BIOREDD+ Program

DELIVERABLE 11: ASSESSMENT OF POTENTIAL LEAKAGE AREAS

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About this Document

This document has been developed for USAID´s BIOREDD+ Program to provide the baseline assessment of carbon pools and deforestation and degradation of designed leakage areas in comparison to the project and reference areas BioREDD+ project areas in the context of larger area deforestation and degradation. The deliverable includes: 1. Assessment of degrees of deforestation and degradation in leakage areas. 2. Assessment of the carbon pools in leakage areas.

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List of Acronyms

AFOLU	Agriculture, Forestry and Other Land use
AGB	Above Ground Biomass
ALOS	Advanced Land Observing Satellite
BGB	Below Ground Biomass
BMyF	Bajo Mira y Frontera
CCBA	Carbon Communities and Biodiversity Alliance
CELI	Consolidation and Enhanced Livelihoods
CONIF	Corporación Nacional de Investigación y Fomento Forestal, National Corporation on Forestry Promotion and Research
CSR	Corporate Social Responsibility
DCA	Development Credit Authority
DEM	Digital elevation Model
ESPA	Environmental Service Purchase Agreement
FAAN	Fondo para la Acción Ambiental y la Niñez
FPIC	Free Prior Informed Consent
GOC	Colombian Government
HRP	Human Rights Program
IDEAM	Instituto de Hidrología Meteorología y Estudios Ambientales, Institute of Hydrology, Meteorology and Environmental Studies
INCODER	Instituto Colombiano de Desarrollo Rural
IRR	Internal Rate of Return
LIDAR	Laser Image Detention and Ranging
LOI	Letter of Intent
MIDAS	Más Inversión para el Desarrollo Sostenible
MODIS	Moderate-Resolution Imaging Spectroradiometer
MRV	Monitoring Registry and Verification
NASA	National Airspace Agency
NPC	Naidi Production Company
NPV	Net Present Value
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PD	Project Document
PES	Payment for Environmental Services
REDD	Emissions Reductions from avoided Deforestation and Degradation
SAR	Synthetic Aperture Radar
SMEs	Small and medium-sized enterprises
SPV	Special Purpose Vehicle
TA	Technical Assistance
TBD	To be determined
tCO2e	Ton of carbon dioxide equivalent
TGC	Terra Global Capital
USAID	United States Agency for International Development
US$	United States Dollar
VCS:	Verified Carbon Standard
VCU:	Verified Carbon Unit

Executive Summary

This document summarizes the assessment of leakage areas designed and used in BioREDD project documents. Development of leakage areas or belts is a major component of any REDD+ projects. The underlying cause behind the leakage of carbon is from various conservation activities resulted from implementing REDD+ projects in the region. In general carbon leakage is a similar off-site effect. Greenhouse gas (GHG) net emission reductions in one area are affected by project-attributable emissions outside of targeted mitigation areas. Leakage can occur whenever the spatial scale of intervention is inferior to the full scale of the targeted problem. Taking a reducing emissions from deforestation and degradation (REDD) example, a farm-level payment for environmental services program may reward the landowner for not deforesting in the REDD project area or forest plot during five years. However, if the owner shifted all planned deforestation from the forest plot within the REDD project to another, non REDD controlled plot, mitigation would be entirely offset by leakage or 'displacement of emissions', as the phenomenon is called in the Bali Action Plan (Thirteenth Session of the Conference of the Parties-COP 13). Shifts in demand for land or land resources such as timber, whether through competitive land markets or other spatial substitution mechanisms, are the dominating leakage force for REDD+ projects (both conservation and SFM): since deforestation is primarily caused by land conversion to agriculture, closing the agricultural frontier will create land shortages, unless technologies allow for intensifications. Induced land shortages are more pronounced for REDD than for afforestation and reforestation (A/R), which is often carried out on degraded lands with low economic value.

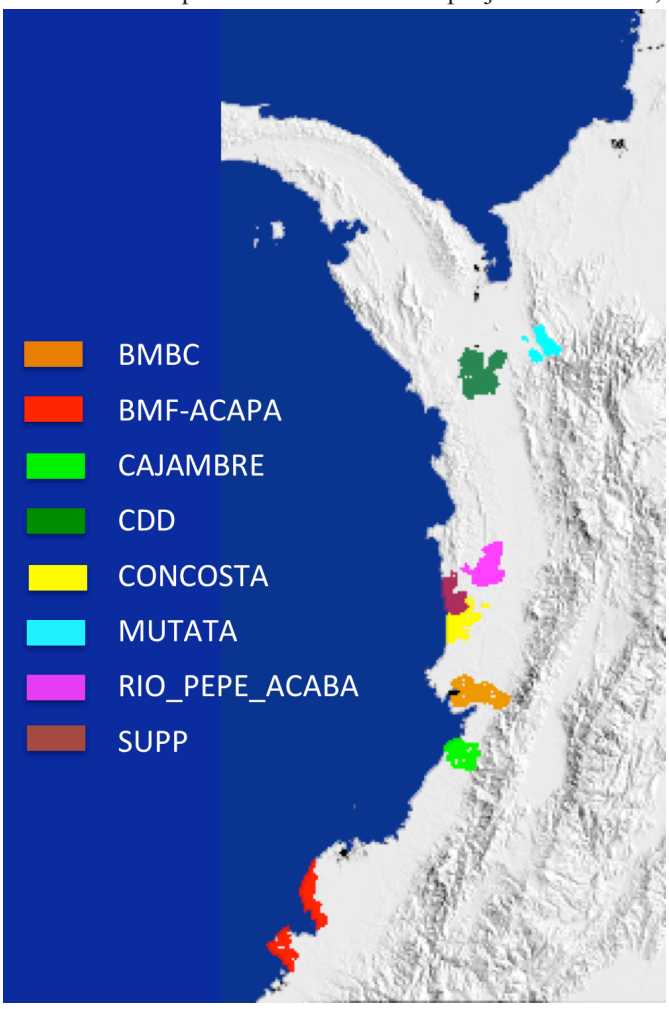

Fig.1. Location of 8 BioREDD+ project areas along the Pacific Coast of Colombia.

The BioREDD project has used a series of protocols based on the VM0006 methodology and various economic and GIS data on roads, market access and other LULC attributes to design the leakage areas within a larger reference areas that should be monitored in future for any carbon leakage and credit development. In this document, we will use the GIS layers delineating the leakage areas within each project and inside the reference areas to assess their baseline LULC and carbon pools to both understand the current status of leakage areas and the future changes through a monitoring plan. We will use the satellite based LULC data, carbon estimates from lidar and ground data to perform an assessment of leakage areas for each of the 8 projects within the BioREDD region. Figure 1. Shows the overall areas of project and leakage areas along the coastal forests of Colombia. The document provides information on LULC and carbon for all projects together but will elaborate on project areas individually if necessary.

1.0 Introduction & Context

The BioREDD project started in 2012 as the flagship environmental program of the United States Agency for International Development (USAID) in Colombia. This US$ 27.9 million program is designed to strengthen Colombian capacity to mitigate and adapt to climate change, protect biodiversity and support the development of remote, impoverished communities. The development of REDD+ projects is a key element of the Program, which seeks to promote sustainable livelihoods compatible with forest conservation. BIOREDD+ is developing a portfolio of 8 REDD+ projects in the Colombian Pacific to be validated under the Climate, Community and Biodiversity Alliance (CCBA) and the Verified Carbon Standard (VCS). The projects are located in four geographic nodes covering over 700,000 hectares.

The BioREDD project selected eight areas along the Pacific coastal region of Colombia for developing REDD+ projects (Figure 1). These areas are distributed in different municipalities along the pacific coastal forests of Colombia, covering a variety of ecosystems, transitioning from coastal mangroves and wetlands to *paramos* and high mountain forests. This area forms part of the Chocó Biogeographic corridor, one of the 10 world´s mega-diverse hotspots that accounts for more than 40% of the total vertebrate population of Colombia. The REDD+ projects will be established in the territories of afrocolombian and indigenous communities along the coast where forests have been degraded and are under the threat of further degradation and deforestation for a variety of reasons. The main drivers of forest cover change have been identified as degradation from timber extraction for fuel and development needs, illegal logging, gold mining, and conversion of forests to agriculture and livestock. The projects are being developed jointly with local communities who have clear legal title to their land and have themselves agreed to REDD+ project development. They will be implementing REDD+ project activities with the expectation of generating revenues in exchange for their conservation efforts. The drivers of forest cover change may cause displacement of carbon emissions or land use change as a result of the implementing of BioREDD+ projects, resulting carbon leakage.

2.0 Definition and Design of Leakage Areas

Leakage areas are designed to quantify the potential Carbon leakage or the displacement of greenhouse gas (GHG) emissions from one place to another due to BioREDD+ emission reduction activities. Leakage is caused by a direct or indirect shift of activities that create those emissions from within an emissions accounting system to out of that system (Henders and Otswald, 2012). The IPCCdefines leakage as "the unanticipated decrease or increase in GHG benefits outside of the project's accounting boundary or areas as a result of the project activities (IPCC, 2000). In other words, leakage is the result of interventions to reduce emissions from deforestation and degradation in a defined geographical area (project area) that indirectly causes an increase in emissions in another area outside the project area. The increased emissions outside the project area must be measured and attributed to the project activity. Leakage is fundamentally an economic process where agents and drivers of deforestation and degradation respond to the new economic conditions and restrictions as a result of implementing REDD+ projects. Following the methodological approach provided the VCS VM0006 Methodology in Section 8.3.3.2, an economic cost-distance analysis was conducted to define the leakage belts using information from the Timber Study, geographic datasets, and ArcGIS software in the Spatial Analyst module. Under this methodology, leakage is estimated *ex-ante*, but actual NERs are based on actual leakage calculated with project monitoring data. Leakage does not only occur on forest land outside of the project area, but also on non-forest land, such as woodlands or grassland.

To determine the size of leakage area belts with respect to an agent's willingness to travel, a raster cost map was developed with a resolution of 30m x 30m using several variables including: 1. remote sensing based LULC maps developed by GeoEcoMap (report # 7) for the period of 1990, 2000, and 2012, 2. Digital elevation data, 3. Logging roads derived from different studies by the BioREDD project, 4. Timber collection centers, 5. Project areas, 6. Boundary of national parks in the region, 7. GIS data on forestry concessions in the region, 8. Mining areas, and 9. Urban areas from IGAC 2012.

in addition to timber extraction costs from the Timber Study were used to develop the leakage areas. Rather than establishing a cost-distance analysis of different land cover types based on traveling speed, an economic cost of timber extraction was used. The basis for the analysis of this information was obtained from the Timber Study by CONIF where forest production costs were estimated from data collected in the field from focus groups, interviews with brokers, buyers and staff performing community forestry between December 2013 and January 2014. Economic costs according to the distance from logging yards by three different means of transport (by foot, mule, motorized boat) that are commonly used in logging in the Colombian Pacific were estimated. This analysis also shows the maximum distance in which each method of transport can be used (e.g. the extraction by foot cannot be more than 3 km).

The use of these methods of extraction depends on the topography (slopes), road conditions, and access. Using the geographic datasets mentioned earlier, for example, the extraction costs per unit area were weighted to give a higher cost to timber extraction for higher slopes. Additionally, areas that are considered inaccessible by agents of deforestation and/or degradation such as national parks, forestry concessions, and mining areas were given an arbitrary high value.

The classification of slopes was conducted by analyzing and accounting for ranges for land use classification established by the USDA (US Department of Agriculture). This resulted in the classification of seven different slope classes, as seen in Table 3. This information was used to create a map from a DEM provided by IGAC (Table 1) at a scale of 1: 100,000, by assigning greater weight to areas that present less resistance to deforestation according to the slope and by excluding areas with slopes greater than 12%, which are equivalent to categories ranging from strongly sloping or strongly rolling to very steep.

Taking into account all the variables described in tables 1 , 2, and 3, this information is calculated in a raster image with a pixel size of 30x30 meters, where each cell indicates the minimum cost that has to mobilize one cubic meter of wood. From this analysis a resulting map of the average cost per cubic meter of timber to move across each pixel was provided in 30m x 30m grid.

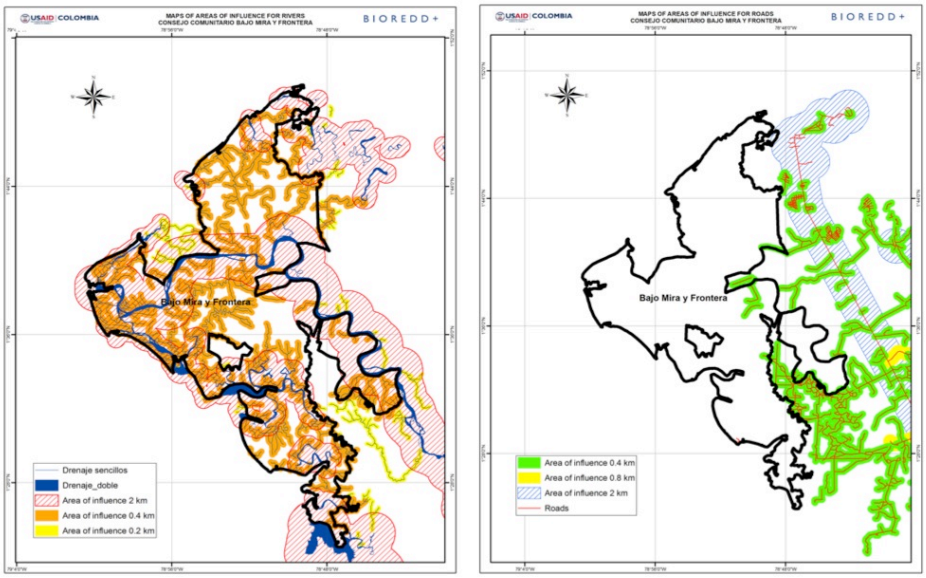

Fig.2. Samples showing the areas of influence developed for roads and rivers based on the economic data in the BioREDD region and for each project area.

Areas of influence were established for rivers and roads based on the associated costs for timber extraction, the average market price for timber, and the carrying capacity of different transport modes along different types of routes depending on size and condition. The areas of influence are based on cost-distance and the maximum willingness to travel, two concepts presented in the VCS VM0006 Methodology in Section 8.3.3.2.

The cost-distance from the project area was determined by using the *Cost Distance* tool in the ArcGIS Spatial Analyst Module. This map provided the cumulative cost (COP) to reach the nearest point of the project area boundary. The maximum willingness to travel was based on the assumption that when logging costs are equal to revenues (i.e. economic gain is zero) agents of deforestation and/or degradation won't travel any further. This was determined by the average market value of timber and the carrying capacity of different transport methods. This

analysis resulted in buffers surrounding the timber extraction routes (rivers, roads) that depend on the carrying capacity of these features. Table 5 shows the carrying capacity and area of maximum influence for primary, secondary, tertiary rivers and drainages.

The following is the list of leakage areas associated with BIoREDD project areas.

2.1 ACAPA_RIO PEPE REDD+ PROJECT

The project proponents are the communities of Río Pepé and Acaba.The entireproject area lies within the areas awarded to these communities through executive resolution (The communities are organized as community councils (consejos comunitarios, or CC), to which the property rights have been allocated. These land rights are protected by Constitutional Law, and by Law 70/93. These lands cannot be expropriated nor have liens set on them. The Right of Use is exclusively placed on the local communities belonging to the same Afro-descendant ethnic group. The project boundaries are depicted in Figure 3 on both the radar and Landsat imagery for visualization. The project area corresponds to 47,902 hectares of forest area within the community lands belonging to Río Pepé (4,757) and Acaba (43,145). Forestry Management Plan areas are excluded as these will continue to be harvested in the future. Using the economic and distance measures and a series of remote sensing LULC transitions, the leakage areas were estimated to be about 34,254 ha.

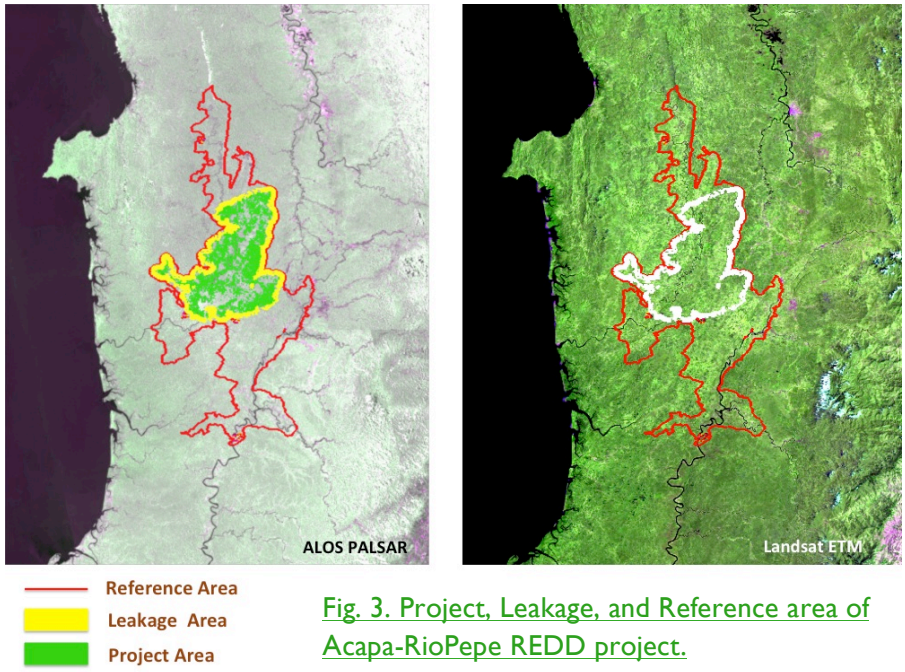

Fig. 3. Project, Leakage, and Reference area of Acapa-RioPepe REDD project.

2.2. ACAPA-BAJO MIRA Y FRONTERA REDD+ PROJECT

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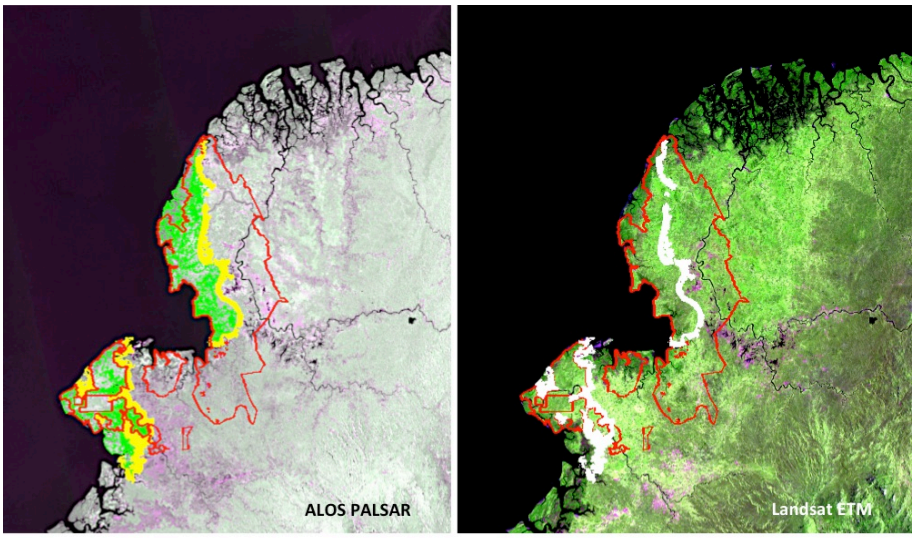
A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various Afro-Colombian and indigenous community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas.

Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference area as similar to the project area with respect to land cover, climate, and geography.



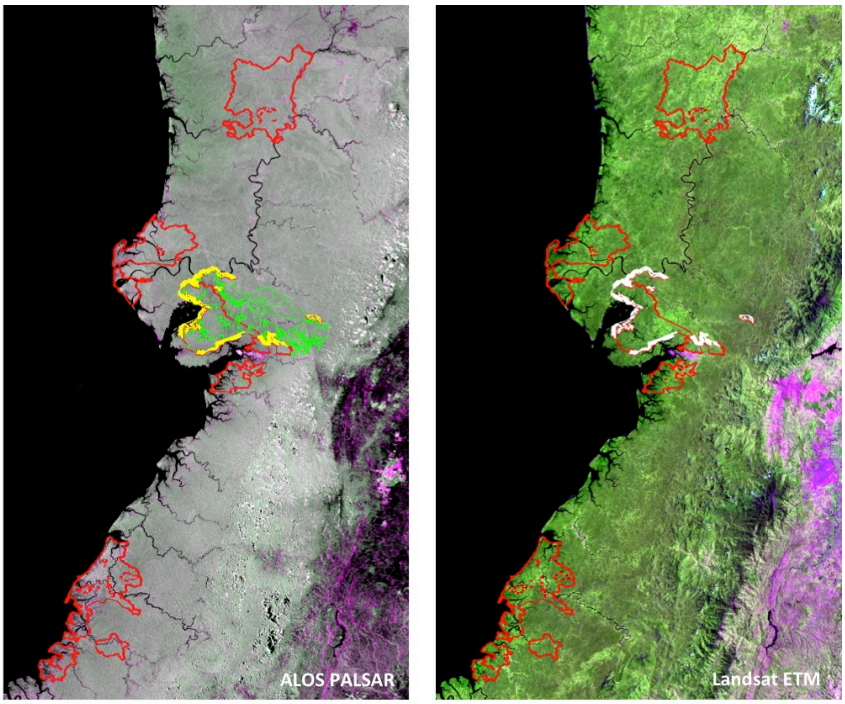
Reference Area
Leakage Area
Project Area

Fig. 4. ACAPA Bajo Mira BioREDD+ project, leakage, and reference areas.

Based on the results provided by the LULC analysis from the remote sensing data and the Timber Study, an economic cost-distance GIS approach was used to define the leakage belts. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from the Timber Study and GIS information as described earlier. Using the areas of influence falling within the project area a 30-meter resolution raster map was created, where each cell was an estimate of the economic cost for each mode of transportation in terms of cubic meters per kilometer. Applying this economic distance to the raster map of costs for each mode of transportation the leakage area was calculated to be 32,492 ha as shown in Figure 4. The leakage area is the sum of all leakage belts.

2.3 BAJO CALIMA & BAHIA MALAGA REDD+ PROJECT

A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various Afro-Colombian community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas.



Reference Area
Leakage Area
Project Area

Fig. 5. Bajo Mira and Bajo Malaga BioREDD+ project, reference, and leakage areas.

Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference

area as similar to the project area with respect to land cover, climate, and geography. There were no areas found in the reference region that were deforested due to natural circumstances.

Based on the results from the LULC analysis and economic and the Timber Study an economic cost-distance GIS approach was used to define the leakage belts. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from the Timber Study. Using the areas of influence falling within the project area a 30-meter resolution raster map was created, where each cell was an estimate of the economic cost for each mode of transportation in terms of cubic meters per kilometer. Applying this economic distance to the raster map of costs for each mode of transportation the leakage area was calculated to be 14,702 ha (see Figure 5).

2.4 CAJAMBRE REDD+ PROJECT

The project proponent is the community of Cajambre. The project area lies within the areas awarded to this community through executive resolution. The community is organized as acommunity council (consejo comunitario, or CC), to which the property rights have been allocated. These land rights are protected by Constitutional Law, and by Law 70/93. These lands cannot be expropriated nor have liens set on them. The Right of Use is exclusively placed on the local communities belonging to the same Afro-descendant ethnic group. The project boundaries are shown in figure 6 along with the reference and leakage areas.

The reference region is 259,856 hectares in size and adequately represents the trajectory of the project area in the absence of the project activities. That is, it is greater than 250,000 ha in size, contains a minimum of 15% forest cover, has boundaries which are unbiased and coincide with natural, geopolitical boundaries and/or the application of a distance buffer. The reference region does not contain areas where agents of deforestation have restricted access such as national parks, military bases, conservation areas, or restricted land concessions. A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various Afro-Colombian community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas.

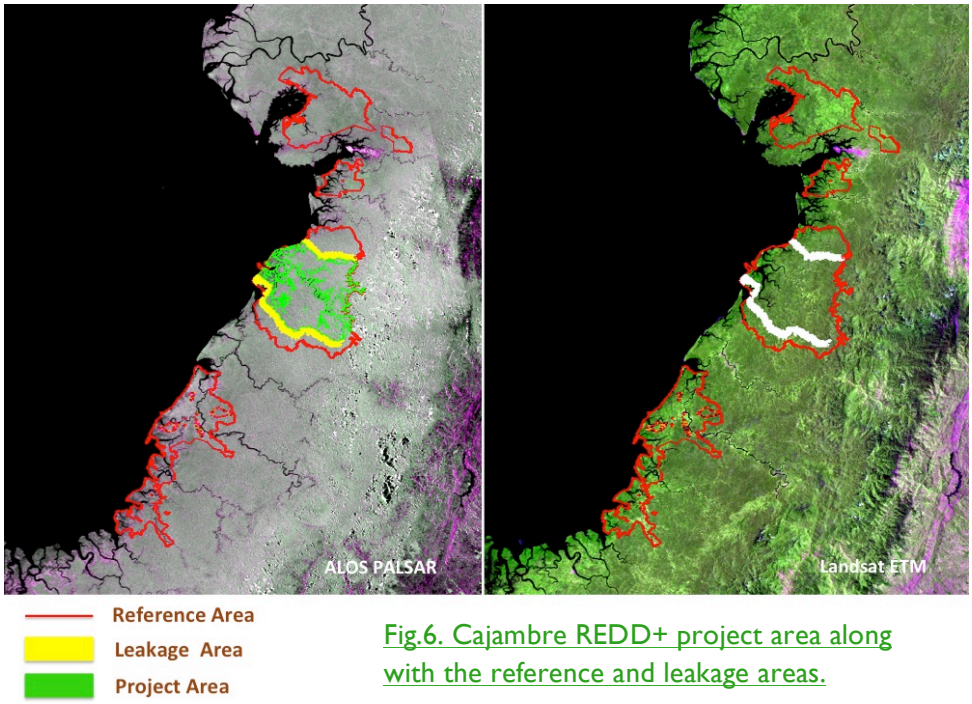
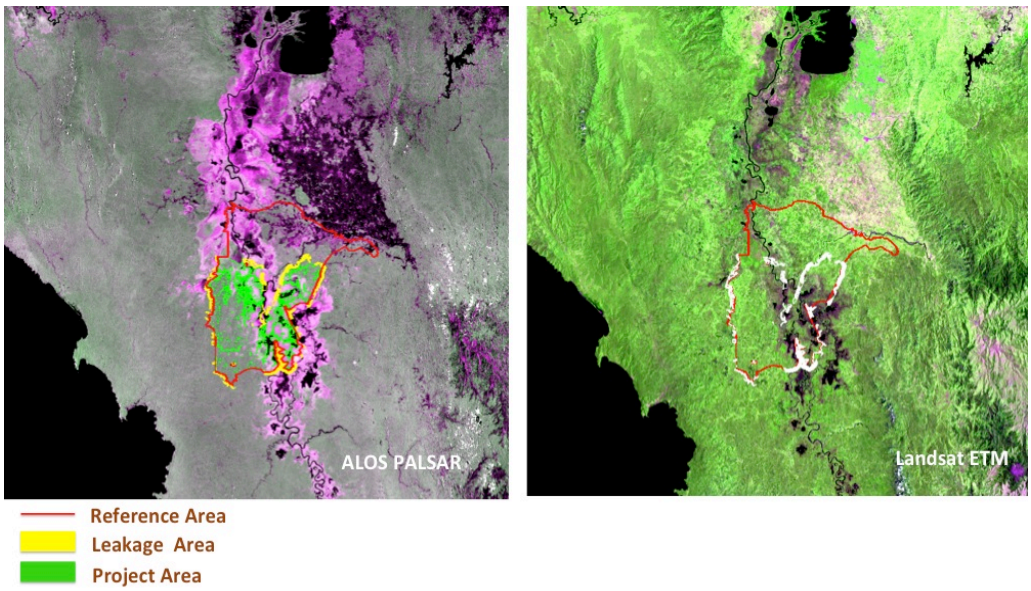


Fig.6. Cajambre REDD+ project area along with the reference and leakage areas.

Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference area as similar to the project area with respect to land cover, climate, and geography. Using a combination of GIS and remote sensing derived LULC and the results of the Timber Study, an economic cost-distance GIS approach was used to define the leakage belts. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from the Timber Study. Applying various economic distance and metrics to the raster map of costs for each mode of transportation the leakage area was calculated to be 11,221 ha (see Figure 6).

2.5 CARMEN DEL DARIEN REDD+ PROJECT

The project area is located in the collective territories of Chicao, La Madre, Apartadó-Buenavista, Domingodó, Vigia de Curvaradó y Santa Rosa de Limón, y Montaño, in the Pacific coastal municipality of Carmen del Darién, in the Department of Chocó.Spatial boundaries and shown in figure 7. The project area is located in the collective territories of Chicao, La Madre, Apartadó-Buenavista, Domingodó, Vigia de Curvaradó y Santa Rosa de Limón, y Montaño, in the Pacific coastal municipality of Carmen del Darién, in the Department of Chocó. Belonging to the biologically diverse Chocó-Darién bioregion, forests of the area are important nationally and internationally for the ecosystem services they provide. The forests in the project area, however, have experienced a continued reduction in biomass due largely to illegal logging. These forests have historically been an important source of income for local families, who periodically harvest timber when the economic needs arise. Illegal timber extraction is historically an important source of income within the project zone and is the major focus of the REDD+ project.



A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various Afro-Colombian and indigenous community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas. Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference area as similar to the project area with respect to land cover, climate, and geography. The reference area consists of 262,262hectares and demonstrates the similarity criteria as required by VM0006 and as shown in figure 7.

The leakage areas as the sum of all the leakage belts were designed based on GIS spatial data, LULC maps derived from the remote sensing data by GeoEcoMap, and the results from Timber Study and an economic cost-distance GIS approach. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from the Timber Study. Using the areas of influence falling within the project area a 30-meter resolution raster map was created, where each cell was an estimate of the economic cost for each mode of transportation in terms of cubic meters per kilometer. Applying these economic distance and metrics to the raster map of costs for each mode of transportation the leakage area was calculated to be 18,339 ha (see Figure 7).

2.6 CONCOSTA REDD+ PROJECT

The project area is located in the collective territory of Concosta, in the Pacific coastal municipalities of Litoral de San Juan y Bajo Baudó, in the department of Chocó. Belonging to the biologically diverse Chocó-Darién bioregion, forests of the area are important nationally and internationally for the ecosystem services they provide. The project area forests, however, haveexperienced a continued reduction in biomass due largely to illegal logging.Project area forests are also an important source of income for local families, who periodically harvest timber when the economic needs arise. The project zone is defined as the entire territory of the community of Concosta. This comprises the area within which REDD+ project activities that directly affect land and associated resources will be implemented (see Figure 8).

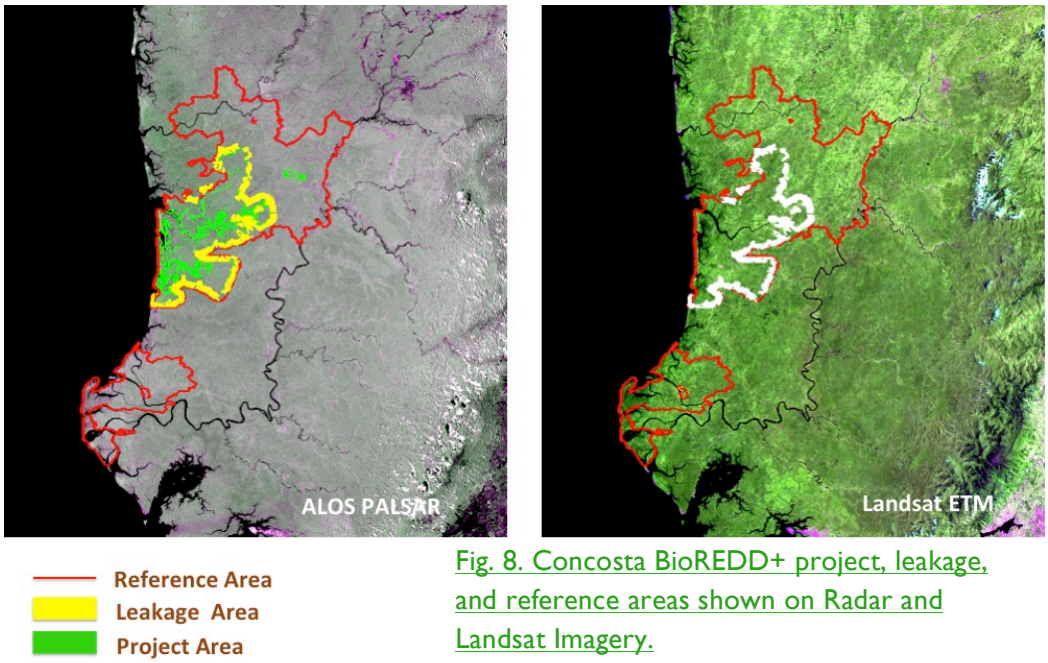


Fig. 8. Concosta BioREDD+ project, leakage, and reference areas shown on Radar and Landsat Imagery.

A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various Afro-Colombian community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas. Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference area as similar to the project area with respect to land cover, climate, and geography. The reference region is 255,737 hectares in size and adequately represents the trajectory of the project area in the absence of the project activities. That is, it is greater than 250,000 ha in size, contains a minimum of 15% forest cover, has boundaries which are unbiased and coincide with natural, geopolitical boundaries and/or the application of a distance buffer. The reference region does not contain areas where agents of deforestation have restricted access such as national parks, military bases, conservation areas, or restricted land concessions.

Leakage areas are delineated within the reference area by using GIS spatial data and LULC maps at 30 m resolution. The leakage belts are delineated using the results of the Timber Study and an economic cost-distance GIS approach. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from the Timber Study. Using the areas of influence falling within the project area a 30-meter resolution raster map was created, where each cell was an estimate of the economic cost for each mode of transportation in terms of cubic meters per kilometer. Applying this economic distance to the raster map of costs for each mode of transportation the leakage area was calculated to be 16,826 ha (see Figure 8).

2.7 MUTATÁ REDD+ PROJECT

This project is an Agriculture, Forestry and Other Land Use (AFOLU) project under the Reducing Emissions from Deforestation and Degradation (REDD) project category. Specifically, the project is of the "Avoided Unplanned Deforestation & Degradation" (AUDD) project category. The project is located within the indigenous reserves of the communities of Embera-Katio of Chontadural Cañero, Embera-Katío of Jaikerazavi, and Embera-Katio of Coribí-Bedadó. These communities are within the jurisdiction of the municipality of Mutatá, located in the department of Antioquia and in the municipality of Carmen del Darién, Department of Chocó, in northwest Colombia. Belonging to the biologically diverse Chocó-Darién bioregion, forests of the area are important nationally and internationally for the ecosystem services they provide. The project area forests, however, haveexperienced a continued reduction in biomass due largely to illegal logging.Project area forests are also an important source of income for local families, who periodically harvest timber when the economic needs arise.

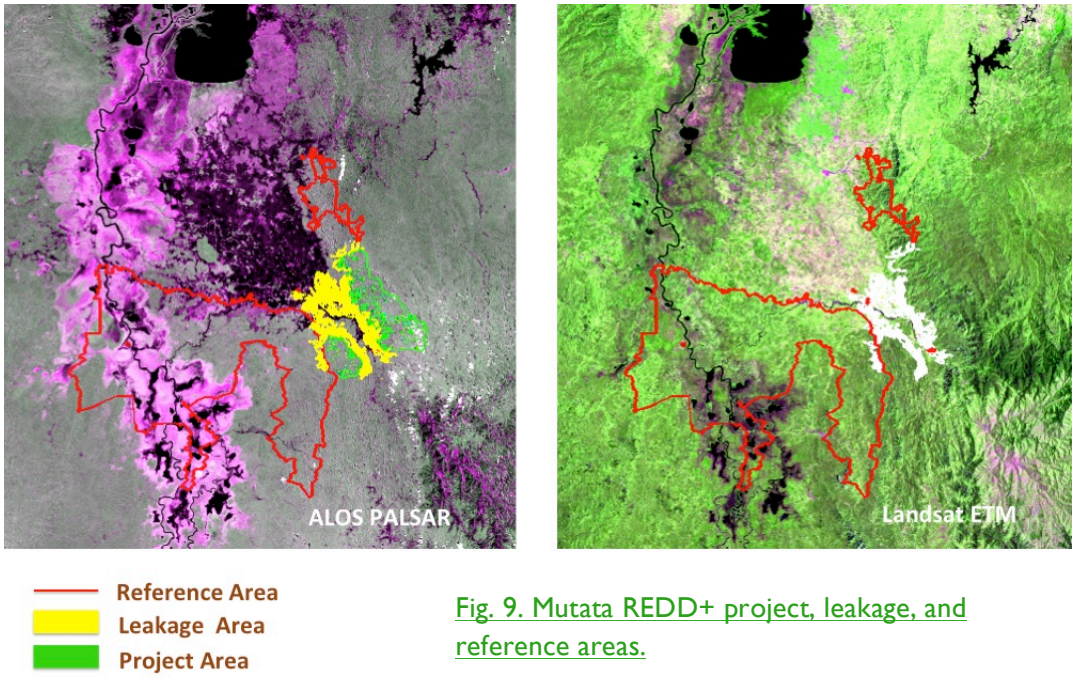


Fig. 9. Mutata REDD+ project, leakage, and reference areas.

A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various indigenous community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas.

Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference area as similar to the project area with respect to land cover, climate, and geography.

The reference region is 252,859 hectares in size and adequately represents the trajectory of the project area in the absence of the project activities. That is, it is greater than 250,000 ha in size, contains a minimum of 15% forest cover, has boundaries which are unbiased and coincide with natural, geopolitical boundaries and/or the application of a distance buffer. The reference region does not contain areas where agents of deforestation have restricted

access such as national parks, military bases, conservation areas, or restricted land concessions. Any areas of planned deforestation are excluded, as well as any large-scale, extraordinary deforestation events.

Based Spatial GIS layers and the Timber Study, an economic cost-distance GIS approach was used to define the leakage belts. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from the Timber Study. Applying this economic distance to the raster map of costs for each mode of transportation the leakage area was calculated to be 21,492 ha (see Figure 9).

2.8 SUPP REDD+ PROJECT

The project area is located in the collective territories of Sivirú, San Andrés de Usaragá, Pizarro, and Piliza, in the Pacific coastal municipality of Bajo Baudó, and the Department of Chocó in Colombia. Belonging to the biologically diverse Chocó-Darién bioregion, forests of the area are important nationally and internationally for the ecosystem services they provide. The forests in the project area, however, have experienced a continued reduction in biomass due largely to illegal logging. These forests have historically been an important source of income for local families, who periodically harvest timber when the economic needs arise. Illegal timber extraction is historically an important source of income within the project zone and is the major focus of the REDD+ project. Following from the gradual degradation of forests caused by continual timber extraction, many forest areas are ultimately converted to agriculture and pasture. The project area corresponds to 47,464hectares of forest area within the community lands. Forestry Management Plan areas are excluded from the project area as these areas continue to be harvested in the future.

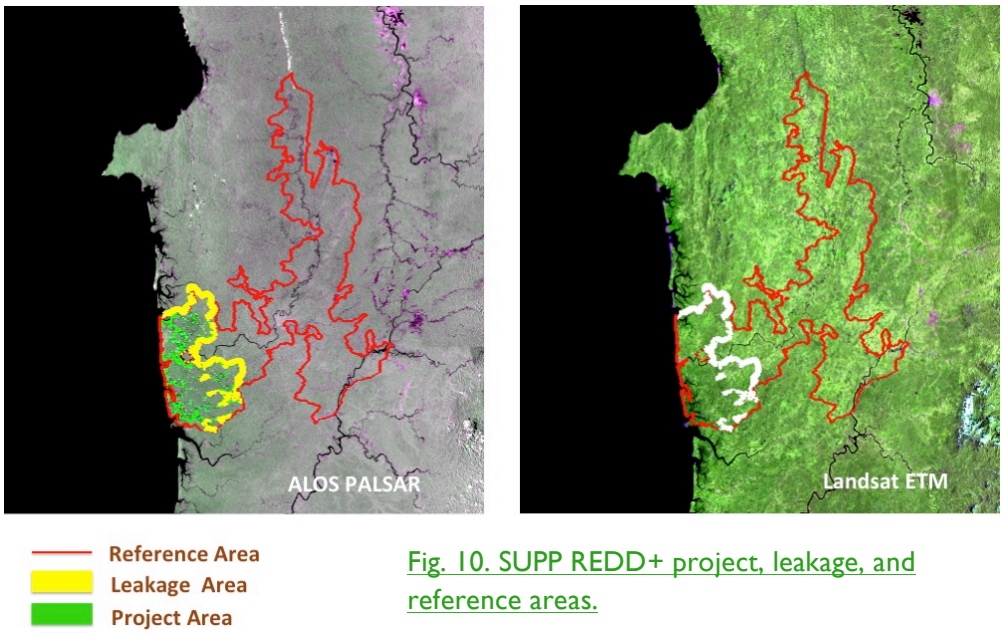


Fig. 10. SUPP REDD+ project, leakage, and reference areas.

A combination of different geospatial data was used to delineate a reference area that conservatively and accurately reflects the baseline scenario in the project area. The main defining unit for the reference area was a combination of various Afro-Colombian community boundaries because the project area itself consists of similar community territories. By restricting the reference area boundaries to these territories, it is ensured that similar systems of governance, regulations, social structure, and customs are present in both the project and reference areas. Within these boundaries, the reference region was further narrowed down using data such as slope, elevation, forest cover types, precipitation, and temperature. These factors were considered in order to make the reference area as similar to the project area with respect to land cover, climate, and geography. The reference area corresponds to an area of 266,294 hectares and demonstrates similar criteria as the project area, as required by VM0006.

Based on GIS spatial data and LULC maps derived from remote sensing data produced by GeoEcoMap and the results from a Timber Study, an economic cost-distance GIS approach was used to define the leakage belts. Areas of influence in the project area including rivers, logging roads, and log yards were mapped using data collected from

the Timber Study. Using the areas of influence falling within the project area a 30-meter resolution raster map was created, where each cell was an estimate of the economic cost for each mode of transportation in terms of cubic meters per kilometer. Applying this economic distance to the raster map of costs for each mode of transportation the leakage area was calculated to be 12,446 ha (see Figure 10).

3.0 LEAKAGE LULC ASSESSMENT

See attached spreadsheet for all calculations of LULC and transitions for Leakage areas

4.0 LEAKAGE CARBON ASSESSMENT

See attached spreadsheet for all calculations of Carbon Pools for Leakage areas