difference in net emissions since 1970
	Tg/year	Tg/year	Tg/year	Tg/year	Tg/year	Tg/year	(%)
1970	3.90	7.24	0.00	0.35	-0.03	11.45	--
1985	3.70	6.82	1.00	0.49	-0.11	11.90	3.9
2000	3.40	5.89	3.76	0.69	-0.45	13.29	16.0
2007	3.24	5.37	5.19	0.86	-0.75	13.91	21.5
2010	3.14	5.08	6.00	1.04	-0.98	14.29	24.8
2020	2.75	4.05	8.71	1.44	-1.88	15.07	31.6

Table 3: Emissions of carbon by CO_2 due to land cover changes of the past and future (1985–2020), indicating per land use/cover source and their contribution in relation to 1970.

4 Regulatory Framework

In the assessment of large conservation areas of savannas, it is important to analyse the global context of their role in the water and carbon cycle, as well as biodiversity. For this reason it is also imperative to incorporate the proposal of the Directive 2009/28/EC of the European Parliament and Council (EU RES-D), which proposes a common framework for the encouragement of energy from renewable sources, identifying areas of importance to this concept.

4.1 Directive 2009/28/EC of the European Parliament and Council (EU RES-D)

As a renewable energy source, biofuels have the potential to reduce the dependence of the transport sector on fossil fuels and reduce greenhouse gas (GHG) emissions. In this context the European regulation (Paragraph 18) stipulates that all member states have a minimum of 10 % renewable energy in their transport energy mix, with the linked reduction of greenhouse gases from the use of biofuels and bioliquids having to be 35 % or more in 2017 and 2018 (Article 17). This could provide new opportunities for agricultural producers, both in the national as well as international markets, and help increase revenue and create jobs in this sector.

However, critics point out that not all biofuels have a positive energy balance and that the negative consequences of their production to the environment and society could outweigh economic benefits, especially in the absence of a coherent policy framework for development (World Bank 2007). The impact of biofuels on the environment depends on many factors, including the type of crop used as raw material, changes in land use, and the processes used in production. Their economic viability without subsidies or protection depends on factors such as oil prices and the cost of raw materials used in their development (World Bank 2007).

To fulfil the goals of the European Union in terms of reducing greenhouse gases, biodiversity loss, and increasing renewable energy use, the policy regulates that such sources either inside or outside the European Community must meet the criteria of sustainability (Article 17). In this context, it is affirmed here that the production of biofuels must not have the effect of encouraging destruction of biodiverse lands and those that store significant amounts of carbon biomass.

4.1.1 High Biodiversity Values

Sustainability criteria for biodiversity as described in RED state that biofuels and bioliquids shall not be made from raw material obtained from land with high biodiversity value, i.e. land that had one of the following statuses in or after January 2008 – whether or not the land continues to have that status:

a) Primary forest *and other wooded land, namely forest and other wooded land of native species, where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed.*

b) Areas designated:
i. By law or by the relevant competent authority for nature protection purposes; or
ii. For the protection of rare, threatened or endangered ecosystems or species recognised by international agreements or included in lists drawn up by intergovernmental organisations or the International Union for the Conservation of Nature (…)

c) Highly biodiverse grassland, *that is:*
(i) natural, namely grassland that would remain grassland in the absence of human intervention and which maintains the natural species composition and ecological characteristics and processes; or
(ii) non-natural, namely grassland that would cease to be grassland in the absence of human intervention and which is species-rich and not degraded, unless evidence is provided that the harvesting of the raw material is necessary to preserve its grassland status.

In the case of the savannas, there are many areas that qualify under the above criteria. There are many protected areas already established in the Orinoco, as well as primary forest (and in particular as natural corridors around rivers), meaning biofuels from these savanna lands should not benefit from production incentives, nor be accepted in the European biofuel market. However, the application of the EU RED relating to highly biodiverse grassland (c) is not completely clear, because the EU commission has not to date published a clear definition[11]. In many cases the interpretation of what highly biodiverse grassland is depends on the information available in the affected areas and the criteria used to identify national and regional conservation priority areas and – on local scales – on high conservation values, including the ecological uniqueness in each context.

11 *"The Commission shall establish the criteria and geographic ranges to determine which grassland shall be covered by point (c) of the first subparagraph" (EU RED, Article 17(c)).*

4.1.2 High Carbon Stock Areas

According to Grace *et al.* (2006), Etter *et al.* (2010), and Romero-Ruiz (2011) there has not been a systematic quantification of the change rate of land use/cover or fire occurrence. The Eastern Colombian Savannas represent around 6 % of the savannas in South America. This study identifies the land use/cover change (LUCC, savannas play an important role in the carbon flow due to their water and fire dynamics. For instance, the floodplain of the Orinoco basin plays a significant role in the carbon cycle for its annual water dynamics in which its behaviour resembles the carbon flux of a permanent wetland and as a base to support high carbon stocks in soils, mainly along riparian and lowland areas. Agricultural soils and wetlands areas play a significant role in the sequestration and storage of carbon under management actions (Batjes 1999; Lal 2004). The loss and degradation of carbon stocks in wetlands such as the flooded savannas may result in the release of large amounts of greenhouse gases into the atmosphere. Therefore conserving wetlands is a viable way of maintaining existing carbon deposits and preventing emissions of CO_2 and other gases.

All effects of land use changes, in terms of carbon output, should therefore be taken into account in calculating the reduction in greenhouse gas emissions obtained by the use of certain biofuels and bioliquids. This is necessary to ensure that in calculating the emission reductions of greenhouse gases, all changes in the carbon flux derived from the use of biofuels and bioliquids are considered (EU RED, Article 19).

Biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall not be made from raw material obtained from land with high carbon stock, namely land that had one of the following statuses in January 2008 and no longer has that status:

(a) *wetlands, namely land that is covered with or saturated by water permanently or for a significant part of the year;*

(b) *continuously forested areas, namely land spanning more than one hectare with trees higher than five metres and a canopy cover of more than 30 %, or trees able to reach those thresholds in situ;*

(c) *land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10 and 30 %, or trees able to reach those thresholds in situ, unless evidence is provided that the carbon stock of the area before and after conversion is such that, when the methodology laid down in part C of Annex V is applied, the conditions laid down in paragraph 2 of this Article would be fulfilled.*

For this reason, when calculating the impact of land conversion on greenhouse gases, the original system ('reference') and land use after conversion should be taken into account. As explained in Paragraph 73:

> *"Land should not be converted for the production of biofuels if its carbon stock loss upon conversion could not, within a reasonable period, taking into account the urgency of tackling climate change, be compensated by the greenhouse gas emission saving resulting from the production of biofuels or bioliquids."*

These systems include wetlands, and in this case also the flooded savannas, wooded areas of 30 % canopy cover, and wooded areas with canopy cover between 10 and 30 %. Within this last category the wooded savannas of the Orinoco must be considered, as they may have a canopy cover between 2–30 %. Only if it can be shown that the carbon in the areas of interest is low enough, may it serve as justification to convert the area for the purpose of biofuel production. The reference to wetlands should consider the definition established in the Convention on Wetlands of International Importance – especially as habitat for aquatic birds – adopted at RAMSAR on February 2nd 1971.

Though there are over fifty definitions of wetlands (Dugan 1992), with ongoing discussion regarding the convenience of using a common one (Scott & Jones 1995), in Colombia the Ministry of Environment has adopted the definition of the RAMSAR Convention

> *"… Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters …"*
> (Scott & Carbonell 1986)

In the production of biofuels and bioliquids, the possible impact on water quality must also be taken into account. Paragraph 74 specifies:

> *"Where biofuels and bioliquids are made from raw material produced within the Community, they should also comply with Community environmental requirements for agriculture, including those concerning the protection of groundwater and surface water quality, and with social requirements. However, there is a concern that production of biofuels and bioliquids in certain third countries might not respect minimum environmental or social requirements."*

From the perspective of land use for the production of biofuels in the Orinoco region, detailed information about land use, land cover changes and trends, and location and rates of change, is very important. As global demand for agricultural raw materials continues to grow, one of the ways to meet this growing demand will be to increase the total area of cultivated land. The restoration of severely degraded or heavily contaminated land, which cannot be exploited in its existing state for agriculture, is a means to increase the total area available for crops. Since the encouragement of biofuels and bioliquids contribute to the increase in demand for agricultural raw materials, the sustainability scheme should promote the use of restored degraded land (Article 88).

Even if biofuels themselves are produced using raw materials from land already intended for farming, the net increase in demand for crops caused by the promotion of biofuels could lead to a net increase in acreage. This could affect land with high carbon stocks, in which case it would cause harmful loss to these stocks. To mitigate this risk, it is appropriate to introduce accompanying measures to encourage a higher rate of productivity on land already used for crops, the use of degraded land, and the adoption of sustainability requirements.

4.1.3 Peatlands Status

In addition to areas with high biodiversity value and high carbon stocks, EU RED makes special mention of those land areas classified as peatland in January 2008, where the sustainable criteria reject drainage of previously undrained soil in those areas. However, despite a high percentage of flooded area in the Llanos in Colombia, the amount of peatlands are minimal, as wetlands in the region are mostly classified as marshes on the land cover map.

Biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall not be made from raw material obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.

4.1.4 Greenhouse Gas Emissions Savings

In addition, RED includes greenhouse emission saving targets as other sustainability criteria for the use of biofuels and bioliquids, establishing a mandatory minimum emission saving threshold of at least 35 % compared to the fossil fuel alternatives, in order to be counted towards the 10 % target imposed on the mineral oil industry. This minimum emission saving threshold will be increased to 50 % in 2017 and 60 % in 2018 for new installations for biofuel production (EU RED 2009). In the Llanos case, the calculation of the greenhouse gas impact of biofuels and bioliquids was lead by Lange and Suarez[12] (2013) following the parameters based on the IPCC (2006) and the guidelines for National Greenhouse Gas Inventories based on Carré *et al.* (2010). It was also guided by Directive 2010/335/EU that gives guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC, which in turn lays down rules for calculating the greenhouse gas impact of biofuels, bioliquids, and their fossil fuel comparators, that take into account emissions from carbon stock changes caused by land use alteration.

4.2 The Colombian Context

4.2.1 Legal Framework for Land Use Planning

Since 1991 the legal framework for land use planning, organisation and regulation has been based on Article 288 of the Political Constitution of Colombia, the Republic's Magna Carta. That article says that the organic law for territorial organisation and planning will establish the distribution of responsibilities between the national government and the territorial entities. It further establishes that the law will adhere to the principles of coordination, concurrence and subsidiarity within the terms established by the law. At the same time the Political Constitution determines the responsibility of the Colombian state for the protection of environmental diversity and integrity and for organizing, regulating and planning the Management, use and exploitation of natural resources in order to guarantee sustainable development of the nation in a way that foresees and controls environmental deterioration.

The Law of Territorial Development (Law 388 of 1997) expresses the legislative principles developed for regulating and planning territorial organisation. This law defines the distribution of responsibilities of the nation and its territorial entities[13]. It is the responsibility of the nation to establish the general policies for land use organisation and regulation in areas of national interest such as national parks and protected areas. It must define the location of large infrastructure projects and determine the limits of areas to be used for security and defense. It is responsible for policy lines for urban development and the system of cities including policy guidelines and criteria to guarantee the equitable

12 *Report made in the SuLu project by Mareike Lange and César Freddy Suarez. Biofuel Policies in Practice – A Carbon Map for the Llanos Orientales in Colombia*

13 *Territorial entities are related to the administrative division of the country: Colombia is divided into 32 departments and one capital district (Bogotá). Departments are subdivided into municipalities, and municipalities are in turn subdivided into corregimientos. Each department has a local government with a governor and assembly directly elected to four-year terms. Each municipality is headed by a mayor and council, and each corregimiento by an elected corregidor, or local leader.*

distribution of public services and social infrastructure among the regions. It must ensure conservation and protection of historical and cultural areas of importance. Furthermore the law is responsible for defining the principles of economics and minimal standards for government practises to which official associations, (departments, municipalities, metropolitan areas) must comply when entering into contracts, planning agreements or delegating authority relating to land use.

The departments are responsible for establishing guidance on organizing and regulating territories in order to determine the legality of certain scenarios for land use and occupation. This should be done taking into account the optimal environmental potential of the region, in accordance with development objectives and considering the biophysical, economic and cultural potential and limitations of the area. Departments are also responsible for defining policies for population settlement and urban centers, for determining the location of physical and social infrastructure, and for integrating and guiding departmental plans for land use by different sectors. Departments must also define policies for their municipalities and indigenous territorial entities. They must articulate policies, directions and strategies for physical and territorial organisation and regulation of various plans through the adoption of POTs for the totality or specific portions of their territories. Departments are also responsible for the establishment of guidelines and directions for land use organisation and regulation for municipalities that make up a metropolitan area including implementation of special protection programs for conservation and recuperation of the environment.

At the level of municipalities, land use regulation, planning and management is defined in the corresponding plans (Planes de Ordenamiento territorial – POT – in Spanish), which constitute the fundamental instruments governing decisions about changes in land use. The law 388 of 1997 provides the mechanisms to allow municipalities to promote territorial organisation and regulation, equitable and rational land use, preservation and defense of the ecological heritage and local cultures within their territorial environments. It also provides guidelines to prevent disasters in high risk settlements, and to execute efficient actions for urbanization. In this way the law seeks to guarantee land use appropriate to the social function of the land, which permits constitutional rights to housing and to public utilities and ensures the establishment and defense of public space, environmental protection, and disaster prevention.

The Colombian Orinoco region's environmental regulation and planning is provided through the Triennial Action Plans (Planes de Acción Trienales – PATs) and the Environmental Management Plans (Planes de Gestión Ambiental – PGAR) of the regional environmental authorities, the Autonomous Regional Corporations (Corporaciones Autónomas Regionales – CARs). These authorities also define the Watershed Management Plans (Planes de Ordenación y Manejo de Cuencas Hidrográficas – POMCAs) in accordance with Regulatory Decree 1729 of 2002 regarding watersheds.

Other instruments such as the National System of Protected Areas (Sistema Nacional de Áreas Protegidas), the Plans of Life (Planes de Vida) and the Ethnic Development Plans (Planes de Etnodesarrollo) of indigenous and Afrocolombian communities contribute to land use planning and management.

Decree 2372 of 2010 establishes regulations related to the National System of Protected Areas (Sistema Nacional de Áreas Protegidas – SINAP), categories of management for that system, and other related topics. In accordance with this decree, SINAP "is the set of protected areas, social actors and institutions and management strategies and institutions which in sum contribute to compliance with the general objectives of conservation in this country." SINAP corresponds to and coordinates the Special Administrative Unit of the National Natural Park System. In relation to protected soils this decree stipulates that, "Even if protected soils are not within protected areas of management, compliance with specific conservation objectives can be supported. In these cases the competent authorities established in the declaration of protected areas in this decree should accompany the municipality to provide the necessary advice for the work of conservation in the area. This may include designation of the area as a protected area within the framework envisioned by this decree."

In some cases there are also Small Farm Reserve Zones (Zonas de Reserva Campesina) established in the National System of Agrarian Reform (Sistema Nacional de Reforma Agraria, Law 160 of 1994) and regulated through Decree 1777 of October 1996.

In addition to the land use planning and management instruments already mentioned, the country has developed technical capacity and tools for land use management which takes the ecosystems approach into consideration.

4.2.2 The Integral Management of Biodiversity and Its Ecosystem Services

In 2012, the Ministry of Environment and Sustainable Development (MADS) presented the Integral Management Of Biodiversity And Its Ecosystem Services, a participatory policy for the review and updating of the National Biodiversity Policy released in 1998, aiming to maintain and improve the flexibility of the socioecological systems on the national, regional, local and trans-frontier levels, taking into account scenarios of change and through the joint, coordinated and concerted action of the State, the productive sector and civil society.

"...the Plan sets forth a significant change in the form of biodiversity management, which is reflected in its conceptual development, as well as the strategic framework which has been constructed. These changes imply, among other aspects, the recognition of a management which allows for the integral handling of closely related ecological and social systems, as well as the conservation of biodiversity in the broad sense, that is, understood as the result of an interaction between systems of preservation, restoration, sustainable use and the building of knowledge and information. Equally, the plan recognizes the strategic character of biodiversity as the foundation of our competitiveness and as a fundamental part of the wellbeing of Colombian society. The aspects which have received the most attention are guided by the consequent wish to insert flexibility into this management, above all in order to open spaces for communication, cooperation and co-responsibility among the actors who, in different degrees, are responsible for the country´s biodiversity."

(Ministry of Environment and Sustainable Development 2012: "National Policy for the Integral Management of Biodiversity and its Ecosystemic Services").

	CATEGORY	SUMMARY	1	2	3	4	5	6	7	8	TOTAL
1	**Primary forests and other woody habitats**	Forests and other wooded land of native species where there is no clearly visible indication of human activity, and ecological processes are not significantly disturbed.	X	X	X	X	X		X	X	**7**
2	**Areas designated by law or by the relevant authorities**	Areas designated by law or by the relevant competent authority for nature protection.	X	X		X		X		X	**5**
3	**Areas of species and ecosystems in any category of vulnerability**	Areas designated for the protection of species or specifically rare, threatened or endangered species, recognised by international agreements or included in lists of intergovernmental organisations or the International Union for the Conservation of Nature.	X	X		X				X	**4**
4	**Natural grassland with a rich biodiversity**	Grassland that would remain biodiverse in the absence of human intervention and that maintain the natural species composition and ecological characteristics and processes.	X	X	X	X			X	X	**6**
5	**Non-natural grassland with a rich natural biodiversity**	Grassland that would cease to be biodiverse in absence of human intervention, which are rich in species and not degraded, unless it is shown that the exploitation of raw materials is necessary to preserve its grassland status.	X	X	X	X			X	X	**6**
6	**Wetlands**	Land covered with water or saturated by water permanently or for a significant part of the year.	X	X	X	X		X		X	**6**
7	**Continuously forested areas > 30 %**	Land spanning more than one hectare, with trees higher than five meters and a canopy cover greater than 30 %, or trees able to reach these values in situ.	X	X	X	X			X	X	**6**
8	**Continuously forested areas 10–30 %**	Land spanning more than one hectare, with trees higher than five meters and a canopy cover between 10 and 30%, or trees able to reach these values in situ.	X	X	X	X			X	X	**6**

Table 4. Conservation categories according to the EU RED, description, and national regulations.

1) The Integral Management of Biodiversity and its Ecosystem Services.
2) National System of Protected Areas, SINAP.
3) National map of ecosystems,
4) Strategic ecosystems.
5) Fund for BioTrade and Nature Heritage Fund.
6) National Plan of Wetlands.
7) CONPES 3797 “Policy for the integral development of the Orinoquia-Phase 1 High plain savannas”.
8) Land use planning – Organic Law 388 of 1997.

4.3 The Orinoco Framework

4.3.1 Regional Planning Instruments

As previously mentioned, environmental and land use planning instruments have been developed for the Orinoco Region according to the national laws (Table 5). This framework represents the regional planning context that establishes the current criteria to order and regulate land use in the Orinoco region. The results of the Sulu project could complement and enhance these political instruments.

Acronym	Document	Description
PGAR	Plan de Gestión Ambiental Regional 2002–2012 (Regional Environmental Management Plan 2002–2012)	Defined by Decree 1200 of 2004 as "the instrument of long-term strategic planning of the Regional Environmental Authority for the area of its jurisdiction, which allows management to guide and integrate the actions of all regional actors to the development process of progress towards sustainability of the regions."
PAT	Plan de Acción Trianual 2007–2009 (Triennial Action Plan 2007–2009)	Investment and action plan associated with the programme lines of the PGAR, corresponds with the Millennium Development Goals of the United Nations and the objectives and areas of environmental policy of the National Development Plan.
POMCA	Los Planes de Ordenación y Manejo de Cuencas 2007/2008 (Management Plans and Watershed Management 2007/2008)	Defines zones and describes strategies for conservation and sustainable use of watershed resources. In the jurisdiction of Corporinoquia, the POMCA emphasises the control of agricultural, industrial, and urban expansion.
POT & EOT	Los Planes y Esquemas de Ordenamiento Territorial de los Municipios (Plans and Zoning Schemes of Municipalities)	Regulated by Law 388 of 1997 on Territorial Development, municipal planning consists of tools that should guide spatial development by regulating the use, process, and use of space, in harmony with economic development and conservation of the environment.
	Determinantes Ambientales (Environmental determinants)	Decree 3600 of 2007 regulates the provisions of laws 99 of 1993 and 388 of 1997 on the determinants of land, in which the Regional Corporations have to define 'Environmental Determinants' to be considered in structuring the POT, the EOT, and municipal development plans.
	Agendas Ambientales Municipales (Municipal Environmental Agendas)	These agendas contain basic sanitation projects, protection of watersheds supplying the municipal water systems, cleaner production, education, and in some cases, institutional strengthening.
	Plan General de Ordenamiento Forestal (General Forest Management Plan)	For defining areas with potential for forest use. In the project case, zoning of the land was done and forest-mapping units defined. Of the areas suitable for forestry, certain strategic ecosystems were excluded (swamps, lagoons, rivers, water rounds, stopped and protected areas). Systematised and analysed information allowed making a proposal for the implementation of biological corridors.
	Integrative analysis	The PGAR, the PAT, the POMCA, POT/EOT, and even the General Forest Management Plan, were all designed with the intention of seeking economic development processes and appropriate utilisation of territory that would variously contribute to the conservation of regional ecosystems.

Table 5. Decrees and environmental planning instruments for the Orinoco Region.

Management Plans and Watershed Management (POMCA) zoned land in the Orinoco according to its use in the areas of:

1. **Conservation:** Areas of high environmental significance, or ecological fragility, designed to maintain its natural resources, promote ecological balance of ecosystems and natural beauty. These areas include: Protective Forest Reserves, Production-Protection Areas, Civil Society Reserves, Integrated Management Districts, Protection Areas designated by the municipalities and departments, unique natural areas, properly regulated buffer areas of national parks, water springs, and well preserved and minimally disturbed wetlands and estuaries (gallery forests).

2. **Preservation:** Zones aimed at ensuring the inviolability and non-disturbance of natural resources in specific areas within watershed areas. These areas may belong to those areas that are not included in any category of special management, or because of their fragility and/or environmental quality deserve to be preserved. They are also part of the Civil Society Reserves, Integrated Management Districts, areas of protection declared by the municipalities and departments, unique natural areas, properly regulated buffer areas of national parks, water springs, and wetlands and estuaries (riparian forests) found at an average grade of natural ecological regeneration.

3. **Protection:** Zones aimed at ensuring the preservation and maintenance of works, actions or activities as a product of human intervention, with an emphasis on intrinsic cultural and historical values. Protection shall be given to public works, security and defence areas, linear projects, water for aqueducts, and space for mining. For purposes of clarity, these areas are not covered by this project.

4. **Ecological restoration:** Zones aiming at the re-establishment of primitive natural conditions in the area, and reversing degradation of fauna, flora, and soils (affected by fires, floods, landslides, and high degrees of anthropogenic and natural erosion), or have important forest remnants. In such areas, reforestation and regenerative processes can be accelerated (including endemic fauna and flora of the area). These areas have certain environmental interest and the aim is to eventually lead them to a level of preservation and/or conservation.

5. **Geomorphological recovery:** Areas where human activities are aimed at restoring natural conditions to allow sustainable use of resources. Includes areas that are currently in production but that show loss concerning soils, fauna, and vegetation characteristics due to improper handling of chemicals, industrial, or domestic waste. Additionally they may have been affected by fire, windstorms, floods, or landslides, and have a high degree of erosion.

6. **Production:** Areas where human activity is directed to produce goods and services required by society, assuming a model of sustainable use of natural resources.

Finally, Table 6 shows the main studies on the status of biodiversity in the Orinoco region.

Author, Year	Title
Alexander von Humboldt Institute 2008	Biodiversity and development in strategic ecoregions of Colombia: Orinoquia
Correa et al 2006	Biodiversity Action Plan Orinoco Basin – Colombia 2005–2015
TNC & WWF 2006	Providing Safe Haven: Habitat Conservation for Migratory Birds in the Orinoco River Basin. Final report to the US Fish and Wildlife Service
Romero et al 2009	Report on the status of biodiversity in Colombia 2007–2008: Orinoco foothills, plains and forests north of the river Guaviare
Andrade et al 2009	The best Orinoquia that we can build: Elements for Environmentally Sustainable Development
Rudas 2003a; 2003b; Rudas, Rodriguez, and Romero-Ruiz 2008	System monitoring and evaluation indicators for the Biodiversity Policy applied to the Orinoquia
Galindo 2007	Conservation priorities of the eastern savanna plains
Bustamante 2010	Development of a proposal for evaluating the effects of the transformation of tropical savannas
Lasso *et al.* 2010	Biodiversity of the Orinoco Basin: scientific basis for identifying priority areas for conservation and sustainable use of biodiversity

Table 6. Major studies on the status of biodiversity in the Orinoco.

5 Methodology

Of all the methods developed for the identification of priority areas for conservation, the concept of High Conservation Value Areas (HCVA) is one of the newest and most recently implemented in South America (WWF 2007; Santivanes & Mostacedo 2008; Martinez-Ortiz 2007) and specifically in Colombia (Usma & Trujillo 2011; Otero-Garcia 2010; Bustamante 2010). According to the Forest Stewardship Council, identifying high conservation values can help to provide guidance for the conservation of these areas in terms of ecosystem functionality and biodiversity. Thus, the HCVAs become sites of significant biodiversity value, being a source of food in terms of animal species, as important areas that provide ecosystem services, and places that are considered essential to the needs of local communities.

This methodology, which is based on the identification, management and maintenance of HCVs, was combined with existing requirements of forest certification as a commercial alternative for forest products (WWF 2007; Santivanes & Mostacedo 2008; Martinez-Ortiz 2007). However in Colombia, with the recognition of the implications of land use change issues such as climate change, biodiversity and poverty, and the negative effects due to improper use, there is a proven need to develop methodologies for the management of other areas of conservation besides forests. In this sense, implementing the Directive 2009/28/EC of the European Parliament and Council (EU RES-De) – which establishes a common framework for the promotion of energy from renewable sources – means that for the certification of biofuels imports, only those that do not come from land with high biodiversity value/carbon stock should be considered. It is within this framework where other areas besides forested areas – such as protected natural areas and peatlands, wetlands, and highly biodiverse savannas – are also included.

In the case of savannas, one of the biggest challenges is the precise characterisation and classification of their ranges of biodiversity, including the functional and social importance of these ecosystems, as well as the effects on their use and handling in terms of biodiversity. Therefore, the methodology presented here focuses on issues related to achieving the proper management of highly biodiverse savannas and achieving great strides in the conservation of their biodiversity. This plays an important role in sustaining ecological processes, the production of goods and services, and the generation of income for local populations.
The Sustainable Land Use Mapping conceptual framework (Figure 9) is based on the definitions of High Biodiversity Values and High Carbon Stocks according to the European Directive (EU RED) as described in the previous chapter.
This regional approach gives guidelines to land use planning and recommends next steps in each case. Ultimately this leads to a monitoring proposal to define areas of conservation and development of the savannas with high, medium, and low biodiversity and carbon values. It requires considering specific aspects of ecosystems and species and their spatial extent and richness, as well as the components showing the conditions of the territory at any given time.

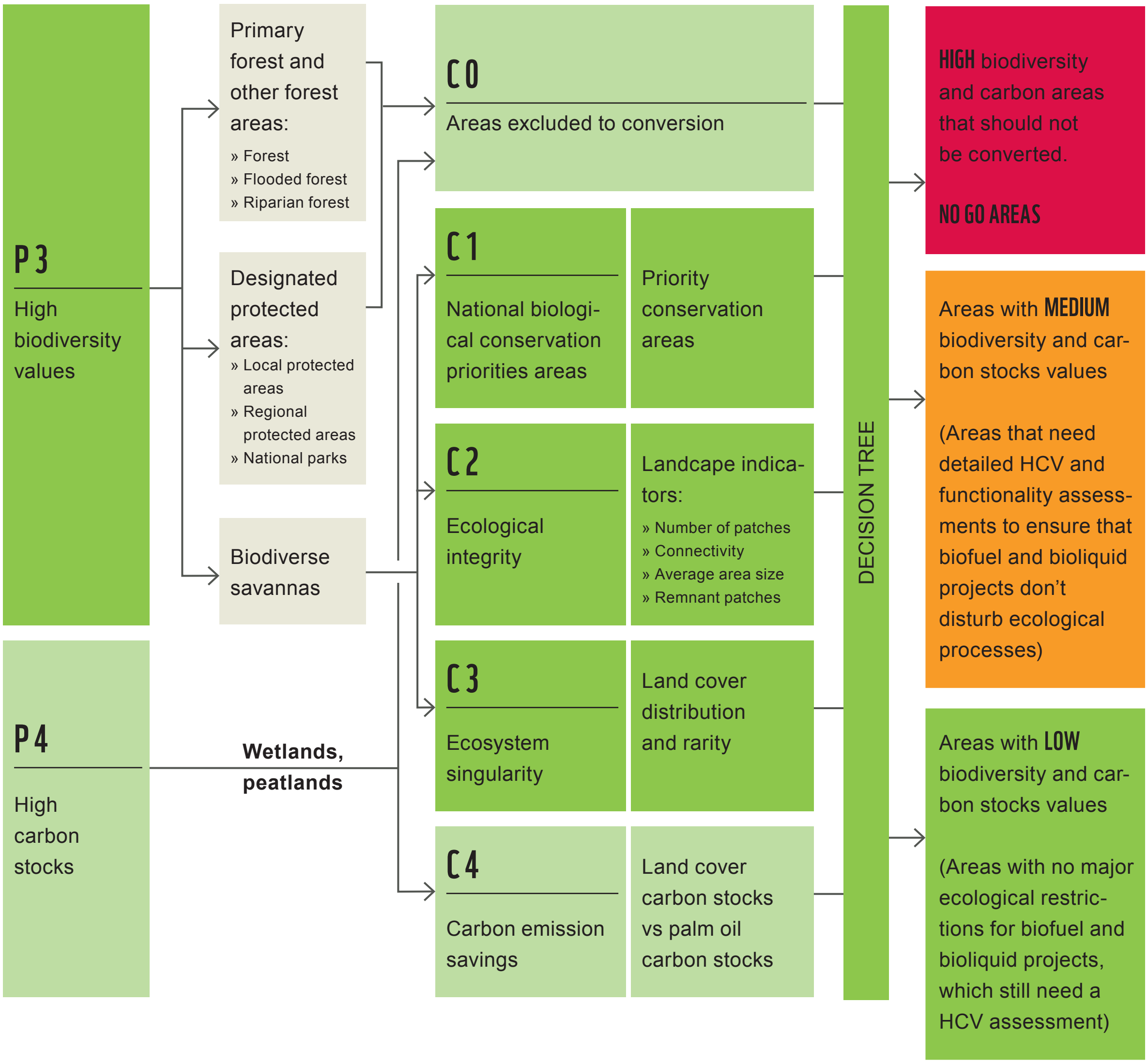


Figure 9.
Conceptual framework and SuLu mapping structure.

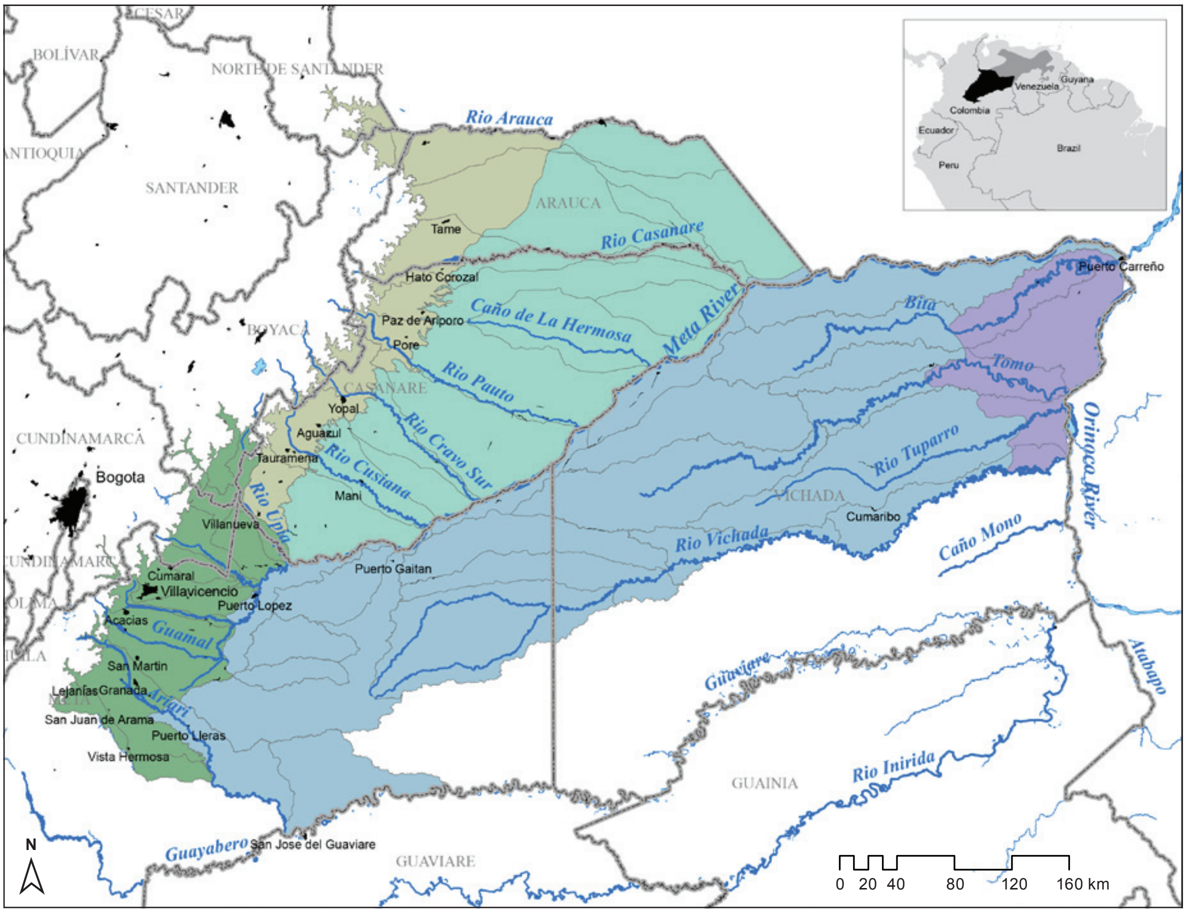


Figure 10.
Identification of biogeographic units as part of the landscape units.

Biogeographic Units

- High plain
- Flooded plain
- Maipures – Orinoco platform
- Meta foot hill
- Casanare – Arauca foot hill

5.1 Definition of Analysis Units

One of the first steps to be taken in the implementation and analysis of the methodology is defining the units of the analysis. This study uses those developed by Etter (1998), Olson *et al.* (2001) and Romero-Ruiz *et al.* (2004), where the definition is obtained from Ecoregions, Biomes, and Basins. The union of these three ecological inputs provides information about the biogeography subdivision in five major regions, namely the high plain savannas, flooded savannas, the Maipures – Orinoco platform, and two specific foothill savannas (Figure 10).

Once the units of analysis are consolidated, they are superimposed with the information on protected areas, forests, and savannas emerging from the analysis, as well as with information about the biological significance, ecological integrity, ecosystem uniqueness, and carbon flux of each analytical unit, as described in the following chapters.

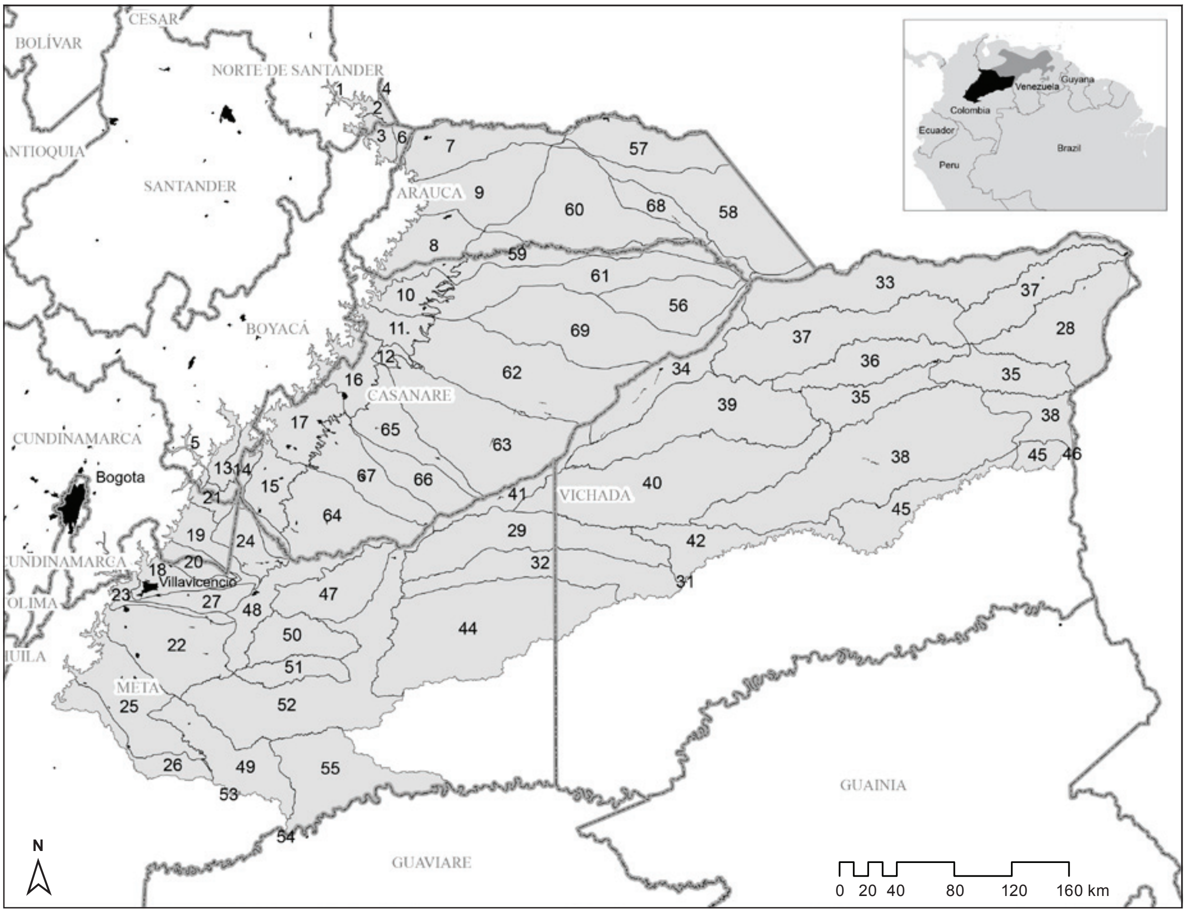


Figure 11.
Landscape units

Landscape Units

Conceptually, this study considers that the ecosystems or the type of vegetation in the Colombian Orinoco are appropriate variables to reflect the spatial heterogeneity of biodiversity and flooding dynamics. Additionally, within these biomes sub-basins of major rivers are identified that define the 62 landscapes of analysis that form the basis for the application of the criteria defined below (Figure 11).

5.2 Definition of Criteria for Identifying Biodiversity Values

Table 7 summarises the criteria for identifying biodiverse savannas in the ecoregion of the Colombian Orinoco. The table provides a brief description of the variables and indicators to be used for its implementation.

Criteria	Description Of The Variables	Indicator
CR 0. Excluded areas	Formal declaration of Protected areas at national scale (National Parks System), regional scale (Protected Areas by the Regional Environmental Corporations) and local scale (protected areas declared by municipalities and nature reserves of civil society).	1. Declared areas for conservation
CR 1. Biological importance	Areas containing concentrations of biodiversity values in terms of important plants and animals at a global, regional, or national level.	**Priority** conservation areas
CR 2. Integrity	Areas with ecosystems in good conservation conditions at landscape level, where viable populations exist with most or all of the species in their natural range.	1. Natural remnant patches
		2. Average area of ecosystems
		3. Connectivity – Euclidean distance
		4. Size/extent of natural patches
CR 3. Singularity	Areas that are or contain rare or endangered ecosystems (singularity).	1. Rarity
		2. Distribution
CR 4. Carbon stock	Areas that provide a role in the carbon flux.	1. Carbon in live organic material above and below ground
		2. Soil carbon

Table 7. Criteria for identifying biodiverse savannas of the Ecoregion of the Colombian Orinoco.

5.2.1 CR 0: Excluding Areas to Conversion

This criterion covers protected areas, and different areas of conservation as well as forest areas and wetlands, defined by law as 'non-transformation' areas and covered by the Directive 2009/28/EC of the European Parliament and Council (EU RES-D).

5.2.1.1 CR 0.1: Declared Areas of Conservation

From the protected areas included in the 'unique national register of protected areas', (Spanish acronym: RUNAP) different categories of management within the region are considered under CR0.1. Although some categories include managed areas, in this regional approach those areas are considered as being excluded areas to conversion, for which it is important to obtain cartographic information related to municipal (natural) parks, national parks, ecological and hydrological reserves, protective forest and nature reserves, and reserves of civil society. Together with conservation efforts, sustainable use and restoration of the terrestrial landscape are essential components of national and global strategies for conservation of biological diversity. Protected areas ensure the continuity of the natural ecological and evolutionary processes to maintain biological diversity, ensure the supply of environmental goods and services essential for human wellbeing, and guarantee the conservation of the natural environment or any of its components as the basis for maintaining the country's cultural diversity and social value of nature. They also offer opportunities for research, including adaptation measures to cope with climate change, environmental education, recreation, and tourism.

The Convention on Biological Diversity (CBD) set a target of at least 17 % of ecosystems to be included in national protected area systems. Colombia has been part of the convention since it ratified the CBD in November of 1994. To achieve this target, the national parks system in Colombia has led a national gap analysis and the conservation priorities identification process (Corzo 2008). In agreement with Awimbo *et al.* (1996) 'representation' is the primary criteria used in this evaluation, as it is the most appropriate in helping determine conservation priorities for a protected area system. In accordance with Pressey *et al.* (2002) it is "the proportion of species, vegetation types or other features contained in a system of protected areas with respect to a threshold level". The protected areas in Colombia (defined within the current national system of protected areas – SINAP) are an assemblage of protected areas, stakeholders, management strategies, and tools that fit together to contribute as a whole to the country's conservation objectives. It includes all the protected areas of public, private, or community governance, in the scope of national, regional, or local management (Zambrano *et al.* 2007).

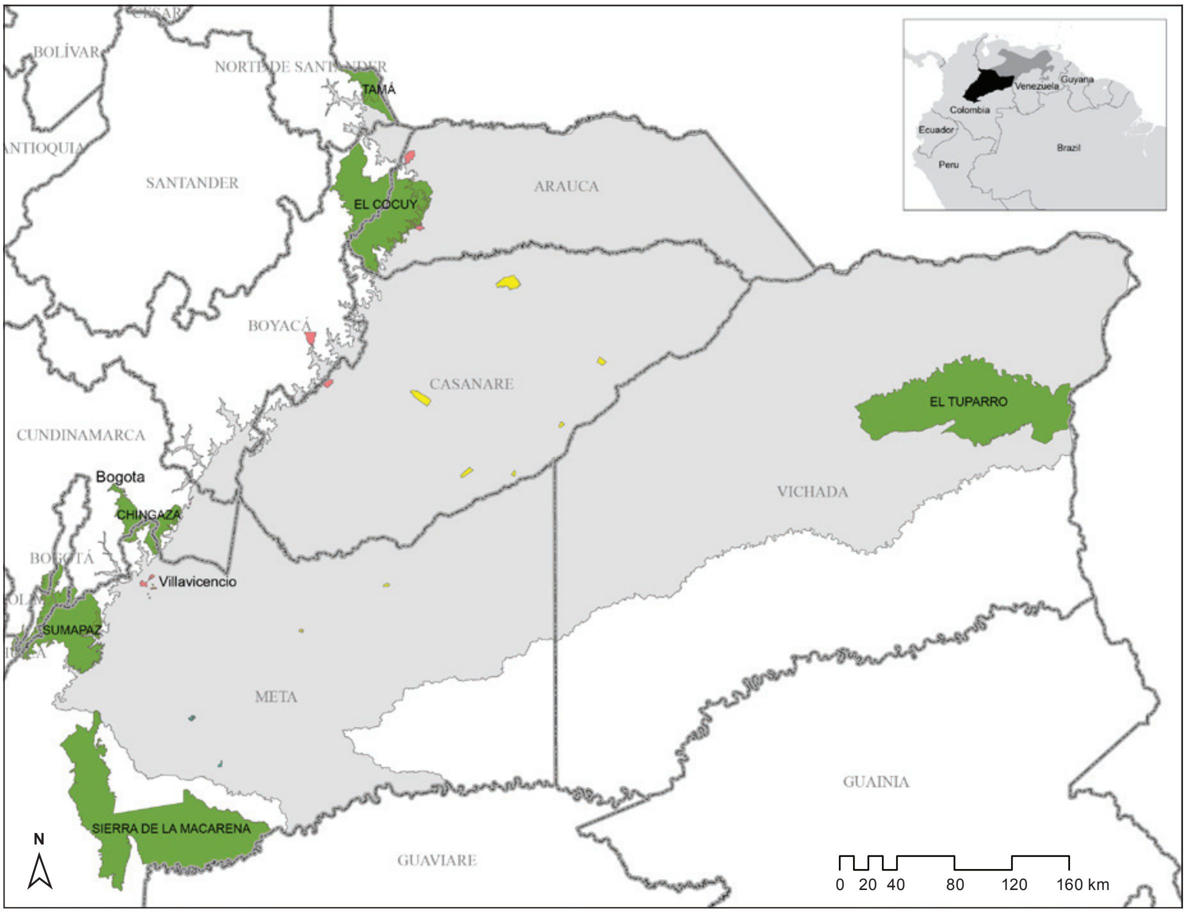


Figure 12.
Location of the protected areas in the Llanos.

- National Parks
- Recreation areas
- Soil conservation districts
- Regional National Parks
- National protected forest reserves
- Regional protected forest reserves
- Civil society natural reserves

5.2.1.2 Results

Annex 1 list the protected areas that are located within the study area. It highlights the low representation of National Park areas, which consist mainly of El Tuparro NP, with 580,000 ha. Partially located in the west of the Llanos are the national parks of Cocuy, Chingaza, Sierra de la Macarena, Tama, and Sumapaz. The presence of 65 areas of other categories of protection is shown, most of them located in the Department of Casanare.

5.2.1.3 CR 0.2: Areas of Forest, Wetlands and Peatlands

In the second category are forest areas and wetlands, defined by law as 'non-transformation' areas and covered by the Directive 2009/28/EC of the European Parliament and Council (EU RES-D). Forest areas in this category are defined as those that in 2008 did not show clearly visible indications of human activity, nor significantly disturbed ecological processes. Wetlands are those areas that are covered by water or saturated by water permanently or for a significant part of the year.

Forested areas and wetlands were defined according to the land cover map produced for the SuLu project, using the 2008 CORINE Land Cover methodology and the interpretation of Landsat satellite images for the same period. Forests were selected from the level 2 categories in the CORINE legend, including forested land cover types that reached a canopy height of five metres, dense or open, high or low, and in flood plains or the mainland. In addition, the selected wetland areas are level 2 categories in the CORINE Land Cover legend considering areas where the water table is at ground level on a permanent basis, namely marshes, bogs, and aquatic vegetation on water bodies.

In the case of peatlands, in Colombia they are commonly located above 3,200 m in the Andean region, although it is possible to find small areas of peatland in the Llanos region. According to the Corine Land Cover map, peatlands are defined as swampy areas with a spongy texture, whose soil is composed mainly of moss and decomposed vegetative material. In the Llanos there are no more than 25 ha of peatlands and therefore they cannot be identified at a 1:100,000 scale (IDEAM *et al.* 2012).

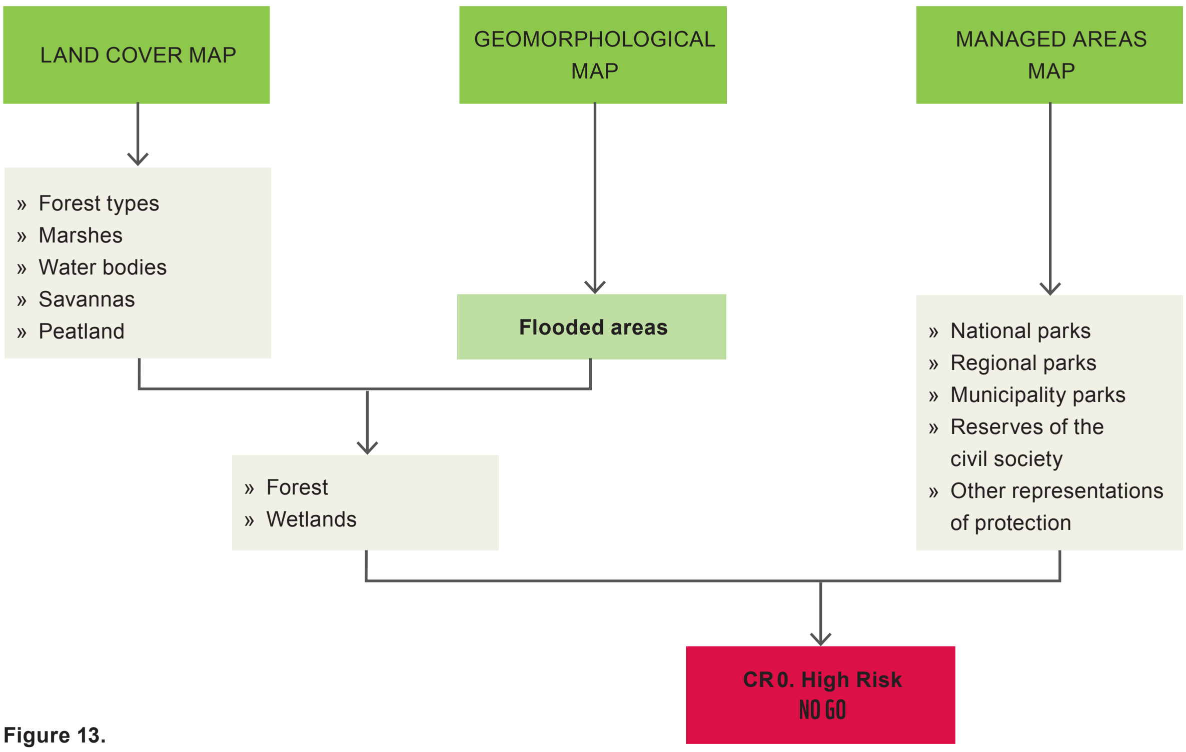


Figure 13.
Flow chart excluding areas to conversion.

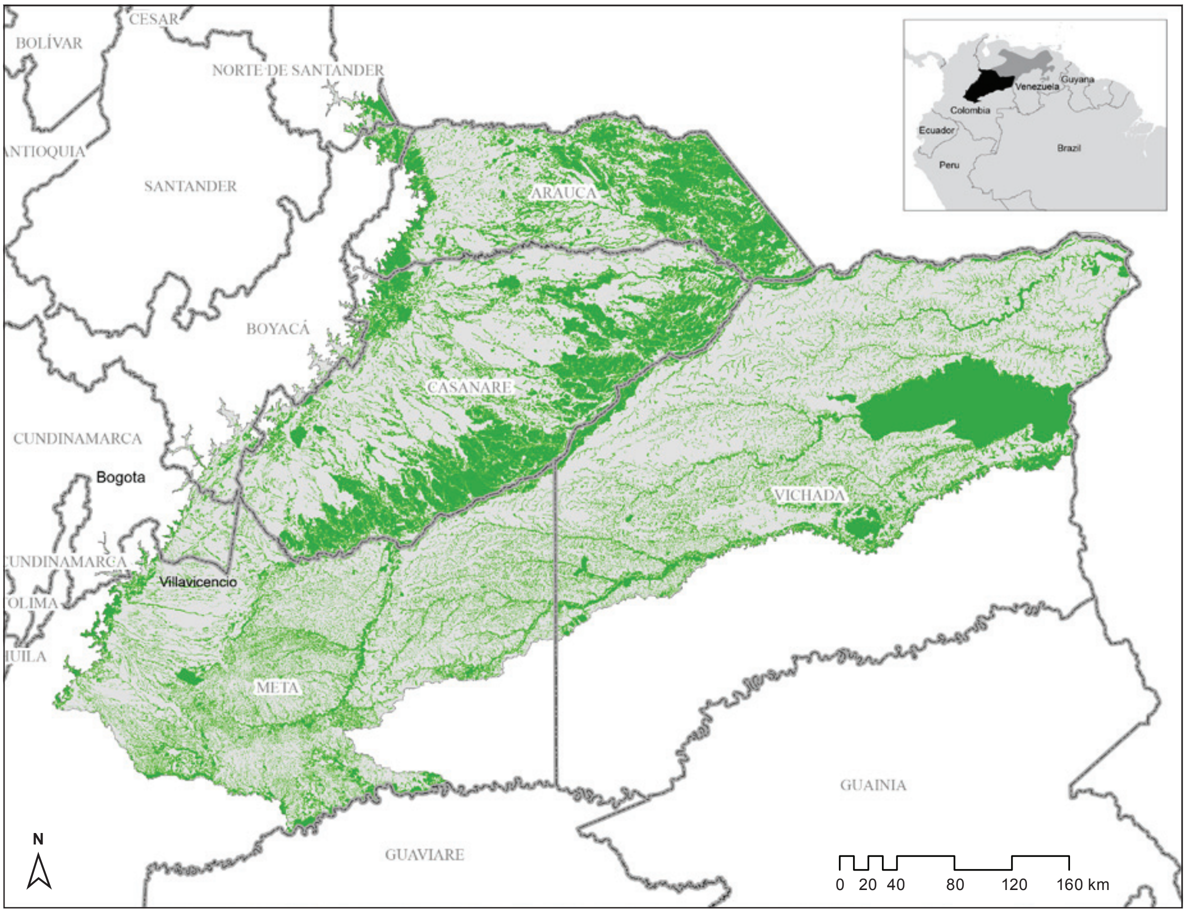


Figure 14.
Excluded areas of forests, wetlands, and protected areas

Excluded areas to conversion: Forest, wetland and protected areas

5.2.1.4 Results

In the study region, areas categorised by CR0 amount to 5,729,105 ha (31.7 % of the region, Table 8), meaning there should be no agro-commodity crop/plantation conversion for development of biofuels or bioliquids projects in these forests, wetlands, and protected areas. However, the remaining area of 68.3 % characterised by natural savannas require other criteria to evaluate their importance and define sustainable uses, as will be detailed subsequently.

Protected areas: Four per cent of the area is categorised as protected. The Tuparro National Park is the largest protected area in the region (580,000 ha) and the only national protected area that includes high savannas, or high dense grasslands and sandy grassland ecosystems. The remaining 140,000 ha are distributed in small areas of protection at regional and local level.

Wetlands: Land covered with water, or permanently saturated by water, or for a significant part of the year. For the region of the Llanos represent 12.1 % of the entire study area, distributed in humid areas with aquatic vegetation on water bodies, wetlands and high floodplain grasslands with a flooded period longer than five months.

Continuously forested areas: These areas represent 18 % of the study area and correspond to what has been determined by the Corine Land Cover classification as open or dense high forests, low areas or floodplain, and riparian gallery forests, fragmented forest with some pasture, and crop areas.

Water surface: Water bodies and permanent, intermittent, and seasonal streams that represent 1.5 % of the study area.

	Level 1	Level 2	Area
Excluding areas to conversion	Forests and other natural areas	High open forest land	2,229
		High open floodplain forest	8,407
		Low open forest land	1,157
		Open forest floodplain	35.29
		Riparian and gallery forest	1,453,607
		High dense forest land	524,637
		High dense flood forest	677,364
		Dense forest on the mainland	7,903
		Dense forest floodplain	141,166
		Fragmented forest	44,206
		Fragmented forest with pastures and crops	129.92
		Fragmented forest with secondary vegetation	144,482
	Wetlands	Aquatic vegetation on water bodies	18,058
		Artificial water bodies	51
		Reservoirs	1
		Rivers	246,553
		Wetlands	96,411
		Oxidation ponds	62
		Natural ponds, lakes, and wetlands	29
		Flooded dense grassland	2,074,482
TOTAL			**5,729,105**
Percentage of the region			**31**

Table 8. Extension of different land covers within the category of excluded areas according to Directive 2009/28/EC of the European Parliament. Map based on Corine Land Cover – 2008.

5.2.2 CR 1: National Biological Conservation Priorities Areas (Biological Importance)

5.2.2.1 CR 1: Priority Areas for Conservation

It is clear that the species assemblages suffer when their habitat is degraded or lost. Biological knowledge is therefore of vital importance to understand the role of species within ecosystems in order to be able to focus on conservation strategies. According to Schwartz *et al.* (2000), species richness in an ecosystem is essential to maximise the stability of ecosystem processes and to maintain ecosystems. In the case of grasslands, Tilman *et al.* (1996) suggest that a highly biodiverse grassland is more sustainable and more productive than a less diverse grassland. Other studies led by Miller and Spoolman (2012) show how plant productivity is high where the ecosystem value in terms of species is also high. In other words, a high variety of 'producing' species can produce more plant biomass, which in turn results in the capacity to support a high variety of 'consuming' species. Moreover, these authors highlight how the richness of species can maintain the stability and sustainability of an ecosystem. The greater the species richness, and the more complex the network of consumers and biotic interactions in an ecosystem, the greater the sustainability and ability to withstand environmental disturbances such as dryness and insect plagues. According to this hypothesis, a complex ecosystem with high species diversity that is the result of a variety of predator-consumer interactions is more likely to be able to respond to environmental stress (Miller and Spoolman 2012).

Finally, a species rich ecosystem with a high level of biomass plays a more robust role in the carbon and nitrogen cycle, by taking more carbon dioxide from the environment. According to Catovsky *et al.* (2002), more diverse ecosystems might store more carbon (as a result of increased photosynthetic inputs) that not only remain in plant biomass, but will be translocated to the soil via root exudation, fine root turnover, and litter fall. Therefore this criterion attempts to assess the areas that contain concentrations of biodiversity values in terms of important plants and animals at global, regional, or national levels. Faber-Langendoen and Josse (2010) identify and recommend the identification of patterns of diversity in natural savannas and grasslands areas, as they are an important measure for evaluating the high diversity of an area, especially those of plants.

Multiple studies have been developed in the Orinoco that identify important or priority areas for biodiversity conservation based on the implementation of different methodologies. The areas identified by these studies were taken as reference points to highlight their importance, regardless of the method used. The sources of information used to calculate the priority areas for conservation are shown in Table 9.

Citation	Title
Biocolombia – UAESPNN (1991)	Design strategies, mechanisms, and procedures for the implementation of SINAP
Fandino and Van Wyngaarden (2005)	Priorities of Biological Conservation in Colombia
TNC & WWF (2006)	Providing Safe Haven: Habitat Conservation for Migratory Birds in the Orinoco River Basin. Final report to the US Fish and Wildlife Service
Galindo *et al.* (2007)	Environmental planning of the hydrocarbons sector for the conservation of biodiversity in the plains of Colombia
Corzo (2008)	Priority areas for the conservation 'in situ' of continental biodiversity in Colombia
Lasso *et al.* (2010)	Biodiversity of the Orinoco Basin
Usma and Trujillo (2011)	Casanare Biodiversity: Strategic Ecosystems of the Department. Government of Casanare – WWF Colombia
Corzo *et al.* (2010)	Environmental planning for the conservation of biodiversity in the operational areas of Ecopetrol located in the Middle Magdalena and Llanos of Colombia

Table 9. Selected sources to obtain the rate of prioritized areas for conservation in the ecoregion of the Colombian Orinoco.

Most of the studies generated a thematic map of priorities, and identified these priority areas based on spatial analysis. Many of these studies have overlapping geographic scope, which were used to develop a coincidence index to find conservation priority areas across the landscape.

$$CI = \frac{\sum_1^n P}{\sum_1^n SA}$$

Where:
CI is the coincidence index,
P is the conservation priority result of each conservation portfolio (n) in binary format, and
SA is the geographic scope of each conservation portfolio study in binary format.

After calculating this index, geographic areas were arranged according to the hierarchical value and reclassified by the CBD minimum target for ecosystem representation (minimum representation of the country must be 17 % and is non-negotiable):

High biological priorities areas: areas where most of the conservation portfolios coincide and represent at least 17 % of the Llanos region.

Medium biological priorities areas: areas where the average of conservation portfolios coincides and represent between 18 and 33 %.

Low biological priorities areas: areas where the coincidence index is low and represents areas with few conservation priorities values.

5.2.2.2 Results

The criteria of biological conservation priorities areas is based on the analysis of Corzo (2008), which highlights the ecosystems with lower representative index into the National Protected Areas System. We have taken these outputs and have integrated them with information from different portfolios identified in the Orinoco region.

In order to determine conservation goals, Corzo (2008) used the representative criteria to identify priority conservation areas using the threshold of 17 % as the minimum amount that we should conserve. Such areas are defined as High Priorities in accordance with the conclusions of the last meeting of the Convention on Biological Diversity (CBD) in Nagoya. For the region, about 6.08 million ha are in this category, corresponding to 34 % of the study area, including the savannas that surround the mouth of the Casanare River, and the basins of the Paz de Ariporo River, la Hermosa B, the lower Tomo River and its catchment basins, as well as the wetlands of Arauca.

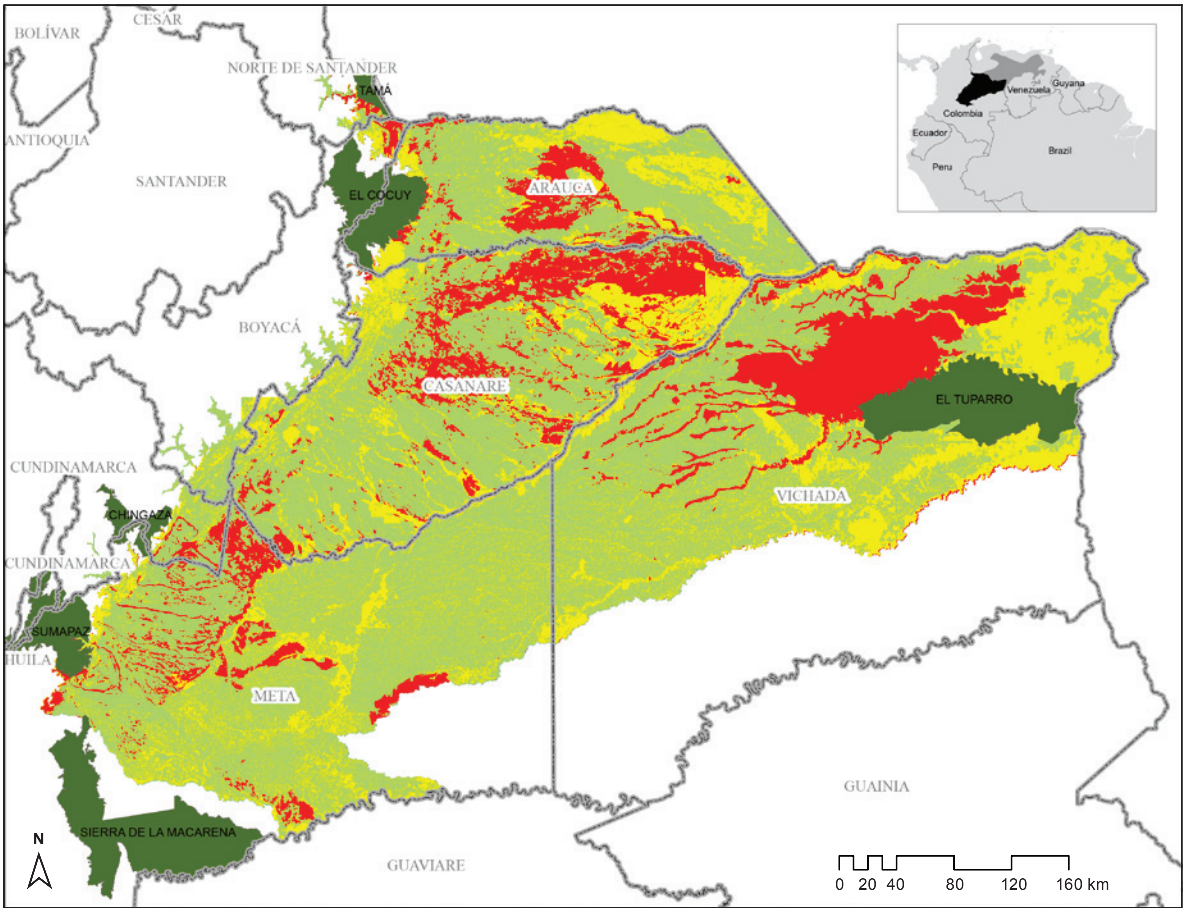


Figure 15.
Biological significance for the Llanos region based on Corzo (2010).

- National Parks
- High biological significance
- Medium biological significance
- Low biological significance

Medium priority areas are those that achieve representativeness values of between 17–33 %, corresponding to areas of dense floodplain grasslands in the states of Casanare and Arauca. This category also covers the savannas of the southern Orinoco region of Puerto Gaitán and Mapiripán, and north eastern savannas in the areas of Cumaribo, Puerto Carreño. A total of 6,029,188 ha (33 % of the savannas of the Orinoco) belong to this category.

Finally, the low priority areas correspond to zones of intervention that are in the foothills. Some areas of grasslands to the south of the Meta River between the municipalities of Puerto Gaitán, Santa Rosalía, and Primavera also fall into this category.

5.2.3 CR 2: Land Cover Integrity

This criterion represents areas with ecosystems in good conservation conditions at the landscape level, where viable populations exist with most or all of the species in their natural range. According to Mackey (2005), ecological integrity refers to the permanent health or proper functioning of ecosystems at global, regional, and local levels, as well as its continued provision of renewable resources and environmental services. Similarly, the National Park Service of Canada (Canada National Parks 2006) considers that the ecosystems of an area have integrity when their original components are intact, including the abiotic features (physical elements such as water and rocks), biodiversity (composition and abundance of species and communities in an ecosystem) and ecosystem processes (those that determine the functioning of ecosystems, such as fire, flooding, and predation). Several authors agree that a healthy ecosystem has integrity when it is stable, sustainable and active, maintains its organisation and autonomy over time, and retains the ability to return to its original condition when disturbed (Constanza, Norton, & Haskell 1992; Rapport, Costanza, & McMichael 1998).

The integrity concept implies a notion of ecosystem unity that is functional and necessary for human wellbeing. However, past and current human pressure on grassland ecosystems has degraded its functionality, resulting in today's low integrity value. Such areas need integral conservation and restoration management actions. By definition, ecosystems are dynamic systems where internal elements (in terms of flora, fauna, microorganisms, soil, etc.) change over time and respond to external conditions to which they are subject at any given time. The natural processes that sustain the ecological integrity of ecosystems include the evolution of new species and the spread of existing species of flora and fauna. Worldwide, ecosystems are effectively 'managed' by natural selection that determines the differential permanence of species under the prevailing conditions in the system. Ecosystems are also at work modifying the local environment (Mackey 2005).

Integrity tests allow us to assess the current state of ecological systems and landscapes as a cumulative expression of different human pressures. These can alter the structure of a landscape, hinder ecological flows (Gardner *et al.* 1987), and compromise functional integrity by interfering with ecological processes that facilitate the persistence of populations, the alpha diversity and its 'health' as a natural system. The ecological integrity of a system is evaluated through the development of indicators that provide information on the status of an ecological system, taking into account the different scales in organisation and time. For example, Noss (1990) proposed an analysis of factors that measure the composition, structure, and function of a system at a given moment in time, in comparison to a historical reference. In places where the impact of modern anthropogenic activity is absent for a long time, integrity is defined as the baseline condition (Groves 2003).

To define the ranges or thresholds of CR2, an analysis of ecological integrity using Fragstats (McGarigal *et al.* 2002) was performed. To assess the rates of integrity at the landscape level, we used the 2008 land cover map at 1:100,000, produced by WWF within this project. The indicators used were adapted from the proposed methodology for assessing integrity (Galindo *et al.* 2007; Zambrano *et al.* 2007) in which three ecological attributes are considered: i) heterogeneity, ii) spatial configuration, and iii) continuity, with indicators that assess the composition, structure, and function of ecosystems.

5.2.3.1 CR 2.1: Remaining Land Cover

Changes in ecosystems and vegetation cover are considered to be of great importance in determining the integrity of an ecosystem over time. Fragmentation is defined as the disruption of large extensions of habitat or areas of land into small plots, and has become an environmental problem that has affected all global ecosystems (Forman 1995). Noss *et al.* (1999) determined that fragmentation has been caused by disturbances that result in the reduction and isolation of areas of natural habitat at the landscape level. The shape, size, and extent of ecosystems give us an insight into the composition and configuration of a territory that determine the dynamics of ecological processes within ecosystems and are a useful tool for policymaking of natural resources management. Understanding the distribution of ecosystems provides an insight into the spatial patterns and trends of ecosystems. The high heterogenity in terms of size and shape of the Orinoco savannas allows us to understand the ecological processes that are fulfilled by the different types of savannas in the area.

A remnant patch is an area of natural land cover for each landscape unit divided by the total area of the landscape. This is calculated as the sum of the area in hectares of all patches or patches that make up a given class and is divided by the total area of the unit of analysis:

$$Rem_{jt} = \left(\frac{a_{ijt}}{A_{jt}}\right) * 100$$

Where:

Rem_{jt} = the percentage that the remnant patch of the natural land cover within an analysis unit j at time t.

a_{ijt} = area with natural land cover within an analysis unit j

A_{jt} = total surface of unit of analysis j

The unit of measurement for this indicator is a percentage that ranges from 0 to 100. When the value tends towards 0, it indicates a complete or strong transformation of the natural land cover, while values closer to 100 indicate a low (or absence) of transformation. Converted land cover types were not assigned any value. For normalisation, the highest percentage of the land cover present in all units of analysis was extracted. The percentage value found by analysis unit is divided by this maximum value and an index is obtained whose range is from 0 to 1. When closer to 0 it indicates that the unit of analysis has a very low natural cover and increases when moving towards 1. This index is an assessment of the state of the land cover that compares the remaining land cover area to the total area of the unit.

5.2.3.2 CR 2.2: Number of Patches

The number of patches gives us a measurement to understand the degree to which the habitat is disrupted (Gonzalez 2008). Habitat fragmentation is one of the anthropogenic processes with highest devastating impact on biodiversity because it involves the loss of habitat, since a portion of the landscape is transformed into another type of land use and natural flows of matter and energy are inhibited. Similarly, loss of habitat is the most important reason for the extinction of species in recent times (Zambrano *et al.* 2007). The smaller patch size and higher vulnerability are adverse environmental conditions to species, which are more frequent along the patch edges, and therefore there is a greater probability of extinction. On the other hand, a lower number of individuals means a higher probability of declination for the populations that are likely to remain in the patches (Martin *et al.* 2008).

In the initial stages of the process of fragmentation, loss of surface is the main cause of biodiversity decline, while in later stages the effects of isolation of individuals become much more important (Rosell *et al.* 2002). Creating patches involves generating edges, abrupt or gradual, that will produce changes in the flow of water, wind, or solar radiation, which consequently have direct or indirect effects on many species. Therefore, it is important to characterise the area surrounding the patches as the 'matrix', an area that has a great influence on the patches. The smaller and more irregular the patches are, the more influence the matrix will have on them due to the lower area/perimeter relationship, causing species movements. The influence increases further when the matrix differs greatly from the natural habitat. This series of influences is known as the 'edge effect' (Martin *et al.* 2008).

This index equals the number of patches of the corresponding type in the landscape. The number of fragments/patches of each ecosystem is a measure of its fragmentation. Its importance lies in that it helps to understand the variations of the original structure of the ecosystem on a timeline. This is calculated as the arithmetic sum of the number of patches (n) of the ecosystem:

$$NP_{ijt} = \sum n_{ijt}$$

Where:

NP_{ijt} = number of patches (i) in a unit of analysis (j) during time period (t)

$\sum n_{ijt}$ = sum of number of patches (i) in a unit of analysis (j) during time period (t)

The unit of measurement for this indicator is the number of patches. The range is from 1 to ∞ where 1 corresponds to a single fragment per unit of analysis and ∞ corresponds to the maximum number of patches per unit of analysis. It is expected that the best-preserved natural ecosystems are less fragmented and that the detriment of that state is reflected in a greater number of patches. Although this measure alone offers no real value of functionality and composition, it is used for comparing land cover classes within units of analysis under the assumption that there is a negative effect of fragmentation on species populations. Values are normalised to create an index ranging from 0 to 1. For standardisation, the maximum value with the largest number of patches is extracted from the analysis unit. Each value representing the number of patches found by analysis of the units is divided by this maximum value and an index is obtained with a range from 0–1, where 0 indicates units with fewer patches, increasing to 1 as the number of patches increases. Anthropogenic land covers were not assigned any value.

5.2.3.3 CR 2.3: Average Area Size

According to Forman (1995), the complexity of form is higher in small patches and lower in large patches. Ecologically this has severe implications for the future viability of ecosystems that may be potentially sensitive to the adverse effect of the surrounding matrix. In other words, if the shape of large areas is altered, small patches can change their functionality, condition, and health. Thus when working at the analytical unit of basins, the distribution of both natural and transformed patches can be identified within each of these basins and related to their function within the region.

The average area of ecosystem is the arithmetic mean of the area of the patches that make up a class calculated in m2, and is calculated as follows:

$$AREA\_MN_{ijt} = \frac{\sum_{j=1}^{n} a_{ijt}}{n}$$

Where:
$AREA\_MN_{ijt}$: average area of patches (i) per unit of analysis (j) in a period of time (t)
a_{ijt} = area of patch (i) per unit of analysis (j) in a period of time (t)
n = number of patches

The unit of measurement of this indicator is in metres, and it ranges from 1 to 100. When the value of AREA_MN is close to 1, the average area of the patches is very low; when the value goes towards ∞, the patches tend to be larger. It is expected that the best-preserved natural ecosystems have higher values of average area size and that the detriment of that state is reflected in a low representation of small areas. Although this measure alone offers no real value of functionality and composition, it is used to compare land cover classes within units of analysis, under the assumption that an increase in edge effect will increase when the index is higher. Values are normalised to create an index ranging from 0 to 1. For standardisation, the maximum value of the AREA_MN is extracted from the unit of analysis. Each AREA_MN value obtained by unit is divided by this maximum value, and an index obtained with a range from 0–1, where 0 indicates units of analysis with small average areas of metres and increasing towards 100 when they achieve values of kilometres. Anthropic land covers were not assigned any value.

5.2.3.4 CR 2.4: Connectivity

It is known that changes in land use affect the ability of organisms to move and disperse, due to the fragmentation process to which populations are subject, bringing problems for their management and conservation (Sastre, de Lucio, & Martinez 2002). The preservation of ecological connectivity (also called functional connectivity) in the territory has emerged as a policy objective of nature conservation and is understood as the ability of organisms to move between separate patches of a given habitat type (Gurrutxaga 2007). Additionally, this concept has been gradually integrated into other strategies that will allow connectivity of linear elements of the landscape and will have a key role in the quality of landscape and the protection of connectivity, through corridors and barriers. Gurrutxaga (2007) also mentions that the term connectivity is commonly used as a synonym for permeability by two interpretations: i) stated as a shared connection/relationship between different populations; and ii) stated as a more general property of a territory that is directly related to the conservation of connectivity for all the different scales.

Our focus on connectivity is mainly associated with the first interpretation, which means that the relationships, ecological flux, associations between different ecosystems, as well as large proportion of native species richness, are required in order to maximise ecosystem stability and sustain function (Schwartz *et al.* 2000). Therefore our approach includes natural mosaics of different ecosystems and the connectivity measured around them.

Connectivity was calculated taking into account the average of the shortest Euclidean distance between the nearest neighbours of natural patches, and is calculated as follow:

$$ENN\_MN_{ijt} = \frac{\sum_{j=1}^{n} h_{ijt}}{n}$$

Where:

ENN_MN_{ijt} = Euclidian distance of the patches (i) in each of the units of analysis (j) during a period of time (t)

h_{ijt} = distance (h) between patches (i) in each of the units of analysis (j) during a period of time (t)

n = number of patches for each class

The range is from 1 to ∞. When the value of ENN gets close to 0, the distance to the nearest neighbours decreases; when the value increases, it means that the patches are more separated. It is expected that the best-preserved natural ecosystems are less fragmented which is reflected in a shorter distance between patches.

5.2.3.5 Sum of the Integrity Components

For the final calculation of the Integrity criterion (CR2), the normalised values for each of the components of integrity are summed. For this purpose, the normalisation value obtained from the indices of connectivity and numbers of patches are reversed so that the summation reflects the true value of integrity. Therefore, the judgment formula 2 is:

$$CR2 = REM + NP + AREA\_MN + ENN\_MN$$

Where:
CR2 = Integrity Indicator (CR2)
REM = Normalized Remanence Index
NP = Inverse index of normalised number of patches.
AREA_MN = Index of Average area normalised patches
ENN_MN = Inverse index of normalised connectivity

For interpretation, the values are grouped into three classes of Integrity based on the estimated average value and the standard deviation of the total set of observations:

High integrity: the average value (x) plus a standard deviation (σ). Every indicator value above this limit is set as 'high', i.e. indicator values greater than x +0.5 σ.

Low Integrity: the average value (x) minus half standard deviation. Any value below this limit value is defined as 'low integrity', i.e. indicators lower than σ x -0.5.

Medium Integrity: defined as the mean, by default, of all indicator values between the two limits above: indicator values that are located between the interval (x +0.5 σ., X-0.5 σ.), including limits.

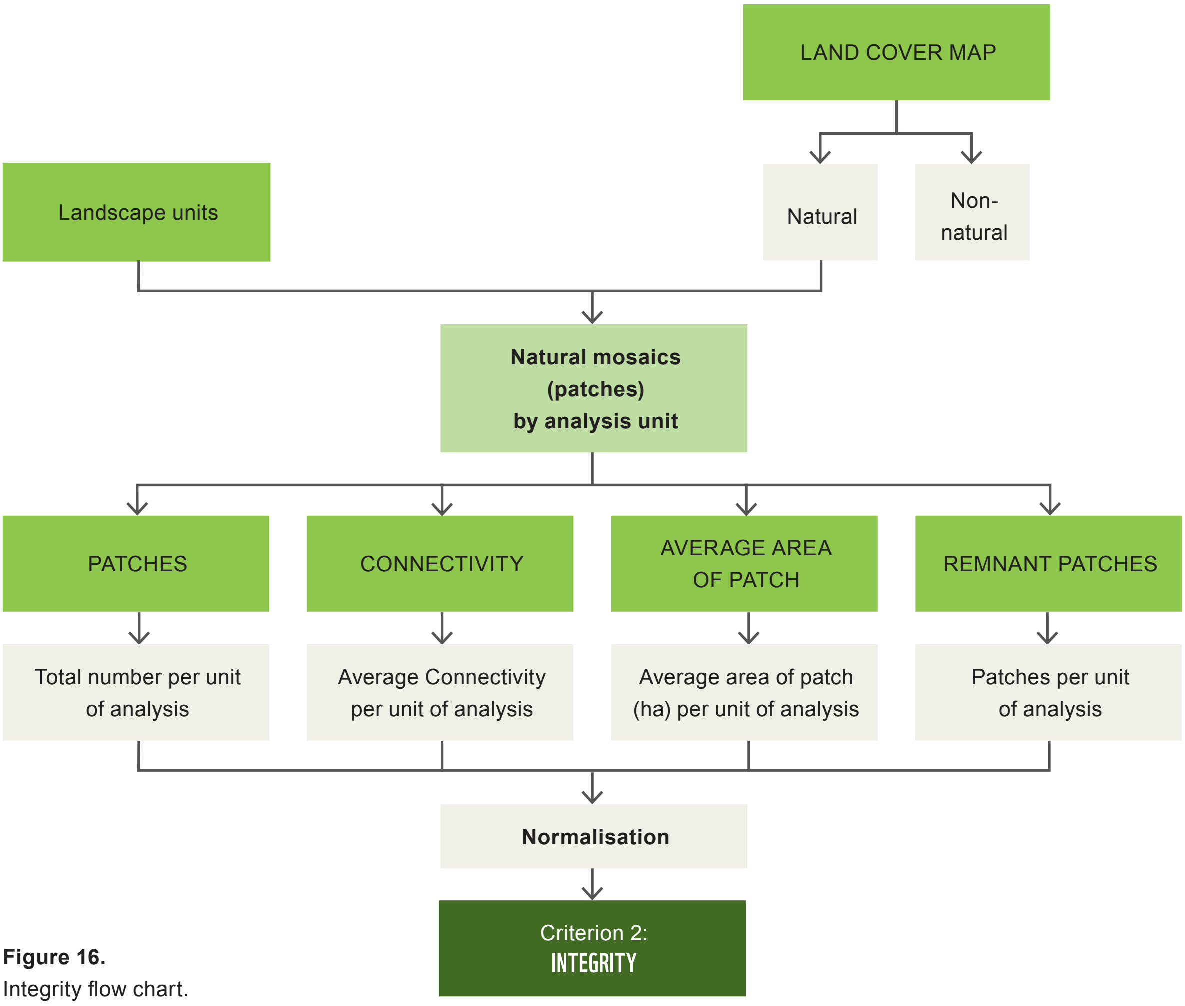


Figure 16.
Integrity flow chart.

5.2.3.6 Results

This analysis takes into account several metrics, and although this measure alone offers no real value of functionality and composition, it is used to compare land cover classes within units of analysis. Values are normalised to create an index ranging from 0 to 1. For standardisation, each index is obtained with a range from 0–1 where 0 indicates units with low integrity, increasing to 1 as the integrity increases. Anthropic land covers were not assigned any value.

With respect to remaining natural land cover, foothill watersheds are those with values less than 60 % per unit of analysis (Annex 2). It highlights the low remanence of the unit of the Negro River, which is barely 10 %. The units of analysis of the foothills of the rivers Guacavia, Tunía, Guatiquía, Metica (Guamal-Humea), the tributaries of the Meta River, the canyon Guanapalo, and the Humea River have values of remanence between 19 and 30 %. The units of analysis of Metica-Manacacias, floodplains, and high savannas have a remanence greater than 60 % and in some cases, reach 99.6 % of the total area.

As for the number of remaining fragments, the units of analysis with greater fragmentation are those in the foothills, to which are added the Manacacias River, the Yucao River, and the tributaries of the Metica-Manacacias. In these

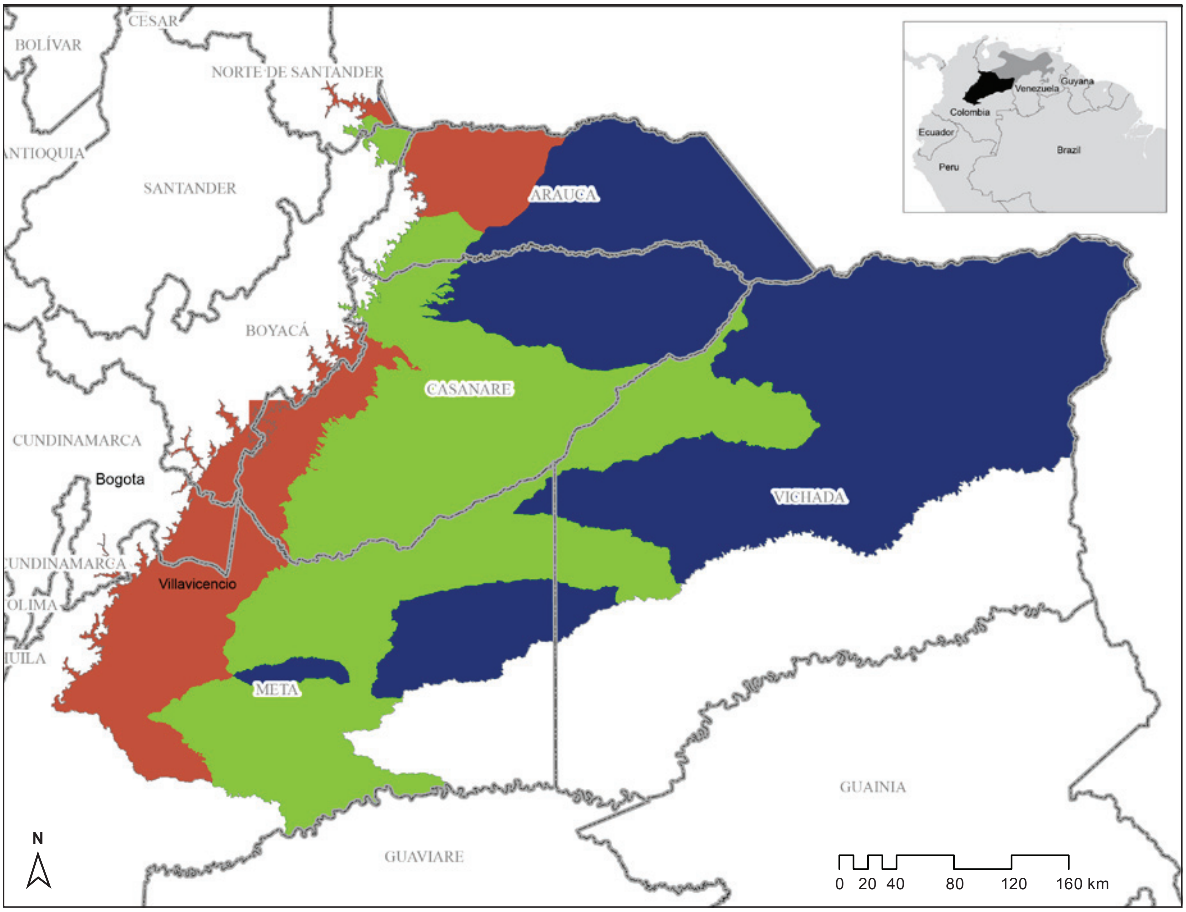


Figure 17.
Map of integrity for the Llanos region.

Low integrity
Medium integrity
High integrity

units, numbers of fragments range from 200 to about 800. At the analytical scale, the units near the Orinoco River (Lower Vichada, Vichada tributaries, Aguaclarita canyon, Lioni caño, lower Tomo River and tributaries of the Orinoco) have a single fragment, while the neighbouring units can reach levels from 2 to 100 fragments.

As for the average patch area, close to the Orinoco River the units of analysis have a high value while the average area of patches in the low foothills is between 25–200 ha, the latter ones again being of the lowest area. Finally, in terms of connectivity the same pattern is observed, showing greater isolation of the fragments of natural land covers in the foothill areas.

Integrity in the foothill area is low in most units of analysis, and intermediate in those corresponding to the Casanare River basins, Ariporo and Pauto. Meanwhile the units of Metica-Manacacias have intermediate integrity (except the basin of the canyon Cumaral). The units of analysis of the floodplain have intermediate integrity in the south western part corresponding to southern Casanare and northern Meta, while this value is high in the north of Casanare and the area of Arauca. In the high plains the basins have high integrity, and the basins of the rivers Muco, Guarrojo, and Meta, and the tributaries of the Meta River, are all of intermediate value.

5.2.4 CR 3: Ecosystem Singularity

According to Hunter and Gibbs (2007), the process of ecosystem classification clouds the issue of ecosystem uniqueness, because each type of ecosystem may seem unique under any classification. For this reason, and to rescue ecosystem values like rarity and distribution, we have called this criterion Ecosystem singularity in order to highlight some areas with special value to be conserved.

5.2.4.1 CR 3.1: Ecosystems Rarity

Ecological systems with a restricted distribution are of great importance in terms of biodiversity. They may become small enclaves important for the functionality of ecosystems and the conservation of biodiversity within. In addition to gallery forests, there is a set of ecosystems in the territory that are of great interest due to their uniqueness and fragility, namely rock outcrops, wetlands, and sandy and woody savannas.

These ecosystems may be important in terms of species diversity, and most are highly fragile. Disturbance of these ecosystems makes their recovery difficult if not impossible, as the taxonomic uniqueness and the genetic, ecological, and physiological characteristics of the species and the complexity of ecological processes taking place in these ecosystems are not repeatable in other habitats.

To determine the rarity of an ecosystem, we adapted the proposal by Galindo *et al.* (2007). As a reference the land cover map 2008 of the Orinoco (scale 1:100,000) produced by the IDEAM *et al.* (2012) was used, and adjusted to assess land cover types by their distribution and rarity.

The rarity index is determined by the percentage of the area of a land cover (i) in an area of interest (h) compared to the total area of the land cover in the entire study area (k). This index allows us to assess how land cover types are distributed within the landscape (h) over the study area (k). For its calculation in the land cover (i) the following equation is used:

$$PEA_{ihkt} = \left(\frac{ATE_{iht}}{ATE_{jht}}\right) * 100$$

Where:

PEA_{ihkt} is the percentage that represents the total area of the land cover (i) present in a unit of analysis (h), of the total surface the land cover occupies in a study area (k) in time period (t).

ATE_{iht} is the total area (hectares) of land cover (i), in the landscape (h) in time period (t).

ATEjht is the total area (hectares) of natural cover (j), in the landscape (h) at time period (t).

The unit of measurement for this indicator is a percentage and is measured for each unit of analysis. The range is from 0 to 100. PEA approaches 0 when the land cover type is very rare and it approaches 100 when it is very common.
The assessment of the rarity of the distribution of conservation targets according to their distribution in each unit of analysis is done by normalisation of the results (Table 10).

Description	Distribution	Qualification
If the land cover is less than 10 % of the unit of analysis over the entire study area.	Very rare	5
If the land cover is less than 10 and 30 % of the unit of analysis over the entire study area.	Rare	4
If the land cover is less than 30 and 50 % of the unit of analysis over the entire study area.	Moderately common	3
If the land cover is less than 50 and 70 % of the unit of analysis over the entire study area.	Common	2
If the land cover is more than 70 % of the unit of analysis over the entire study area.	Very common	1

Table 10. Classification of the rarity of land covers in the ecoregion of the Orinoco.

5.2.4.2 CR 3.2: Ecosystem Distribution

Worldwide, biomes, landscapes, ecosystems, and habitats do not have a uniform spatial distribution. The geographical location reflects the role of each of the ecosystems within a system. So, understanding the distribution of the different ecosystems allows an insight into their interrelation and their functions.

This is the percentage area of a land cover of interest (i) in the unit of analysis (h) with respect to the total area of land cover within the same sub-basin (% of presence). This index allows us to assess the distribution of land covers within each unit of analysis, and is calculated as follows:

$$PEA_{ijht} = \left(\frac{ATE_{iht}}{ATE_{ikt}}\right) * 100$$

Where:

PEA_{ijht} is the percentage that represents the total area of the land cover (i) present in a landscape (h), compared to the total surface the land cover (i) occupies in the Llanos area (h) in time period (t).

ATE_{iht} is the total area (hectares) of the land cover (i), in the area of landscape (h) in time period (t).

ATE_{ikt} is the total area (hectares) of natural cover (i), in the Llanos (k) in time period (t).

The unit of measurement for this indicator is a percentage and is measured for each unit of analysis. The range is from 0 to 100. When PEA approaches 0 the analysed land cover is peripheral and approaches 100 when it is endemic or unique to this unit. Similarly to the previous index, the interpretation of the results is made based on the normalisation (Table 11).

Description	Distribution	Qualification
If the land cover (i) provides more than 85 % of its area within the landscape (h) with respect to the total area of land cover (i) in the Llanos area (k).	Restricted	5
If the land cover (i) is between 50 % < x < 85 of its area within the unit of analysis (h) with respect to the total area of land cover (i) in the Llanos area (k).	Limited	4
If the land cover (i) is between 25 % < x < 50 of its area within the unit of analysis (h) with respect to the total area of land cover (i) in the Llanos area (k).	Extended	3
If the land cover (i) is between 10 % < x < 25 of its area within the unit of analysis (h) with respect to the total area of land cover (i) in the Llanos area (k).	Disperse	2
If the land cover (i) has less than 10 % within the unit of analysis (h) with respect to the total area of land cover (i) in the Llanos area (k).	Wide disperse	1

Table 11. Classification of the distribution of land covers in the ecoregion of the Orinoco.

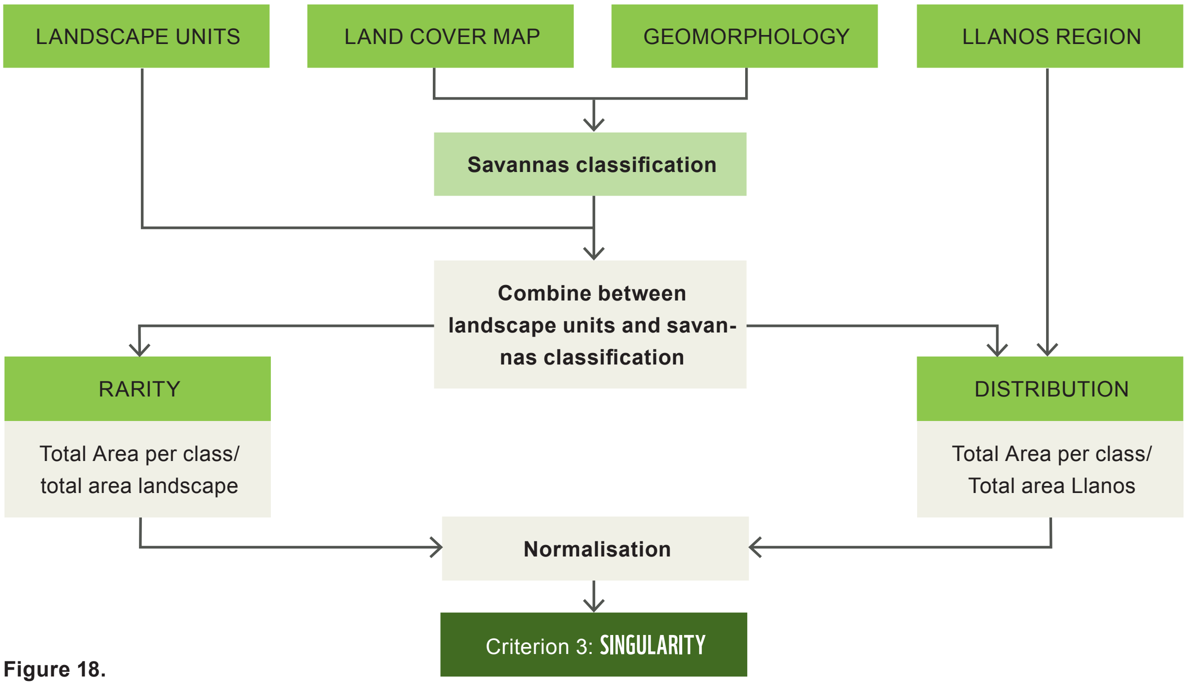


Figure 18.
Singularity flow chart.

5.2.4.3 Sum of the Singularity Components

For the final calculation of the Singularity criterion (CR3), the normalised values for each of its components are summed. For this purpose, the value obtained by normalising the distribution index is reversed so that the sum reflects the true value of singularity. Thus the formula of criterion 2 is:

$$CR3 = RARITY + DISTRIBUTION$$

Where:
CR3 = Index of Singularity
RARITY = normalised index of Rarity
DISTRIBUTION = normalised Index of Distribution

For the interpretation and formation of the three classes, the values high, medium, and low uniqueness are defined. For the definition of these criteria the average value and standard deviation of the total set of observations is estimated and based on results referencing these three classes:

High singularity: the average value (x) plus a half standard deviation (σ). Every indicator value above this limit is set as 'high', i.e. indicator values greater than x +0.5 σ.

Low singularity: the average value (x) minus half standard deviation. Any value below this limit value is defined as 'low integrity', i.e. indicators lower than σ x-0.5.

Medium singularity: defined as a means, by default, all indicator values between the two limits above; indicator values that are located between the interval (x +0.5 σ., X-0.5 σ.), including limits.

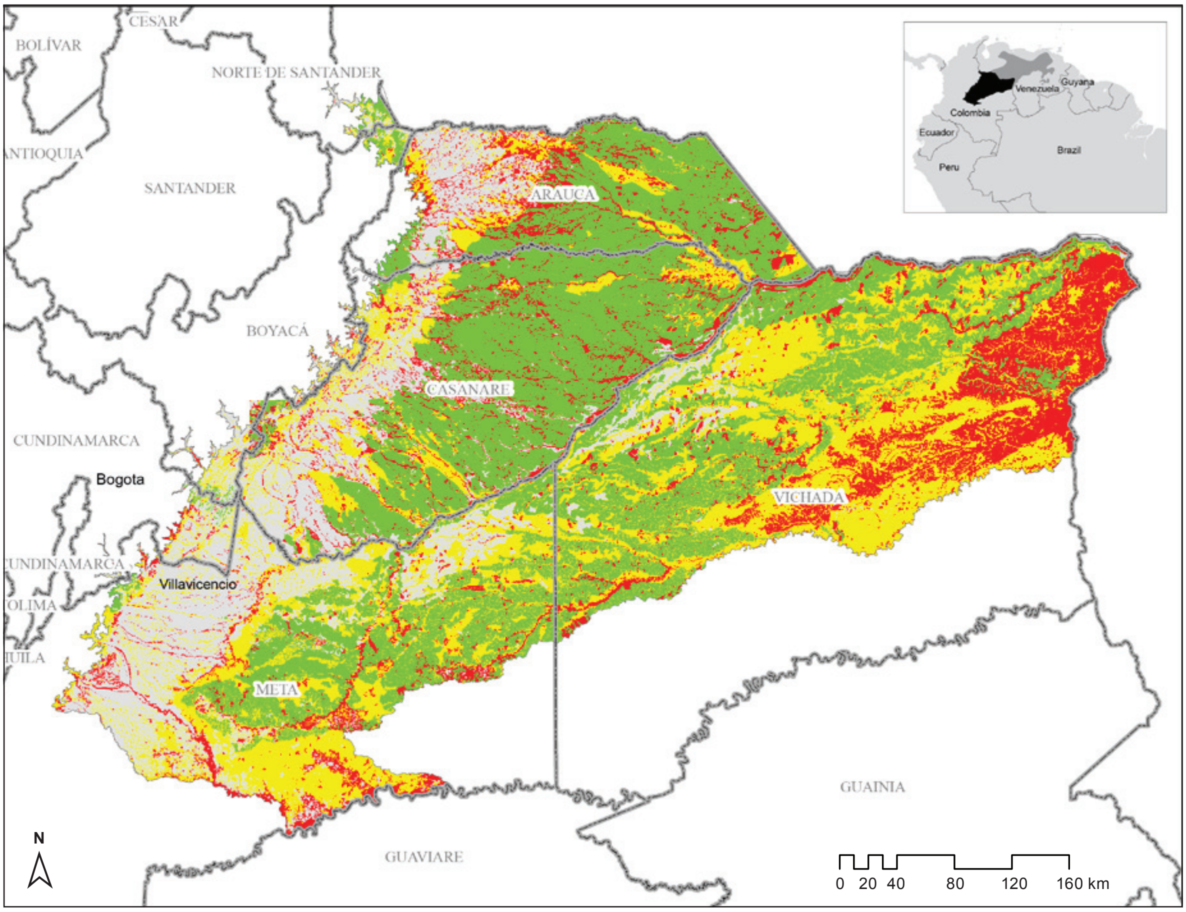


Figure 19.
Map of singularity of the Llanos.

- No natural ecosystem
- Low singularity
- Medium singularity
- High singularity

5.2.4.4 Results

Based on our analysis, the unit of the upper Apure River of the foothill savannas is one of the units of analysis that contains rare ecosystems (Annex 3) and occupies 2,792 ha corresponding to high dense forests. Moreover, about 432,427 ha of rare ecosystems of dense grasslands in rolling savannas are found in the high plains of the units of analysis of the upper Vichada. Also the units of analysis of the Cravo Norte, Cinaruco, Ariporo and Casanare rivers, the tributaries of the Orinoco and the Arauca and the caño Samuco are areas with rare ecosystems mainly represented by dense grassland in rolling savannas, rocky outcrops, and sandy savannas.

As for the distribution of ecosystems over the entire savanna region, only five units have unique ecosystems. The units of savannas of the foothills of Chivoy, the high plains of the tributaries of the Orinoco River, and the River Muco and the savannas of the foothills of the Negro River and south Cravo, are those with unique ecosystems of open and rocky grasslands. Meanwhile the unit of the tributaries of the Orinoco River is the only one with ecosystems with limited distribution represented by rocky outcrops. Finally, six units have widely distributed ecosystems: the Ariporo, Casanare, and Cusiana rivers of the savanna foothills, tributaries of the Orinoco River, the Cravo Norte River of the flooded savannas, and the Middle Guaviare of the savannas of Manacacias-Metica, represented by the ecosystems of dense scrubs, marsh vegetation, low open forest, and sandy grasslands.

Consequently, the units with the highest values of singularity are found along the Orinoco riverbank, especially in the region of Andén Orinocense, followed by areas of open forests and open grassland, and the vegetation of the floodplain swamps (Figure 19).

5.2.5 Definition of Criteria for Identifying Carbon Stocks

5.2.5.1 CR 4: High Carbon Stocks

Sustainable agriculture requires reduced emissions through the adoption and implementation of sustainable practices, something EU RED regulations promote in avoiding land use change caused by expansion of production of biofuels. It means that biofuels cannot be produced in soils with high carbon stock, such as continuous forests, wetlands, or peatlands. Therefore EU RED sets a mandatory minimum threshold of at least 35 % emission savings compared to fossil fuel alternatives. This minimum limit of emission savings will increase to 50 % in 2017 and 60 % in 2018 for new crops for biofuel production (EU RED 2009). This implies that biofuel crops produced on land with high carbon content are less likely to reach this threshold.

Like other ecosystems, savannas store carbon. Inappropriate management worldwide has increased emissions from these ecosystems. In the case of the Orinoco this degradation has been associated with: i) changes in land use due to introduction of exotic grasses intended to increase livestock productivity, ii) reducing the frequency of fires, and iii) increasing agro-industrial crops. The potential effects arising from these transformations with respect to this coverage are described by Etter *et al.* (2010) who show that the dependence of the carbon exchange with the atmosphere involves various ecological systems in the Orinoco, the biophysical processes that drove the evolution of the savannas, and differences in land use and tenure. Wassmenn and Vlek (2004) show how spatiotemporal variability of carbon emissions from fire and livestock in savannas is high, due to the variation of the land use and biophysical context. Van Der Werf *et al.* (2003) and Romero-Ruiz *et al.* (2009) show the same trend with carbon emissions from fires, which vary significantly due to differences between coverage types, biomass combustion, and efficiency.

For the calculation of the total carbon stock we took the results of Lange and Suarez (2013) where the equation according with the EU (2010) and the IPCC (2006) was:

$$Ctotal = Cbm + Cdom^* + SOC$$

Where:
Ctotal: total carbon stock
Cbm: above and below ground carbon in living organic matter
Cdom*: above and below ground carbon in dead organic matter. For unavailable data and high uncertainties, this measure was not taken into account.
SOC: organic carbon in the soil

In the following sections each factor of the equation is described.

5.2.5.1.1 CR 4.1 Living Organic Material (Cbm) / Carbon in Above and Below Ground Biomass

Carbon stocks of grasslands in the tropics and specifically in the Llanos have not been studied by many authors. Moreover, Trumper (2009), San Jose *et al.* (1991; 2001; 2003), Grace *et al.* (2006), and Etter *et al.* (2010) have lead studies that help us characterise these ecosystems in a general way. For the forest classes we mainly use data from the Institute for Hydrology, Meteorology, and Environmental Studies (Phillips *et al.*; IDEAM 2011). Carbon values for other land cover classes were taken from Yepes *et al.* IDEAM (2011), who compiled and summarised the biomass and carbon stored on various land cover types in Colombia.

The aboveground biomass was estimated using secondary information (Table 12), for each type of land cover based on a map made by the SuLu project from satellite images for the period January 2008 (IDEAM *et al.* 2012). The estimation of the belowground biomass was made using the rates from the aboveground biomass proposed by IPCC (2006)

The final equation summarises both stocks as follows:

$$CBM = CAGB + CBGB$$

Where:
CBM: carbon above and below ground in living biomass
CAGB: above ground carbon in living biomass (measured as mass of carbon per hectare)
CBGB: below ground carbon in living biomass (measured as mass of carbon per hectare); this value is calculated through CAGB * R, where R is the ratio of the amount of carbon belowground in living biomass compared to the amount of carbon in living aboveground biomass.

Code	Land Cover	CAGB	Source	R[1]	CBGB	CBM
3222	Open shrubland	23.80	IDEAM, 2011	2.80	66.64	90.44
3221	Dense shrubland	23.80	IDEAM, 2011	2.80	66.64	90.44
31211	High open forest land	132.10	IDEAM, 2011	0.37	48.88	180.98
31212	High open floodplain forest	132.10	IDEAM, 2011	0.37	48.88	180.98
31221	Low open forest land	132.10	IDEAM, 2011	0.37	48.88	180.98
31222	Open floodplain forest	132.10	IDEAM, 2011	0.37	48.88	180.98
3141	Flooded Riparian and gallery forest	132.10	IDEAM, 2011	0.37	48.88	180.98
3142	Riparian and Gallery forest on high plains	132.10	IDEAM, 2011	0.37	48.88	180.98
31111	High dense forest	132.10	IDEAM, 2011	0.37	48.88	180.98
31112	Flooded High dense forest	132.10	IDEAM, 2011	0.37	48.88	180.98

Code	Land Cover	CAGB	Source	R(1)	CBGB	CBM
31121	Low dense forest	132.10	IDEAM, 2011	0.37	48.88	180.98
31122	Flooded low dense forest	132.10	IDEAM, 2011	0.37	48.88	180.98
313	Fragmented forest	22.27	Sierra (2007)	0.37	8.24	30.51
3131	Fragmented forest with pastures and crops	22.27	Sierra (2007)	0.37	8.24	30.51
3132	Fragmented forest with secondary vegetation	22.27	Sierra (2007)	0.37	8.24	30.51
2222	Café	28.90	IDEAM, 2011	0.24	6.94	35.84
3212	Open grassland	2.94	Etter *et al.* 2010	1.60	4.70	7.64
32121	Open sandy grassland	1.72	Etter *et al.* 2010	1.60	2.74	4.46
32122	Open rocky grassland	1.96	Etter *et al.* 2010	1.60	3.14	5.10
321111	Undulated dense grasslands	1.96	Etter *et al.* 2010	1.60	3.14	5.10
321112	Plain dense grasslands	1.96	Etter *et al.* 2010	1.60	3.14	5.10
321113	Dense grasslands of rolling firm land	1.96	Etter *et al.* 2010	1.60	3.14	5.10
321114	Sandy dense grassland	1.96	Etter *et al.* 2010	1.60	3.14	5.10
321121	Dense permanently flooded grassland	3.19	Etter *et al.* 2010	1.60	5.10	8.28
321122	Dense seasonally flooded grassland	3.19	Etter *et al.* 2010	1.60	5.10	8.28
241	Crop mosaic	5.80	IDEAM, 2011	1.60	9.28	15.08
245	Mosaic of crops and natural areas	5.80	IDEAM, 2011	1.60	9.28	15.08
243	Mosaic of crops, pastures and natural areas	5.80	IDEAM, 2011	1.60	9.28	15.08
244	Mosaic with natural pastures	5.80	IDEAM, 2011	1.60	9.28	15.08
242	Mosaic of pasture and crops	5.80	IDEAM, 2011	1.60	9.28	15.08
2211	Other permanent herbaceous crops		IDEAM, 2011			5.00
2231	Other permanent arboreal crops		IDEAM, 2011			34.40
2232	Oil Palm		IDEAM, 2011			60.00
232	Wooded pastures	3.92	Etter *et al.* 2010	1.60	6.27	10.19
233	Weedy grasses	23.80	IDEAM, 2011	1.60	38.08	61.88
231	Clean pastures	6.40	IDEAM, 2011	1.60	10.24	16.64
315	Forest plantations	89.90	IDEAM, 2011	0.24	21.58	111.48
323	Secondary vegetation in transition	19.60	IDEAM, 2011	0.37	7.25	26.85

Table 12. Parameters used in the equations for calculating biomass.

5.2.5.1.2 CR 4.2: Organic Carbon in the Soil (SOC)

For this item, we used the Tier 1 approach proposed by the IPCC (2006) where the actual soil carbon stocks is the product of the soil carbon stock under natural land cover and the influence of land use , management and input factors. The estimation combines the soil carbon map with the land cover map to allocate carbon values for each soil type with each land cover class and then allocate the influence factors from the IPCC 2006 according with the land use as follows:

$$SOC\left(\frac{tC}{ha}\right) * 100 = SOCref_i\left(\frac{tC}{ha}\right) \times Flu_l \times Fmg_l \times Fi_l$$

The data used for this calculation is mainly the land use indicators from the IPCC (2006), the soil map based on the FAO, and the land cover map for the Llanos region. To calculate the current carbon stock in soil, the carbon stock under natural land cover must be adjusted with the soil use factors that correspond to current (2008) land use. The corresponding values for the factors are taken exclusively from the EU/RED and the IPCC. Detailed soil dataset for the Llanos was analysed, however, due to gaps and uncertainties with the IPCC factors values, it was not taken into account. Thus, once this information from IGAC is harmonised and made available, analysis can be updated.

The values obtained for each of the land covers are shown in Annexes 4 and 5.

5.2.5.2 Carbon Emissions Savings

To implement the sustainability regulation of the EU RED, we used the proceedings developed by Lange and Suarez (2013). To prove the compliance with the 35 % emission saving threshold of the EU RED, we calculated the emission savings for each spatial unit that would occur if this spatial unit were to be converted into cropland to produced biofuel feedstock. Emission savings represent average annual savings for a production period of 20 years. According to Lange and Suarez (2013), calculating emissions caused by land use change is as follows:

$$LUC_i = CS_{i_{before}} - CS_{i\_biofuel\_feedstock}$$

Where:

LUC_i are the emissions caused by land use change (C/ha)

$CS_{i_{before}}$ is the carbon stock stored in the land use for 2008

$CS_{i\_biofuel\_feedstock}$ is the carbon stock stored in the feedstock for biofuel production

The authors then convert the total emissions caused by the land use change into emissions per year on the basis of a 20-year period as follows:

$$LUC_{mj\_i}\frac{CO_2}{MJ} = LUC_i\frac{C}{ha} * 3.664 * \frac{1}{20} * \frac{1000000}{P_i\frac{MJ}{ha}} * AL_i$$

Where:

LUC_{mj_i}	are emissions caused by land use change in biofuel unit CO_2/MJ
3.664	is the factor to convert carbon stock in carbon dioxide stocks
P_i	is the energy yield per hectare of the biofuel feedstock (140758 in the case of palm biodiesel with methane capture in the production process[14])
AL_i	is the allocation factor of the resulting land use change emission for oil palm (0.91)

The last step is to calculate emission savings. Lange and Suarez (2013) used the default values for production emission from the EU RED for palm biodiesel with methane capture in the production process using the following equation:

$$ES_i\,\% = \frac{100}{83,8} * [83,8 - (LUC_{mj\_i} + WTW_i)]$$

14 *We assume no production on degraded land and thus ignore a possible emission bonus granted by the EU RED for emission savings.*

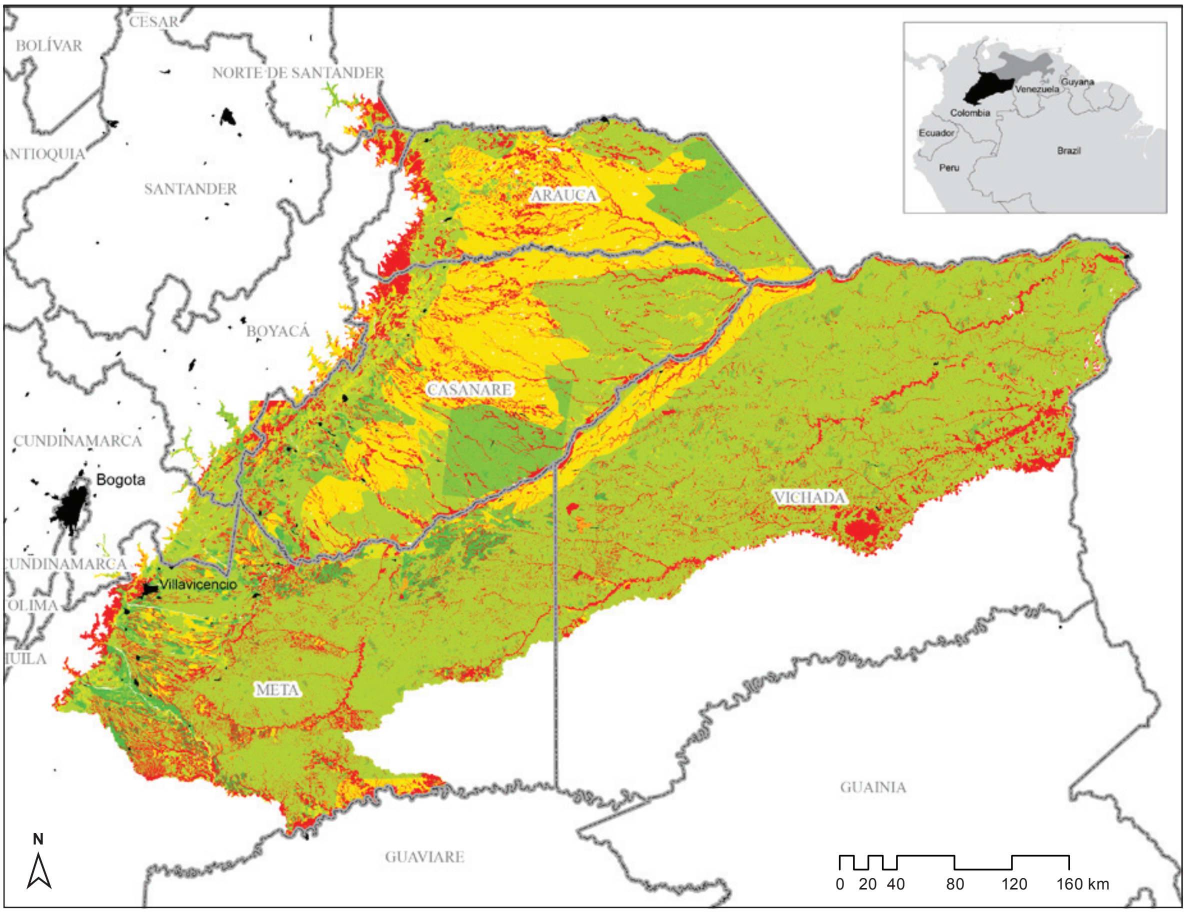


Figure 20.
Carbon stocks.

5.2.5.3 Results

After applying the different equations for the calculation of carbon in living organic material (CBM) and organic soil carbon (SOC), we obtained the estimate of the total carbon stock (C total) and the values for the definition of CR4.

Wetlands, different forest covers, permanent tree crops, forest plantations, and areas with arboreal crops as coffee are those with most stored carbon (Figure 20) and for that reason should not be transformed for the production of biofuels according to this criteria. Finally, open sandy dense grasslands on mainland and miscellaneous areas of pasture and crops are those that have lower carbon stock.

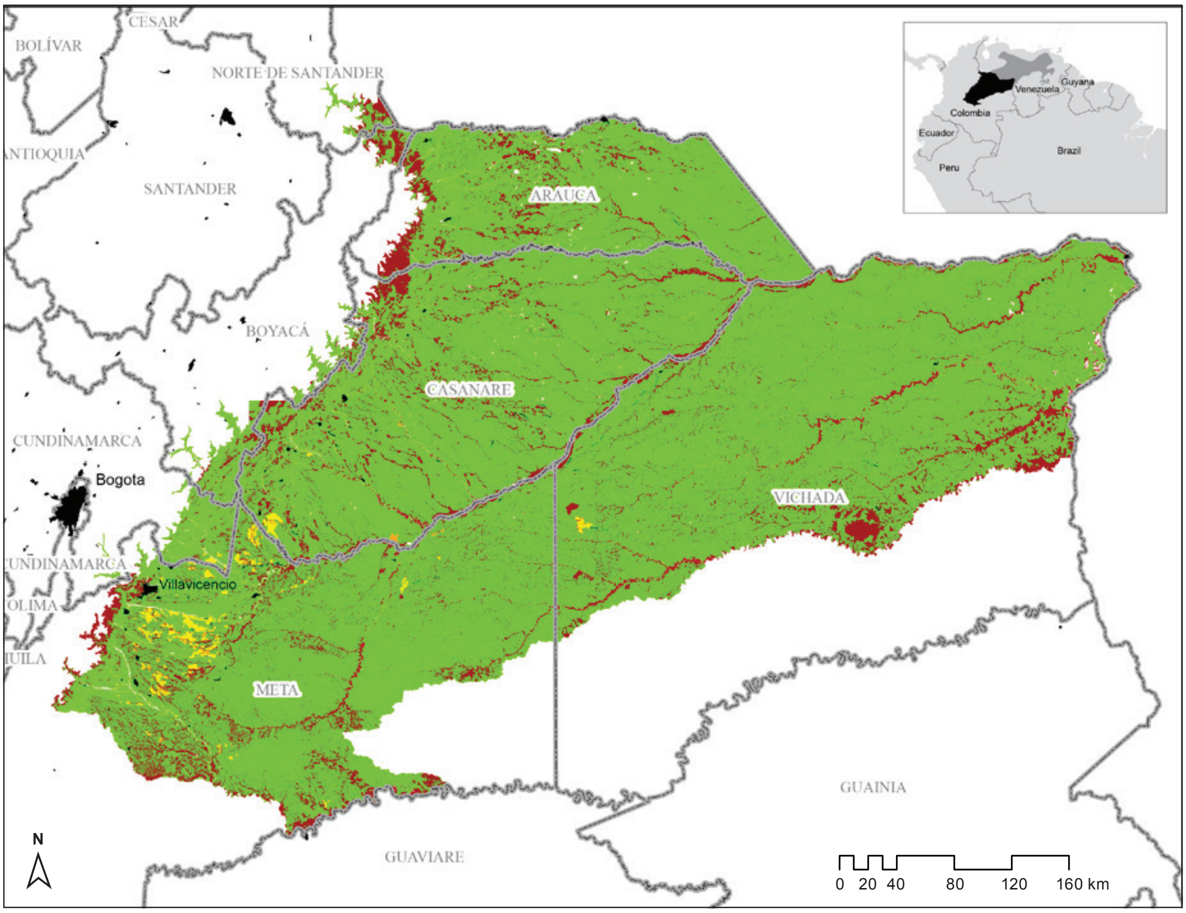


Figure 21.
Potential Emission Savings.

Emission savings in %

- -61.80 – 0.0
  No climate change mitigation
- 0.1 – 39.9
  EU RED no go
- 40.0 – 49.9
  EU RED no go 2017
- 50.0 – 59.9
  EU RED no go 2018
  new instalations after 2017
- 60.0 – 215.0
  In line with EU RED with respect to carbon emissions

Figure 21 shows that an expansion of palm plantations in order to produce feedstock for biodiesel would be possible with respect to carbon emissions, according to the EU RED, in a large part of the Llanos. However, this data should not and cannot be used alone. Biodiversity aspects are not considered in this map and the EU RED also prohibits converting high biodiversity grassland to produce feedstocks for biofuels. The natural grasslands in the Llanos can be very rich in biodiversity as shown in the previous chapters. The carbon data needs to be connected with biodiversity data and an individual biodiversity assessment needs to be applied to determine whether an area is an acceptable site for sustainable cultivation of agricultural production for bioliquids.

5.3 Stakeholders Engagement

The methodological process incorporates an outreach strategy with key institutional stakeholders in charge of policy, research, land planning, and sectoral processes. This approach was implemented to disseminate the initiative and facilitate information exchange, technical support, and discussions during the project, as well as to get decision makers interested in the results and their potential use. Stakeholder's engagement can be separated into five separate phases:

- Presentation of the project and activities
- Exchange of information (official and technical inputs)
- Joint analysis and work
- Presentation of progress, technical discussions, and feedback
- Final presentation

Among the institutions involved during the process were:

Government Agencies
- Ministries of Environment and Sustainable Development, Agriculture and Rural Development, Trade, Industry and Tourism, Mining and Energy and Transportation-Infrastructure.
- Decision-making bodies such as the Intersectoral Committee on Biofuels (a national level commission composed by the Ministries mentioned above and National Planning Department)

Institutes (national and private)
- Alexander von Humboldt Institute for Research on Biological Resources – IAvH
- National Institute of Hydrology, Meteorology and Environmental Studies – IDEAM
- National Geography Institute – IGAC
- International Centre for Tropical Agriculture – CIAT
- Corpoica
- Omacha Foundation
- Calidris – Association for the study and conservation of aquatic birds in Colombia (Asociación para el estudio y conservación de las aves acuáticas en Colombia)

Regional Environmental Authorities
- Cormacarena
- Corporinoquia

Unit of Protected Areas
- National Natural Parks (Orinoco territorial Direction)

Oil Palm and Biofuels Sub-Sector representatives
- Fedebiocombustibles (Colombian Federation of Biofuel Producers)
- Fedepalma (Federation of Colombian Oil Palm Growers)

Local and sub-regional stakeholders
- Academy
- Productive sectors
- Local NGOs

The results of stakeholder engagement had a differentiated scope; with some of them it was possible to develop joint formulation of a specific and timely product, not only for this project but also for ongoing national processes, such as the land cover map which was worked together and coordinated with IGAC and IDEAM. This product was an input to the map result of the methodology implementation, ensuring quality control and official standards of compliance, as well as making a contribution to the national process of reinterpretation of land cover (1:100,000).

On the other hand, the work and interaction with stakeholders at national or sub-regional/local level allowed improvements to be made to the methodology from a scaled perspective, strengthening through feedback the input information and modelling analyses.

In political terms, it was possible to progress positioning the technical product and to promote its incorporation into decision-making processes.

6 Generation of SuLu Risk Map

6.1 Equation for the Generation of SuLu Map

The process to generate the SuLu map was completed using the decision tree (Figure 22), where the different criteria are combined to identify three distinct categories. This framework first, identifies those areas that are qualified as 'no-go', in which conversion to agricultural use for bioenergy is not acceptable at any time. The 'no-go' category includes all areas excluded for conversion as forests, wetlands and protected areas. At the same time 'no-go' areas include all areas with national conservation priorities as well as all ecosystems with high singularity and land cover with high carbon stocks.

The second category, medium biodiversity and carbon stock, concerns areas with good (high/ medium) ecological integrity but with some signs of human intervention. In these areas, biological values are not exceptional, but there is evidence of significant conservation needs at the landscape scale, so that special ecological considerations must be taken into account to keep processes functional. For this reason a detailed analysis of 'High Conservation Values' (HCV) is required as well as a connectivity assessment to guarantee the preservation of conservation objectives and natural processes.

The third class, low biodiversity and carbon values, describes areas with an already high conversion rate, where most of the native biodiversity and carbon stocks have already been converted and the ecological integrity is low. The areas are not part of the conservation priorities and have low values of singularity. A basic site assessment following the HCV method at local scale (or an equivalent one) needs to be applied to determine whether this land is an acceptable site for sustainable cultivation of agricultural production for biofuels/bioliquids.

6.2 Results

After integrating the results from the previous analysis, it was found that 50 % (9,050,259.87 ha) of the total area must be excluded from consideration for biofuel production. The excluded areas are determined as 'no-go' areas, meaning conversion to agricultural use for bioenergy is unacceptable at any time. On the grounds that use is restricted by applicable regulations and covers the land categories described in the EU RED. Within these areas, forests, wetlands, and protected areas, as well as highly biodiverse grassland and significant carbon stocks (measured as GHG emission savings) are all considered within the EU RED.

Regions with large proportions of 'no-go' areas can be found all over the Llanos. We want to highlight some of them in each biogeographic unit: Along the foothills savannas, the Upper Apure River unit has 99 % of its surface classed in the 'no-go' category, followed by the Bojabá River (77.9 %), Ariporo River (72.3 %) and Margua River (69.0 %). In the flooded savannas landscape, the Cinaruco River (83.5 %), tributaries of the Orinoco River (72 %), tributaries of the Arauca River (70 %), Caño Aguaclarita (83 %), and tributaries of the Meta River (mi) (65.5 %) present 'no-go' areas. In the savannas of the high plain, the Bita River (60.5 %), Tuparro River (74.5 %), lower Tomo River (88.7 %) and the Lower Vichada River (55 %) are those with the highest percentage of their surface classed as 'no-go'.

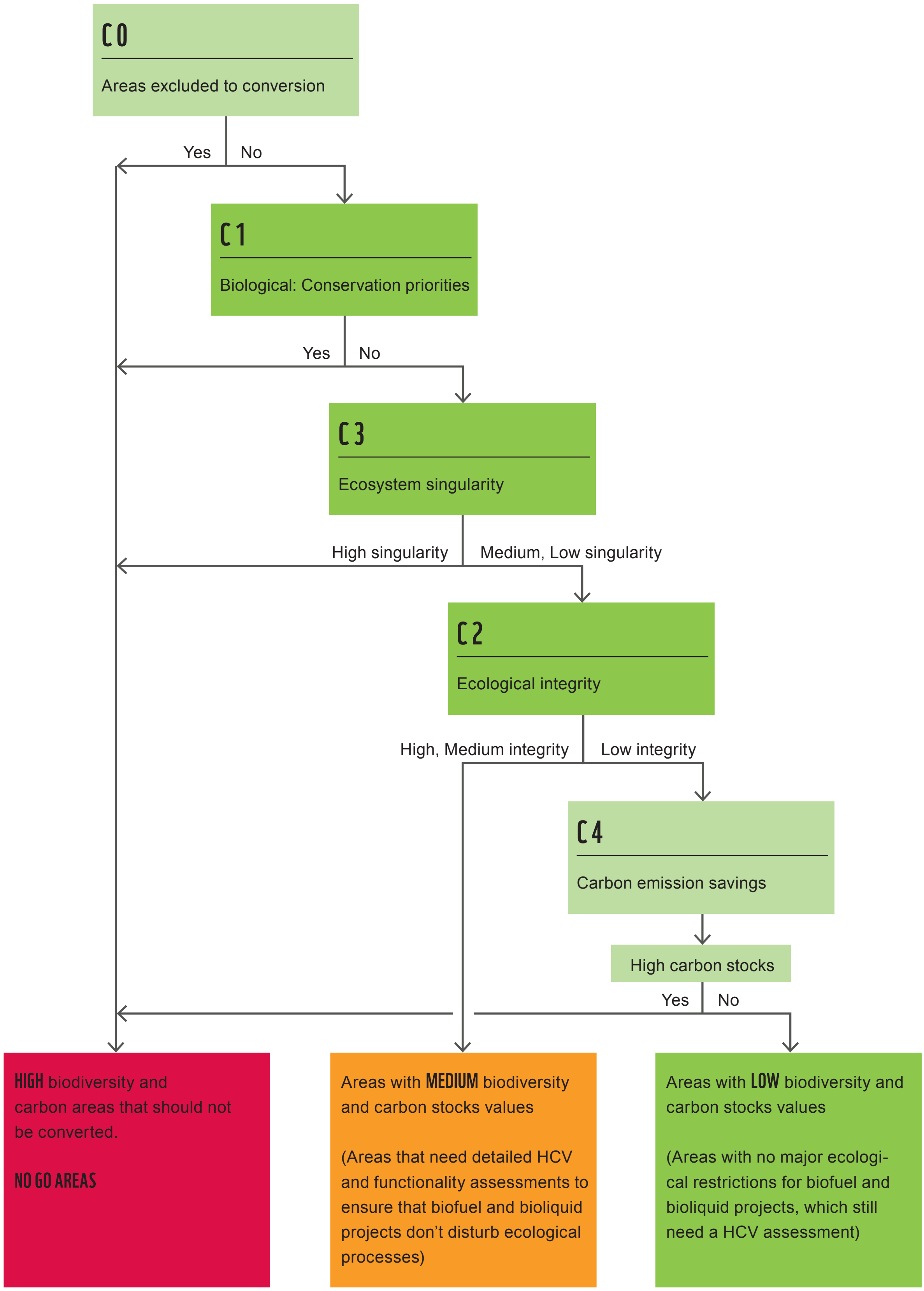


Figure 22. Flow chart Sustainable Land Use Map.

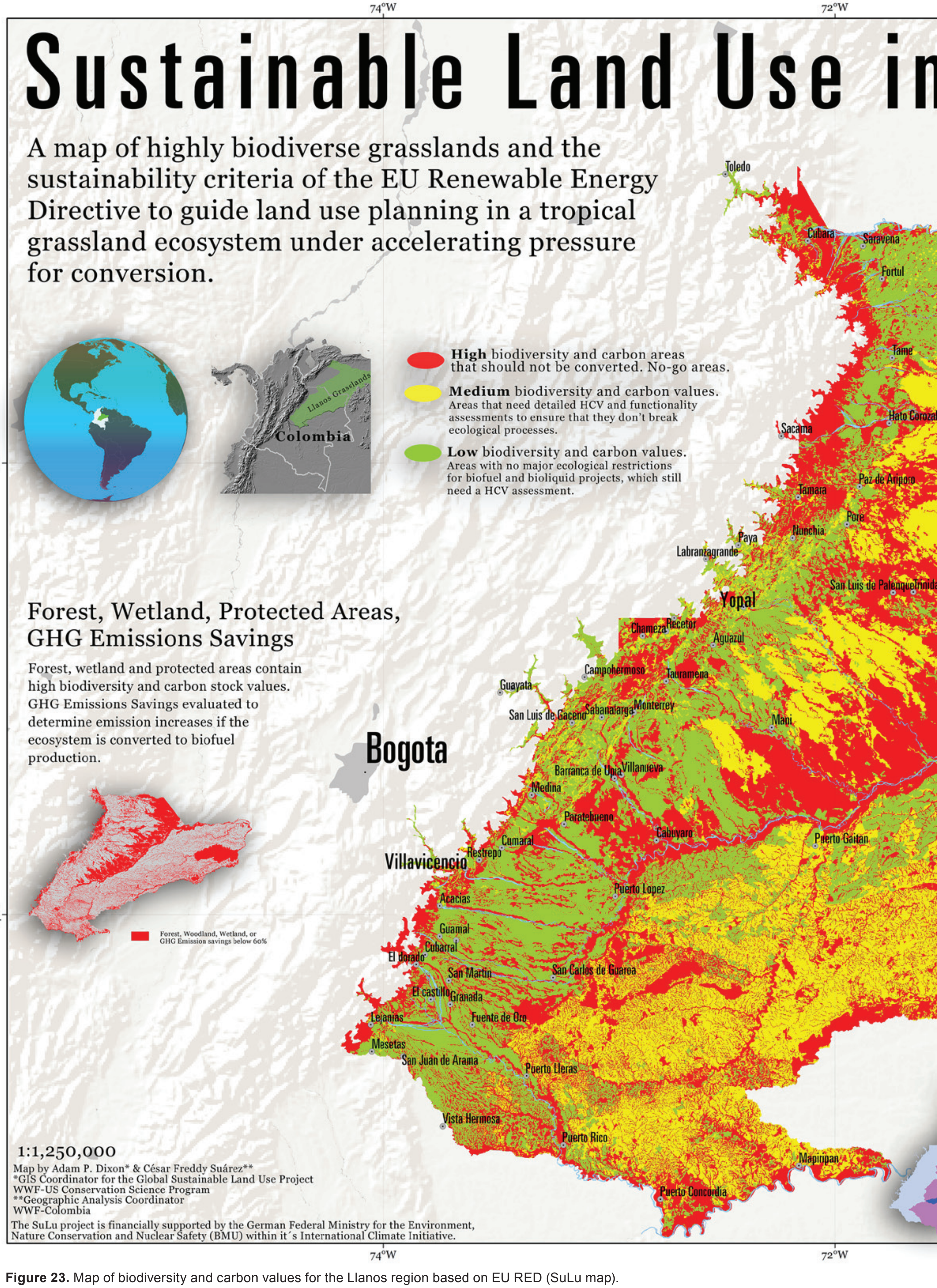


Figure 23. Map of biodiversity and carbon values for the Llanos region based on EU RED (SuLu map).

...n the Colombian Llanos

Supported by:
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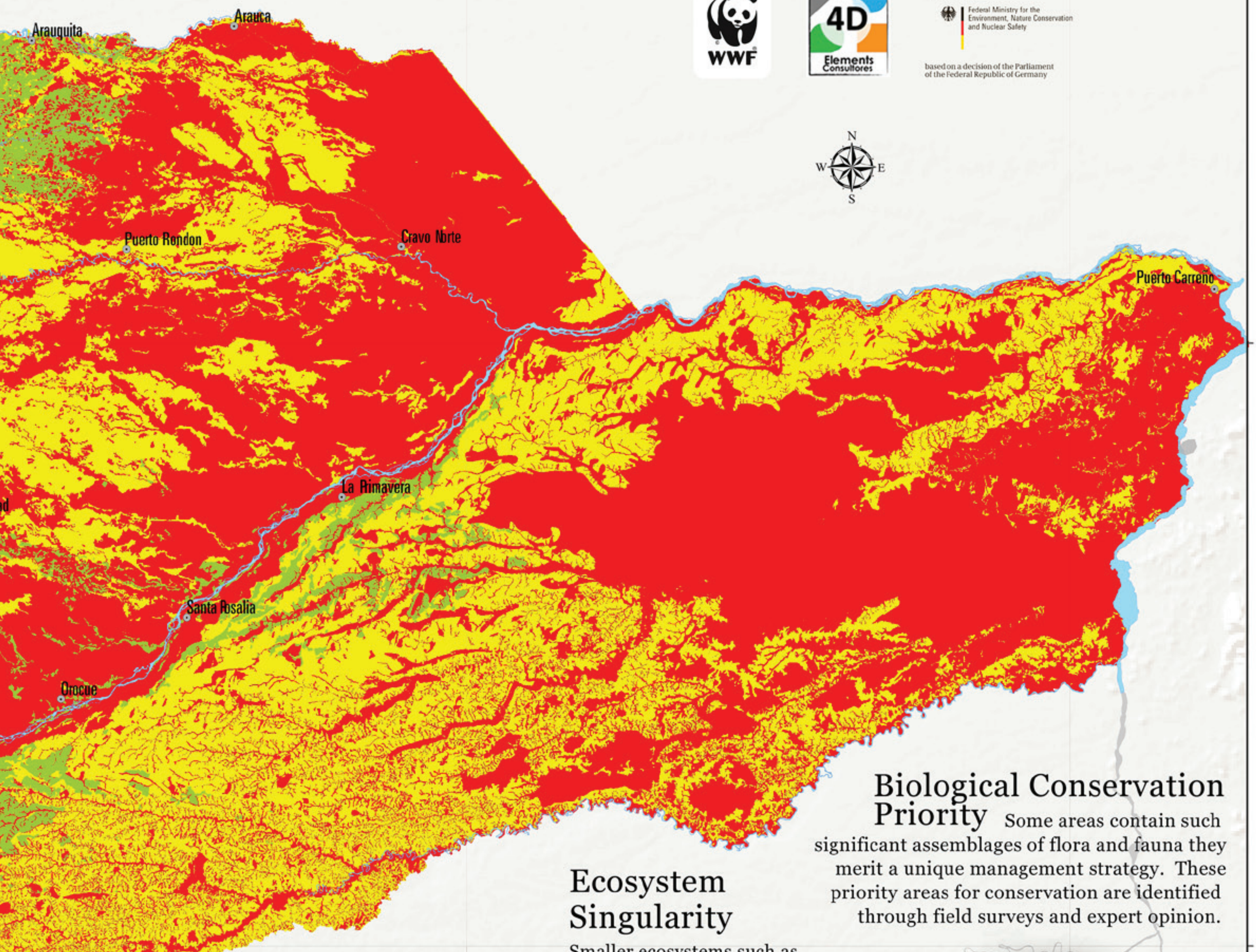
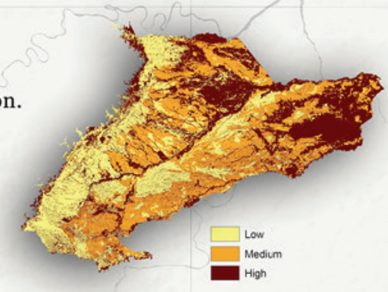


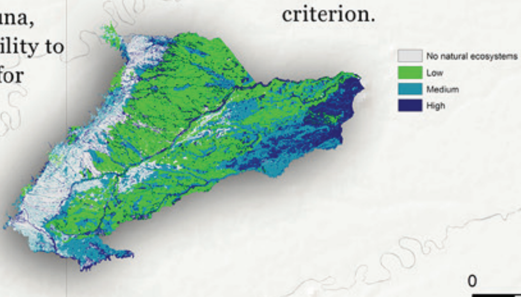
Biological Conservation Priority

Some areas contain such significant assemblages of flora and fauna they merit a unique management strategy. These priority areas for conservation are identified through field surveys and expert opinion.



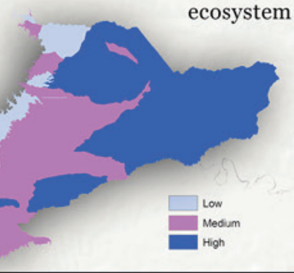
Ecosystem Singularity

Smaller ecosystems such as "moriches," wetland areas in the Llanos with unique species compositions and restricted distributions, require special representation. Gallery forests and rocky outcrops are also commonly represented by this criterion.



Ecological Integrity

The capacity for an ecosystem to sustain itself through natural life cycle processes of flora and fauna, stable hydrologic and soil systems, and the ability to recover after disturbance is foundational for ecosystem persistence.



Thirty-four per cent of the study area (6,186,977.1 ha) was identified as medium biodiversity. These areas are dominated by the savannas of the high plains of Metica and Manacacias, characterised by the presence of rolling, undulated, and flat savannas. Other areas with this category are located on the high plains of the Upper Tomo River, Upper Bita River, Upper Vichada River, Caño Lioni or Teracay, and the tributaries of the middle Vichada.

The areas with medium values of biodiversity and carbon stocks, describe areas with good ecological integrity but with some signs of human intervention and with evidence of important conservation needs, in which special ecological considerations must be taken into account to keep processes functional. For this reason, a detailed analysis of 'High Conservation Values' (HCV) is required as well as a connectivity assessment to guarantee the preservation of conservation objectives and natural processes.

Finally, 15.7 % of the area (2,843,904.15 ha) is in the low biodiversity category and are mainly savanna areas of the foothills and high flat plains on the right bank of the river between Puerto Lopez, Meta, and Primavera. In the foothills, values reached up to 90 % (Río Negro/Black River), and in the high plains, 30.5 % of the Muco River. The floodplains show 42.7 % along the Tua River and the savannas Metica-Manacacias reach 41 % in tributary areas of the Metica River and Yucao.

The low biodiversity and carbon stock value category describes areas with low diversity and low carbon storage, as well as already converted landscapes.
A basic site assessment following the HCVA method (or equivalent) needs to be applied to determine whether this land is an acceptable site for sustainable cultivation of agricultural production for bioliquids. This is for two reasons. Firstly, mapping exercises can produce scenarios where biodiversity and carbon stock values are likely to be highest, but sometimes fail to identify smaller discontinuous areas of value. The second reason is that cultural and social values of lands are not identified through a mapping process, but through a canvassing of the area gathering information from the local inhabitants. Social and cultural values are furthermore not covered by the EU RED sustainability criteria.

7 Conclusions and Recommendations

This document presents the first methodology and regional map to have been developed in Colombia within the conceptual and methodological framework of the renewable energy strategy of the European Union (EU-RES-D), and Directive 2009/28/EC of the European Parliament, and therefore its analysis should be taken from a regional perspective. The information obtained in the process shows significant methodological progress in determining biodiverse savannas and high carbon stocks. While progress on carbon analysis has been successful in recent years, this has only covered the forest areas in Colombia. While the Orinoco region has been the focus of most studies in the last decade, it currently faces a process of loss of natural cover due to development of specialised agriculture, mining, exploitation of hydrocarbons, and other external threats. In this document we present an approximation to the dynamics of carbon capture and storage for each identified land cover in the region and go beyond this type of analysis, as it is also one of the first advances to incorporate more detailed variables in the analysis of this great region of the country, as carbon in organic matter and the soil.

We believe that the methodology is a universal method that can be implemented in other savanna areas, due to the following characteristics:

1. The indicators used have been implemented and verified and could be replicated or adapted in many studies worldwide.

2. Flow charts associated with the mapping process explain the methodology in detail and can be adjusted where necessary (while maintaining the baseline without major modifications) to reach the final map of biodiverse savannas.

3. To be applied in other areas, it only requires the setting of parameter values to local characteristics.

To improve the implementation of this methodology, we recommend:

1. The component of the carbon stock is an important step in identifying biodiverse savannas for conservation and sustainable development, but it is also the component with a lack of accurate data that results in the use of generalised and standardised data in some cases. It requires verification and validation of the data by fieldwork in order to be able to differentiate more effectively between different land covers (as is the case for the calculation of above ground biomass or organic material in the soil).

2. It is advisable to process the cartographic data in vector format rather than raster. Although it increases the time required to process information, they have a greater capacity for analysis; overlay operations are very simple; they do not lose their characteristics when expanding the scale display or analysis; and they have a greater compatibility to link external databases.

3. To improve the identification of biodiverse savannas we propose to include the savannas ecosystem services as a criterion. An important ecosystem service provided by the different types of savannas is their role in the carbon flux cycle. Although the savannas are currently considered as carbon sinks,

inappropriate worldwide conservation management has led to a degradation of the vegetation and associated soil leading to carbon release to the atmosphere. A second important ecosystem service is the dynamics of fires in the savanna regions, representing an ecosystem service of Regulation: in savanna systems and humid areas, as fire management plays an important role in terms of maintaining ecosystem services. It is in this biome, where fire activity is essential for conservation, that species have evolved methods of adaptation, responding positively to its effects. Moreover, fire exerts strong control over the structure and composition of savannas, and the dynamics between the savannas and forests.

7.1 Policy Recommendations and Land Planning:

The sustainability criteria established by EU RED and their interpretation in Colombia through the SuLu initiative, represent an opportunity to leverage national processes around the Orinoco savannas which are a highly biodiverse but highly threatened ecosystem, bringing them into focus and highlighting the international market context.

Sustainability criteria incorporated by EU RED regarding biomass production (bioenergy) might not be enough to conserve biodiverse savannas. Most palm oil in Colombia is still used in the domestic market, especially for food, though some is for export. Therefore, the results of the SuLu initiative could help to enhance decision-making processes if their land planning input potential is presented not only to the productive sector, but also to land planning and environmental planning decision makers.

There is still a need to develop deeper studies and research regarding functionality and ecosystem services of the savanna ecosystem and their representation in social and cultural values.

Regarding methodological aspects and scales, it has been identified that each analysis provides a different kind of information applicable to different decision-making arenas. Therefore, regional analysis allows recognition of biogeographic differences inside a region and the identification of different high value conservation categories (including biodiverse savannahs, as 'no-go' areas according to EU – RED 2009/28/EC criteria), restrictions and management, which could indicate requirements for future more in-depth studies. This information could be useful as a technical input to Ministries, Regional governments, Regional authorities, Municipalities, etc. to strengthen policy formulation and land planning. On the other hand, local and site analysis results are more related to farm planning and certification schemes, and the direct decision-maker is the owner of the land. It is both possible and feasible to promote articulation between scales through the inclusion of technical results in land planning instruments. However, it is necessary to keep working on an HCV toolkit proposal for the local scale in savannas, based on these results.

Once generated, the first approach to the identification of high, medium, and low biodiversity and carbon stocks savannas, involves the important step of addressing these results and positioning them in strategic dialogues, so the competent authorities may adopt them for the purposes of environmental policy and agro-production policy with considerations of land planning. In this regard, we make the recommendations below.

7.1.1 Policy:

- Once generated, the first approach to the identification of sustainable land use involves the dissemination of these results in strategic institutional and policy scenarios to encourage the use and adoption by competent authorities in relation to environmental and productive policy with considerations of land use planning processes. For this purpose, WWF will strengthen strategic alliances with research institutions and organisations such as the Humboldt Institute (National Biodiversity Institute), IDEAM, etc. to promote the incorporation of these results in national policy processes.
- The Ministry of Environment and Sustainable Development and other competent Ministries[15], need to discuss and agree guidelines in relation to export-oriented production planning. Given the infrastructure development caused by the productive expansion of the region, it is also very important that the Ministry of Transportation also incorporates these results as input for feasibility studies and subsequent planning of infrastructure development in the region.
- Given the current formulation of the Conpes Document[16] for the High Plains Savannas 'Policy to promote the sustainable development of Colombian High Plains (Altillanura)'[17], WWF recommends including the results concerning biodiverse and carbon rich areas into it.
- The Biofuels Intersectoral Committee should also adopt sustainability criteria.

7.1.2 Land and Productive Planning:

- The SuLu outputs provide different kinds of information applicable to different decision-making arenas. This information will be useful as technical inputs to Ministries, regional governments, regional environmental authorities (Corporinoquia and Cormacarena), and municipalities, to strengthen policy formulation and the inclusion and adoption of key elements of biodiversity and carbon conservation in land use planning processes[18].
- The Agricultural Planning Unit of the Ministry of Agriculture and Rural Development needs to agree an action plan to support the inclusion of the results in the guidelines for credits and incentives. Furthermore, this strategy also applies to key instruments of Sector Planning Agencies (National Agency for Oil, National Agency for Mining, and National Agency for Infrastructure).
- Sustainability criteria as well as the definition of priority areas for conservation are also lacking in the sector planning of Colombia and need to be incorporated by the National Federation of Biofuels Producers (Fedebiocombustibles), National Federation of Oil Palm Producers (Fedepalma), Association of Sugarcane Growers of Colombia (Asocaña), National Federation of Grains Growers (Fenalce), National Federation of Timber Industry (Fedemaderas), and Productive Transformation Program, etc.

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15 *Ministry of Agriculture and Rural Development, Ministry of Mining and Energy, Ministry of Commerce, Industry and Tourism.*

16 *Policy Document formulated by the National Social and Political Economy Council of the National Planning Department of Colombia (Consejo Nacional de Política Económica y Social) lead by National Planning Department.*

17 *Política para el desarrollo incluyente y sostenible de la Altillanura colombiana*

18 *Environmental Regional Authorities are responsible to determine environmental elements of the landscape that must be conserved or specially managed and establish them as key elements (determinantes ambientales in Spanish) that must be incorporated by Municipalities during Land planning instrument formulation (Planes de Ordenamiento Territorial – POT – in Spanish).*

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9 Annexes

Annex 1.
Protected areas and their area in hectares of the ecoregion in the Orinoco Savannas of Colombia, by corporation, department, municipalities and category.

Corpo-ration	Department		Category	Name Area	Hectares (Ha)
	Name	Municipality			
CORPORINOQUIA	ARAUCA	Tame	NNP	El Cocuy	15,077
		Saravena	FPR	Rio Satoca	1,494
		Tame		Rio Tame	1,632
		Arauquita	FPR	L. B. Guaimaral	1,568
		Puerto Rondón	RSC	El Torreðo	998
		Puerto Rondón		La Culebra	684
		Area without designation of category of protection in the department of **Arauca**			2,161,001
	CASANARE	Yopal	PM	La Iguana	700
		La Salina, Sacama	NNP	El Cocuy	51
		Hato Corozal	EHR	Cuenca Hidrografica Quebrada Las Guamas	5,256
		Hato Corozal		Microcuenca de la Quebrada Las Guamas	2,498
		Yopal	FPR	Quebrada la Tablona	2,179
		Maní		Rondas e Islas Antiguas Sobre El Río Cusiana	18
		Paz de Ariporo, Pore, Tamara		Cerro Zamaricote	9,567
		Mani		Islas Y Riberas del Río Cusiana	14
		Aguazul, Tauramena	RN	Los Farallones	10,208
		Tauramena		Mata de Los Cajuches	40
		Tamara		Microcuenca Los Ariporitos	1,311
		Aguazul, Mani		Tinije	1,736
		Paz de Ariporo	RNP	Caðo El Vainillal	32
		Aguazul	RPC	Santiago de las Atalayas	3,746
		Yopal	RSC	Cagui La Upanema	78
		Orocue		El Boral	10,448
		Hato Corozal, Paz de Ariporo		La Aurora	9,904
		Paz de Ariporo		La Esmeralda	1,909
		San Luis de Palenque		Matesanto	806
		Orocue		Palmarito	2,439

Corporation	Department		Category	Name Area	Hectares (Ha)
	Name	**Municipality**			
CORPORINOQUIA	CASANARE	Trinidad		Rn La Esperanza	461
		Trinidad		Rn La Gloria	775
		Orocue		San Pablo	11,435
		Aguazul	ZU	Microcuencas De Las Quebradas La Cascada, San Juan	2,543
		Area without designation of category of protection in the department of **Casanare**			4,263,703
	CUNDINAMARCA	Medina	NNP	Chingaza	1,304
		Quetame	FPR	Quebradas Blanca Y Grande	48
		Quetame		Quebradas Las Cajitas Y Las Lajas, Honda Y Negra	74
		Gutierrez		R. F. Protectora E25	22
		Medina, Ubala	RN	Buenavista Y Los Man.	64
		Paratebueno	RSC	Agua Caliente	500
		Area without designation of category of protection in the department of **Cundinamarca**			204,230
	VICHADA	Cumaribo, La Primavera, Puerto Carreño	NNP	El Tuparro	557,641
		Puerto Carreño	RSC	Agua Linda	1,243
		Puerto Carreño		Bojonawi	1,410
		Puerto Carreño		La Ventana	1,311
		Puerto Carreño		Nimajay	2,674
		Puerto Carreño		Pitalito	1,242
		Cumaribo		Rancho Santa Barbara 1 Y 2	3,380
		Cumaribo		Rn Villa Miriam	416
		Cumaribo		Serranias De Casablanca	385
		Cumaribo		Villa Miriam	1,743
		Area without designation of category of protection in the department of **Vichada**			5,630,224
	BOYACA	Cubara	NNP	Tama	96
		Labranza grande, Mongua	RF	Rio Cravo Sur	64
		Area without designation of category of protection in the department of **Boyaca**			259,711

Corpo-ration	Department		Category	Name Area	Hectares (Ha)
	Name	Municipality			
CORMACARENA	META	Cumaral, Restrepo	NNP	Chingaza	556
		Mesetas, San Juan de Arama		Sierra de la Macarena	348
		El Astillo, Guamal, Lejanías, San Luis de Cubarral		Sumapaz	7,452
		Villavicencio	RF	Cerro Vanguardia Y Caðo Vanguardia	197
		Restrepo, Villavicencio		Cuenca Alta Del Canyon Vanguardia (Aguas Claras) Y Q	534
		Villavicencio		Nacimiento Caðos Grande, Pendejos, San Luis de Oco	20
		Villavicencio		Quebrada Honda Y Cerros Parrado Y Buque	1,452
		Villavicencio	FPR	El Charco	6
		Acacias	RSC	Altamira	32
		San Martin		Anamaria	22
		Villavicencio		Caðo Quetame	32
		Puerto Gaitán		El Boral	40
		San Martin		El Caduceo	136
		Restrepo		El Paraiso	1
		Acacias		El Zocay	15
		Cumaral		Floresta	20
		Cumaral		Kaliawirinae	5
		San Martin		La Macarena	374
		San Martin		La Casa De La Abuela	1
		Villavicencio		La Esperanza	11
		Puerto López		La Reseda	85
		San Martin		Las Unamas	8,401
		San Martin		Mata Redonda	2,193
		Restrepo		Sin Nombre	35
		Cumaral, Restrepo		Rancho Camana	3
		San Martin		Rey Zamuro	1,790
		Restrepo		Santa Teresita	144
		Area without designation of category of protection in the department of **Meta**			4,691,134

Corporation	Department		Category	Name Area	Hectares (Ha)
	Name	Municipality			
CORPONOR	SANTANDER	Toledo	NNP	Tama	17,081
		Area without designation of category of protection in the department of norte de **Santander**			42,681
CDA	GUAVIARE	San José del Guaviare	RF	Serranias De La Lindosa, El Capricho, Mirolindo Y	4
		Area without designation of category of protection in the department of **Guaviare**			12,107

Annex 2.

Remanence, number of fragments, mean area of fragment, connectivity and integrity calculation (CR2) calculated based on the Corine Land Cover Map 2008

Unit of analysis	Remanence (%)	Fragments (#)	Area fragments (Ha)	Connectivity (M)	Total	Cr 2
River Metica (Guamal – Humadea) of the savannas of the foothills	26.51	782	126	232.61	1.02	1
River Negro of Foothill savannas	10.38	377	25	262.21	1.18	1
River Banadia and other tributaries of the River Arauca of Foothill savannas	39.55	598	161	276.41	1.29	1
River Ariari of Foothill savannas	32.71	577	184	236.75	1.37	1
River Túa of Foothill savannas	20.98	329	88	283.76	1.39	1
River Cravo Norte of Foothill savan-nas	45.26	551	279	295.55	1.40	1
River Guatiquía of Foothill savannas	24.23	208	124	312.65	1.52	1
River Cravo Sur of Foothill savannas	38.60	382	168	269.61	1.58	1
River Tunjita of Foothill savannas	31.54	218	94	275.63	1.66	1
River Upía of Foothill savannas	31.93	206	166	294.63	1.67	1
River Guacavía of Foothill savannas	19.84	146	102	251.81	1.70	1
River Guaanduriba of Foothill savannas	42.22	94	295	378.86	1.74	1
Canyon Guanápalo and other Foothill savannas	28.99	82	97	298.05	1.75	1
River Cusiana of Foothill savannas	40.14	249	312	287.12	1.77	1
River Humea of Foothill savannas	29.77	170	208	266.40	1.79	1
River Guejar of Foothill savannas	43.65	343	188	225.46	1.81	1
Tributaries of the River Meta of Foothill savannas	28.56	189	188	239.98	1.81	1
Reservoir of the river Guavio of Foothill savannas	38.54	153	167	290.78	1.82	1
River Chivor of Foothill savannas	38.28	89	67	254.43	1.92	1
River Margua of Foothill savannas	56.79	89	263	300.65	2.09	1
River Casanare of Foothill savannas	56.04	106	1,237	328.21	2.11	2
River Cusiana of savannas of Flooded savannas	63.92	133	1,138	328.28	2.15	2
Tributaries of the River Metica (md) of savannas of Metica-Manacacías	56.25	188	589	249.16	2.16	2
River Tua of savannas of the flooded savannas	64.18	170	1,384	304.61	2.18	2

Unit of analysis	Remanence (%)	Fragments (#)	Area fragments (Ha)	Connectivity (M)	Total	Cr 2
River Yucao of savannas of Metica-Manacacías	68.56	251	666	257.49	2.19	2
River Ariporo of Foothill savannas	60.61	103	681	295.41	2.20	2
River Pauto of Foothill savannas	57.16	91	654	266.11	2.25	2
Medio Guaviare of the Metica-Manacacías savannas	83.35	358	1,595	231.75	2.33	2
River Bojabá of Foothill savannas	68.45	21	948	312.60	2.36	2
River Muco of the high plains savannas	69.49	151	2,053	263.05	2.40	2
River Cobugón – River Cobaría of Foothill savannas	69.59	69	612	251.64	2.44	2
River Cravo Sur of flooded savannas	75.30	78	1,950	299.63	2.45	2
Canyon Guanápalo and other areas of flooded savannas	85.85	105	4,887	330.75	2.51	2
Tributaries of the River Meta (md) of high plain savannas	66.27	22	6,847	300.36	2.52	2
River Manacacías of savannas of Metica-Manacacías	91.45	298	2,146	222.01	2.54	2
Tributaries of the river Meta (md) of high plain savannas	78.50	23	4,012	268.08	2.69	2
Tributaries of the river Meta (mi) of Flooded savannas	95.05	10	15,695	353.85	2.75	2
River Elvita of high plain savannas	85.22	22	21,615	315.41	2.76	2
River MelXa of savannas of Metica-Manacacías	89.15	84	1,999	228.81	2.77	2
River Guarrojo of high plain savannas	92.44	45	7,548	268.62	2.85	2
River Pauto of Flooded savannas	92.43	82	7,083	228.72	2.90	2
River Ariporo of Flooded savannas	97.39	29	13,686	271.05	2.96	3
Tributaries River Arauca of Flooded savannas	98.19	23	12,044	248.99	3.02	3
Tributaries Bajo Meta of high plain savannas	97.62	16	38,798	247.74	3.12	3
River Vita of savannas of high plain savannas	97.92	20	40,320	232.13	3.16	3
River Casanare of Flooded savannas	98.23	6	43,949	241.20	3.16	3

Unit of analysis	Remanence (%)	Fragments (#)	Area fragments (Ha)	Connectivity (M)	Total	CR 2
Upper Vichada of high plain savannas	97.82	23	34,520	218.72	3.18	3
Upper River Tomo of high plain savannas	97.27	14	55,954	227.78	3.20	3
River Cravo Norte of savannas of Flooded savannas	98.60	9	52,942	233.43	3.20	3
Canyon Cumaral of savannas of Metica-Manacacías	99.36	6	18,432	203.93	3.21	3
Canyon Samuco of Flooded savannas	98.96	2	49,479	223.61	3.23	3
Tributaries of River Meta (mi) of Flooded savannas	97.12	3	176,479	249.07	3.24	3
River Cinaruco and Tributaries of Flooded savannas	99.22	4	113,128	205.90	3.34	3
Upper River Apure of Foothill savannas	97.74	1	3,085	0.00	3.60	3
Tributaries of middlge Vichada river of high plain savannas	99.48	1	208,956	0.00	3.94	3
Canyon Aguaclarita of savannas of Flooded savannas	99.53	1	247,159	0.00	3.95	3
Canyon Lioni o Terecaand of the high plan savannas	99.55	1	255,441	0.00	3.96	3
Bajo Vichada of High plain savannas	98.78	1	286,584	0.00	3.96	3
River Tuparro of High plain savannas	99.63	3	383,881	0.00	3.99	3
Bajo River Tomo of High plain savannas	99.78	1	409,219	0.00	3.99	3
Tributaries of the Orinoco river of High plain savannas	100.00	1	419,463	0.00	4.00	3

Annex 3.

Parameters used in the calculation equations for soil carbon. Source: Adapted from European Union (2010) and IPCC (2006)

Code	Land cover	SOC(st) [(1)]	Flu [(2)]	Fmg [(3)]	Fi [(4)]	SOC
332	Rocky outcrops	0.00	1.00	1.00	1.00	0.00
3222	Open shrubland	122.36	1.00	1.00	1.00	122.36
3221	Dense shrubland	122.36	1.00	1.00	1.00	122.36
2121	Rice	146.09	0.48	1.00	1.00	70.12
31211	High open forest land	194.24	1.00	1.00	1.00	194.24
31212	High open floodplain Forest	173.43	1.00	1.00	1.00	173.43
31221	Low open forest land	194.24	1.00	1.00	1.00	194.24
31222	Open floodplain forest	194.24	1.00	1.00	1.00	194.24
3141	Flooded Riparian and gallery forest	959.54	1.00	1.00	1.00	959.54
3142	Riparian and Gallery forest on high plains	318.26	1.00	1.00	1.00	318.26
31111	High dense forest	99.29	1.00	1.00	1.00	99.29
31112	Flooded High dense forest	173.43	1.00	1.00	1.00	173.43
31121	Low dense forest	199.89	1.00	1.00	1.00	199.89
31122	Flooded low dense forest	173.43	1.00	1.00	1.00	173.43
313	Fragmented forest	174.49	1.00	1.00	1.00	174.49
3131	Fragmented forest with pastures and crops	174.49	0.83	1.07	1.00	154.82
3132	Fragmented forest with secondary vegetation	174.49	1.00	1.00	1.00	174.49
2222	Coffee	194.50	1.00	1.22	1.00	237.29
212	Cereals	101.24	0.48	1.00	1.00	48.60
3212	Open grassland	146.09	1.00	0.97	1.00	141.71
32121	Open sandy grassland	146.09	1.00	1.00	1.00	146.09
32122	Open rocky grassland	0.00	1.00	1.00	1.00	0.00
321111	Undulated dense grasslands	47.78	1.00	1.00	1.00	47.78
321112	Plain dense grassland	199.89	1.00	1.00	1.00	199.89
321113	Dense grasslands of rolling firm land	122.42	1.00	1.00	1.00	122.42
321114	Sandy dense grassland	72.01	1.00	1.00	1.00	72.01
321121	Dense permanently flooded grassland	308.82	1.00	1.00	1.00	308.82
321122	Dense seasonally flooded grassland	166.86	1.00	1.00	1.00	166.86
241	Crop mosaic	101.25	0.48	1.22	1.00	59.29

Code	Land cover	SOC(st) (1)	Flu (2)	Fmg (3)	Fi (4)	SOC
245	Mosaic of crops and natural areas	154.47	0.74	1.11	1.00	126.88
243	Mosaic of crops, pastures and natural areas	70.58	0.83	1.07	1.00	62.62
244	Mosaic with natural pastures	42.84	1.00	1.00	1.00	42.84
242	Mosaic of pasture and crops	101.25	0.74	1.11	1.00	83.17
2211	Other permanent herbaceous crops	101.24	1.00	1.00	1.00	101.24
2231	Other permanent arboreal crops	308.82	1.00	1.00	1.00	308.82
211	Other transient crops	101.24	0.48	1.00	1.00	48.60
2232	Oil Palm	110.48	1.00	1.00	1.00	110.48
232	Wooded pastures	69.56	1.00	1.00	1.00	69.56
233	Weedy grasses	119.19	1.00	1.00	1.00	119.19
231	Clean pastures	94.37	1.00	1.00	1.00	94.37
315	Forest plantations	181.52	1.00	1.00	1.00	181.52
333	Degraded and bare lands	42.84	1.00	0.97	1.00	41.55
413	Aquatic vegetation on water bodies	0.00	0.00	0.00	0.00	0.00
323	Secondary vegetation in transition	194.24	1.00	1.00	1.00	194.24
331	Areas of natural sands	0.00	1.00	1.00	1.00	0.00
411	Wetlands	959.54	1.00	1.00	1.00	959.54
334	Burned areas	131.90	1.00	1.00	1.00	131.90

(1) IPCC: 2006; (2) IPCC: 2006; (3) IPCC: 2006

Annex 5.
Parameters used in the calculation for the carbon stock.
Source: Adapted from European Union (2010), IPCC (2006)

Code	Land cover	SOC	Cbm	Cdom	C Total	CRI 4
31211	High open forest land	194,24	180,98	13,21	388,43	3
31212	High floodplain open Forest	173,43	180,98	13,21	367,62	3
31221	Low open forest land	194,24	180,98	13,21	388,43	3
31222	Open forest on floodplains	194,24	180,98	13,21	388,43	3
3141	Riparian and gallery forest and flooded savannas	959,54	180,98	0,00	1140,52	3
3142	Riparian and gallery forest and high plain savannas	318,26	180,98	0,00	499,24	3
31111	High dense forest on mainland	99,29	180,98	13,21	293,48	3
31112	High dense flooded forest	173,43	180,98	13,21	367,62	3
31121	Dense forest on mainland	199,89	180,98	13,21	394,08	3
31122	Dense forest on floodplains	173,43	180,98	13,21	367,62	3
2222	Café	237,29	35,84	0,00	273,13	3
321121	Dense permanently flooded grassland	308,82	8,28	0,00	317,10	3
2231	Other permanent arboreal crops	308,82	34,40	0,00	343,22	3
315	Forest plantations	181,52	111,48	0,00	293,00	3
411	Wetlands	959,54	0,00	0,00	959,54	3
3222	Open shrublands	122,36	90,44	0,00	212,80	2
3221	Dense shrublands	122,36	90,44	0,00	212,80	2
313	Fragmented forest	174,49	30,51	0,00	205,00	2
3131	Fragmented forest with pastures and crops	154,82	30,51	0,00	185,34	2
3132	Fragmented forest with secondary vegetation	174,49	30,51	0,00	205,00	2
321112	Plain dense grasslands	199,89	5,10	0,00	204,99	2
321122	Dense seasonally flooded grass-lands	166,86	8,28	0,00	175,14	2
2232	Oil Palm	110,48	60,00	0,00	170,48	2
233	Weedy grasses	119,19	61,88	0,00	181,07	2
323	Secondary vegetation in transition	194,24	26,85	0,00	221,09	2
334	Burned areas	131,90	0,00	0,00	131,90	1
2121	Rice	70,12	0,00	0,00	70,12	1
212	Cereals	48,60	0,00	0,00	48,60	1

Code	Land cover	SOC	Cbm	Cdom	C Total	CRI 4
3212	Open grasslands	141,71	7,64	0,00	149,35	1
32121	Open sandy grasslands	146,09	4,46	0,00	150,55	1
32122	Open rocky grassland	0,00	5,10	0,00	5,10	1
321114	Pasture land Dense sandy	72,01	5,10	0,00	77,11	1
321111	Pasture land Dense wavy	47,78	5,10	0,00	52,88	1
321113	Dense grassland rolling mainland	122,42	5,10	0,00	127,51	1
241	Crop mosaic	59,29	15,08	0,00	74,37	1
245	Mosaic of crops with natural areas	126,88	15,08	0,00	141,96	1
243	Mosaic of crops, pastures and natural areas	62,62	15,08	0,00	77,70	1
244	Mosaic with natural pastures	42,84	15,08	0,00	57,92	1
242	Mosaic of pastures and crops	83,17	15,08	0,00	98,25	1
2211	Other permanent herbaceous crops	101,24	5,00	0,00	106,24	1
211	Other transient crops	48,60	0,00	0,00	48,60	1
232	Wooded pastures	69,56	10,19	0,00	79,75	1
231	Clean pastures	94,37	16,64	0,00	111,01	1
333	Degraded and bare lands	41,55	0,00	0,00	41,55	1

Tables List

Figures List

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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