MOCUPP

MONITORING LAND USE CHANGE WITHIN PRODUCTION LANDSCAPES

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Monitoring Land Use Change Within Production Landscapes

MONITORING LAND USE CHANGE WITHIN PRODUCTION LANDSCAPES (MOCUPP)

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Foreword

Robust environmental information systems foster governance and enable countries like Costa Rica to move toward the achievement of the Sustainable Development Goals.

For this reason, the Ministry of Environment and Energy has established the National Environmental Information System since 2014. We started by issuing directives to organize information management by public institutions through the coordination of the National Center for Geo-environmental Information (Centro Nacional de Información Geo-ambiental-CENIGA), and by mandating the creation of the National System for Monitoring Land Use Dynamics (Sistema Nacional de Monitoreo de la Dinámica de Uso de la Tierra-SINAMOCUTE) and the National System of Climate Change Metrics (Sistema Nacional de Métrica de Cambio Climático-SINAMECC).

Monitoring of Land Use Change within Production Landscapes, (MOCUPP) is a vital element of these environmental information systems. It is a strategy for institutional coordination and the generation of yearly images on the total cover of specific agricultural commodities, and low-cost generation of countrywide images of forest cover loss or gain on private property.

MOCUPP is based on several premises. First, that inexpensive or free satellite images can be used to identify whether agricultural commodities land cover has increased or decreased, or to ascertain compliance or noncompliance with the Forest Law. Second, annual processing of these images can be done by national professionals through neutral, specialized institutions such as Laboratorio PRIAS de Costa Rica, with public universities processing the images. Third, a system of information about total agricultural commodities land cover and forest cover loss or gain, such as MOCUPP, can become a land management tool if those maps are linked to land tenure layers which are published periodically and publicly. Fourth, annual monitoring of forest cover loss or gain on private land warrants investments in three areas: I) generation of annual cover maps; II) maintenance of a map viewer linking that information with land tenure (as the National Land Information System) does; and III) advancing digitalization of the national cadaster so that 100% of the land tenure of the country's production territory may be monitored. Fifth, MOCUPP generates benefits for the state and private sector. It lowers government costs of verifying compliance with the Forest Law by making it easier for officials to identify where the law is not being observed each year, associated with specific land tenure. MOCUPP also provides a low-cost way of certifying farms as deforestation-free private property so that the users of those properties can enhance their export competitiveness.

More than a complex technology, MOCUPP represents a monitoring and land management strategy that is practical, low-cost and replicable. That is why we describe here its rationale, outputs, scope and costs as transparently as possible, so that other countries can follow this path and begin annual monitoring of land use dynamics as a way of complying with the Sustainable Development Goals and commitments under the Conventions on Climate Change, on Biodiversity and for Combat of Desertification and Land Degradation.

Dr. Edgar Gutiérrez Espeleta,
Minister of Environment and Energy of Costa Rica

I. Contents

I. Contents 3
II. Introduction 5
III. Background 7
IV. Legislation Applying to MOCUPP 8
V. MOCUPP's Linkage with the National Development Plan and the Long Range Vision of Sustainable Development in Costa Rica 11
VI. MOCUPP as Part of the National Environmental Information System 13
VII. Strategic Framework of Monitoring of Land-Use Change in Production Landscapes to 2020 14
VIII. Strategic Coordination between Partners with Complementary Roles and Jurisdictions 16
IX. Component 1: Annual Generation of Maps on Land Cover Used for Export Commodities (Commodities) and Determination of Loss and Gain of Forest Cover 18
Component Leader: PRIAS Laboratory 18
PRIAS Human and Technical Resources 18
State of the Matter: Remote Sensing of Forest Cover in Production Landscapes 18
Procedure for Preparing Maps on Land Cover of Commodities for Export (Commodities) for Annual Monitoring at National Level 21
Delimitation of Production Landscapes: Total Area of Annual Monitoring 21
Selection of Main Remote Sensing and Complementary Actions for Annual Monitoring 22
Radiometric Correction 25
Atmospheric Correction 25
Geometric Correction 25
Image Classification 25
Generation and Reduction of Spectral Signatures 26
Automated classification (unsupervised) 27
Advanced Classification (Supervised) 27
Validation 28
Generation of Maps from Images 28
Determination of Cover Loss and Gain 29
Images and Processing 29
Analysis of Change in Land Cover 31

	Analysis of Legal and Environmental Restrictions. Forest Law	32
X.	**Component 2:** Generation of Land Tenure Information Available in Online Cadastral Maps	37
	Component leader: Directorate of Real Property Registration and the National Registry	37
	Registration System in Costa Rica	37
	Cadastral Progress in the Publication of Tenure Data	38
XI.	**Component 3:** Map Viewer that Relates Maps of Land Cover in Production Landscapes with Tenure Information on a Periodic and Public Basis	41
	Legal and Technical Foundation for SNIT's Development. Decree 37773	41
	Technological Infrastructure and Installed Capacity	44
	Response Capacity	44
	Statistics	45
	Demand	46
	Information Published. Internal and External Generators	47
XIII.	Benefits and Comparative Advantages of MOCUPP	51
	Identification of Illegal Expansion of the Agricultural Frontier	51
	Monitoring of Forest Cover Loss and Gain from Urban Sprawl	52
	Certification of Deforestation-Free Production Units	53
	Reduce State Costs of Verifying Compliance with the Forest Law	54
XIII.	Strategy for Long-Term Financial Consolidation	55
XIV.	Bibliography	59

II. Introduction

Monitoring of land use change within production landscapes linked with tenure (MOCUPP, in its Spanish acronym) is a tool for sustainably managing landscapes where agricultural commodities are grown for export. It strengthens public sector capacity of land-use management through low-cost, digital identification of the total commodities land cover that can be teledetected through remote sensing[1] . It also identifies focal points of deforestation or forest regeneration each year, making it possible to generate incentives for expanding forest cover on private land. With this tool, Costa Ricans will be able to differentiate deforestation-free production units with no cost to producers or buyers, thus contributing to country competitiveness by facilitating its positioning as agro-exporter in sustainable development, by showing it complies with the Sustainable Development Goals (SDG).

The strategy of MOCUPP is to link, take advantage of and optimize the mandate and technical abilities of three entities: I) the Laboratory of the Airborne Research Program (PRIAS); II) the Directorate of Real Property Registration (Dirección de Registro Inmobiliario-DRI) and III) the unit of the National Geographic Institute that manages the National Environmental Information System (SNIT).

Each year, these three entities in coordination with MINAE's National Geo-Environmental Information Center (CENIGA) generate the following outputs for the National Environmental Information System:

1. Maps on total cover of agricultural commodities that can be differentiated through teledetection
   a. Total cover of pineapple (based on 2015 as reference year).
   b. Total cover of pasture (reference year 2017).
   c. Total cover of sugar cane (reference year 2018).
   d. Total cover of Palm oil (reference year 2019).
   e. From 2020 on, all commodities, every year.

2. Maps on forest cover loss and gain superimposed on maps showing commodities land cover
   a. By 2017, 2000-2015 baseline of forest cover loss and gain in pineapple production landscape, followed by yearly analysis of loss and gain.
   b. By 2018, 2000-2016 baseline of forest cover loss and gain on pasture landscape, followed by annual analysis of loss and gain.
   c. By 2019, 2000-2018 baseline of forest cover loss and gain on production landscape with sugar cane, followed by analysis of loss and gain.
   d. By 2020, 2000-2015 baseline of forest cover loss and gain 2000-2015 Palm oil production landscape, followed by analysis of loss and gain.
   e. From 2020 onwards, maps of forest cover loss and gain for the four previously mentioned commodities, every year, using the previous year as reference.

3. A pilot study on urban area and forest cover loss and gain around the María Aguilar Interurban Biological Corridor to determine the viability of monitoring all main urban areas of the country as of 2020.

1. *Pineapple, African palm, sugar cane. Other crops such as coffee and cacao are not yet included since it is more complex to differentiate these through remote sensing and monitoring costs are higher. However, these may be included in the future to differentiate production units of these crops.*

The maps are generated by PRIAS and published through the National Land Information System, so any user can connect them with registry information on the specific tenure of farms in areas of national territory with officialized cadaster. With public dissemination of geospatial information about commodities land cover and loss and gain of forest cover, deforestation is avoided in two ways:

First, government institutions with a mandate to enforce the Forest Law and other environmental legislation, such as the National System of Conservation Areas (Sistema Nacional de Áreas de Conservación-SINAC) can use the maps generated by MOCUPP every year to process noncompliance and plan verification tours at specific sites defined by their coordinates, reducing the cost of public investment in control. Also, SINAC itself and other MINAE institutions such as the National Forest Financing Fund (Fondo Nacional de Financiamiento Forestal-FONAFIFO) and municipalities can use the annual maps to plan and expand incentives schemes, such as payment for environmental services or payment for ecosystem services.

Second, the private sector can take advantage of the system to differentiate from international competitors by marketing commodities from deforestation-free farms. MOCUPP does not generate any cost to landowners or producers; it is simply a public access tool that can be used to demonstrate, for example, that pineapple or sugar cane comes from a farm comprised of several properties with forest that remains intact over time, or that meat or dairy production on a given farm is following the Ministry of Agriculture's Low-Emission Livestock Raising recommendations (NAMA Livestock) on using live fences and recommended silvopastoral methods. Producers can thus differentiate their product and obtain better prices.

This document provides a strategic, legal, technical and financial description of MOCUPP. It begins with current legislation supporting development of the tool, followed by its relation to the current National Development Plan and other environmental policy instruments, such as the National Biodiversity Policy, National Wildlife Areas Policy, National Climate Change Strategy and its action plan, and others. This section concludes that MOCUPP continues the Costa Rican vision of sustainable development pursued throughout many years and political administrations. The document proceeds with a summary of objectives and expected results, followed by a description of the strategic linkage between three entities, independent but functioning and growing together to monitor yearly land use change within production landscapes at national level, the first service of its kind in the world. A technical section looks at the procedure for generating maps on forest loss and gain and total commodities land cover with teledetection. Finally, the last section presents a design for the system's consolidation with funding obtained to date, it identifies the resources required for for its long-run operation. The transparency in providing cost data reflects the intent to demonstrate that this is a lost-cost and highly meaningful investment compared to ordinary investments and given the savings this tool generates in activities by MINAE and other public agencies to enforce the Forest Law and other environmental legislation. The document is designed to show all of the components and costs of the Costa Rican monitoring system so that other countries can study, replicate and improve the tool. This way, more and more agro-exporters with forest to protect will be able to monitor agricultural commodity land cover and forest cover associated with land tenure—annually, permanently, and at low cost.

III. Background

The idea of monitoring land use change in production landscapes linked with tenure (MOCUPP) arose from democratic dialogue directed by the Costa Rican ministries of environment and agriculture between 2011 and 2015. This process was facilitated by UNDP, with more than 1000 individuals in the public sector, civil society and private sector participating, aimed to promote collective action for improving the environmental and social performance of the country's pineapple production chain. The culmination was the presidential approval of Decree No. 39462 MAG-MINAE-MTSS officializing public sector actions contained in the National Action Plan for Responsible Pineapple Production and Trade. Some the plan's tasks are to i) "establish a public information system on land use and legislation at the farm level" and "develop a program for control and registration of protection areas adjacent to the production farms."

In 2014, the Green Commodities Program (GCP), the UNDP unit in charge of facilitating development of the plan for the ministries of environment and agriculture, designed the original concept of MOCUPP as a tool enabling Costa Rica to carry out those tasks. This first concept entailed an initial investment of $60,000 for a preliminary study of MOCUPP. It was at that moment that Laboratorio PRIAS, part of the Center for High Technology (Centro Nacional de Alta Tecnología-CENAT), was contacted to partner with the initiative. Midway through that year, UNDP expanded on the idea of connecting MOCUPP with the process of defining the National REDD Strategy, as a very powerful tool to fight deforestation associated with agricultural commodities.

In 2015, MINAE through FONAFIFO requested a Targeted Support from the UN-REDD Program (TS2) for studies and investments to finalize the design of the National REDD Strategy. Activities to be funded included a second investment to create MOCUPP. This paid for Laboratorio PRIAS' work to generate a map of pineapple cover in Costa Rica by developing a spectral signature and use of a advanced classification as an analytical method. This map is now visible through the National Land Information System (SNIT) (www.snitcr.go.cr)[2].

Throughout the development of that cover map (2015-2016), the UNDP Green Commodities Program continued working on the MOCUPP concept in close association with the National Center for Environmental Information (Centro Nacional de Información Ambiental-CENIGA), mainly with respect to coordination for MOCUPP.

In 2016, MINAE, which in this administration has aimed to consolidate the National Environmental Information System (Sistema Nacional de Información Ambiental-SINIA), requested UNDP to formulate the project Conservation of Biodiversity through Sustainable Management in Production Landscapes in Costa Rica, funded by the Global Environment Fund (GEF). This project, which GEF approved in July 2016, strengthened MOCUPP and provided financing for the main outputs of the system up to 2020, amongst others. In this way, MINAE, under the leadership of CENIGA and with support from the UNDP Green Commodities Program and UN-REDD, developed the operational and consolidation strategy for MOCUPP, as described in this document.

2. SNIT has a web map viewer (WMS) (http://snitcr.go.cr/visor/). MOCUPP shares cover maps and loss and gain maps in both the SNIT and CENIGA viewer. In both cases, cover maps can be viewed from a GIS by loading a WMS layer.
http://snitcr.go.cr/visor/

IV. Legislation Applying to MOCUPP

The creation and implementation of MOCUPP has extensive juridical support. The Costa Rican Constitution mandates state transparency, publicness and accountability (Article 11), and establishes the right to participation and to request and access information of public interest (Articles 9, 27 and 30, respectively). Most especially, Article 50 guarantees the right to a healthy and ecologically balanced environment, which includes the right to effective access to environmental information, to be informed, and to disseminate that information freely.

At the international level, Costa Rica has signed a large number of declarations, treaties and agreements requiring the nation to implement environmental information systems, keep them updated and provide citizens proper access. Principle 10 of the 1992 Rio Declaration on Environment and Development[3] establishes that each individual shall have appropriate access to information on the environment held by public authorities, and requires States to facilitate and encourage public awareness and participation by making information widely available. Agenda 21,[4] in section 10.11, urges countries to strengthen their information systems, necessary for decisions and to assess future changes in land use and management, as well as to provide the appropriate technical information required for informed decision-making on land use and management. For its part, the "The Future We Want" Declaration emanating from the Río+20 Summit[5] recognizes the importance of access to environmental information and the need for global, integrated and science-based information on sustainable development, with an emphasis on global mapping and developing global environmental observing systems. Along that same line, the Bali Guidelines set out the State's obligation to provide affordable, effective and timely access to environmental information, including environmental legislation and policy, and to create information systems on the quality of the environment and environmental impacts on health.

In turn, the United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought or Desertification,[7] the United Nations Framework Convention on Climate Change,[8] the International Tropical Timber Agreement,[9] and the Regional Conventions on Climate Change[10] and Management and Conservation of Natural Forest Ecosystems and the Development of Forest Plantations[11] establish the obligation to create information systems and national land and forest inventories[12].

3. Adopted at the United Nations Conference on Environment and Development held in Río de Janeiro, June 1992.
4. Agenda 21.is a comprehensive plan of action to be taken globally, nationally and locally by the United Nations System, Governments and Major Groups in every area in which human activity impacts on environment. Source: https://sustainabledevelopment.un.org/outcomedocuments/agenda21
5. Adopted during the United Nations Conference on Development and Environment, Rio de Janeiro, June 2012.
6. Bali Guidelines for the Development of National Legislation on Access to Information, Public Participation and Access to Environmental Justice in Environmental Matters of the United Nations Environmental Program, 2010.
7. Law No. 7699 published in Diario Oficial La Gaceta number 211, 3 November 1997
8. Law No.7414 published in Diario Oficial La Gaceta number 126, 4 July 1996.
9. Law No.7143 published in Diario Oficial La Gaceta number 158, 20 August 2013.
10. Law No.7513 published in Diario Oficial La Gaceta number 128, 6 July 1995.
11. Law No.7572 published in Diario Oficial La Gaceta number 47, 6 March 1996.
12. Further, at the level of international law regulating free trade and investment, both the Free Trade Treaty between Central America, Dominican Republic and the United States and the Cooperation Agreement with the European Union call for effective enforcement of environmental legislation and the maintenance, development or improvement of goals and indicators on environmental performance.

In domestic law, under the Internal Control Act[13] State institutions must have information systems enabling the active administration to have institutional documentary management. In conformance with the above, Article 2 of the Organic Law on Environment[14] stipulates that the State must create information systems with environmental indicators to measure evolution and correlation with economic and social indicators, while articles 28 to 31 require that the environmental variable be integrated in land use planning.

The obligation to control, watch over and systematically monitor environmental goods located in State natural patrimony[15] and private land, whether water resources, wetlands, soil, forest, wild flora and fauna or biological diversity, as well as waste management, derives from the Organic Environmental Act (Articles 41, 48, 50, 52 and 53), the Forest Law[16] (Articles 1, 18, 19, 33, 34, 58, 59, 60, 61, 62 and 63), Water Law[17] (Articles 1, 3, 148, 149 and 150), Law on Land Use, Management and Conservation[18] (Articles 1, 2, 3, 51 and 52), Biodiversity Law[19] (Articles 6, 8, 89 and 90), Law on Wildlife Conservation[20] (Articles 3, 90, 98, and 100) and Law on Comprehensive Waste Management[21] (Articles 5, 17 and 18). Similarly, the National Land Use (Plan Nacional de Ordenamiento Territorial-PLANOT 2014-2020)[22] orders consolidation of the National Land Information System (SNIT) and guarantees universal access to land management information, while the National Climate Change Strategy (Estrategia Nacional de Cambio Climático-ENCC)[23] and its Action Plan, in addition to preventing land use change in forest ecosystems, mandates effective control and inspection of forest cover through national inventories.

With respect to private land, constitutional jurisprudence fully supports the prohibition on change in use of forestland[24] and the establishment of protection areas for water resources,[25] considered typical limitations of social interest on private property, backed by Article 45 of the Constitution.[26] Its control, inspection and surveillance, along with dissemination of information related to its state of conservation, therefore constitute a State obligation.

Costa Rica now has several information systems in operation[27] for environment, land use planning and health, particularly the National Environmental System (SNIA),[28] National Land Registry[29] and Land Information System (SNIT).[30] According to the executive decree creating SNIT, its general objective is to promote the generation of

13. Law No.8292 published in Diario Oficial La Gaceta number 169, 4 September 2002.
14. LawNo.7554 published in Diario Oficial La Gaceta number 215, 13 November 1995.
15. Article 13 Forest Law: Constitution and administration. The natural patrimony of the State shall be constituted of forests and forestlands in national preserves, areas declared inalienable, properties registered in its name and those belonging to municipalities, autonomous institutions and other Public Administration entities, except property used as guarantee for credit operations with the National Banking System and become part of its patrimony. The Ministry of Environment and Energy will administer the patrimony. When applicable, through the Attorney General's Office it will register the lands in the Public Property Registry as separate properties belonging to the State. Nongovernmental organizations that acquire property with forest or with forest vocation, with funds deriving from donations or the public purse, that have been obtained in name of the State, shall be transferred and placed under its name.
16. Law No. 7575 published in Diario Oficial La Gaceta number 72 of 16 April 1996
17. Law No. 276 of 27 August 1942
18.Law No.7779 published in Diario Oficial La Gaceta number 97, 21 May 1998.
19. Law No.7788 published in Diario Oficial La Gaceta number 101, 27 May 1998.
20. Law No.7317 published in Diario Oficial La Gaceta number 235, 7 December 1992.
21. Law No.8839 published in Diario Oficial La Gaceta number 135, 13 July 2010.
22. At: http://www.mivah.go.cr/PNOT.shtml
23. Executive Decree No.39114 published in Diario Oficial La Gaceta number 117, 10 September 2015.
24. Articles 19, 33 and 34 of the Forest Law.
25.
26.Constitutional votes 4545-1996, 6054-2008, resolutions 199-2010 and 858-2012 of the First Court, and sentence 366-2003 of the Higher Court of Cassation of Criminal Matters may be consulted in this regard.
27. Sistema Información Geográfico institucional [Institutional Geographic Information System], Sistema de Información de los Recursos Forestales (SIREFOR) [Forest Resource Information System], Sistema Nacional para la Gestión Integral de Residuos [National Comprehensive Waste Management System], and Sistema de Información en Salud (SIVEI) [Health Information System], and work is currently taking place on the design, development and implementation of a national information system for comprehensive water resource management.
28. Executive Decree No. 37658 published in Diario Oficial La Gaceta number 93, 16 May 2013.
29. Law No.6545 of 25 March 1981.
30. Executive Decree No.37773 published in Diario Oficial La Gaceta number 134, 12 July 2013.

products, services and georeferenced geographical information on national, regional and local cover, to publish in integrated and georeferenced form land information produced by public agencies and bodies, as well as private individuals or corporate entities, and to harmonize standardized geospatial information in the frame of a common data infrastructure.

Based on the above, SNIT became the legal means and disseminating platform of the MOCUPP sheet on change in regeneration or change in land use, inasmuch as its constituting decree mandates that the Executive Power publish, through that system, all of the standardized georeferenced territorial information SNIT generates, administers and manages, and may make agreements with autonomous and semiautonomous institutions, municipalities and public enterprises for publication of geo-referentiable land information they administer, manage and construct.[31]

The information fed into MOCUPP and to be disseminated through SNIT is of public nature, character and interest because it forms part of the documents that make up the nation's scientific and cultural patrimony,[32] because this is information about a human right of collective impact, as the environment is,[33] and moreover since it rests on environmental goods of public domain[34] or declared of public interest under the legal system.[35] Its effective access and dissemination is hence a State obligation in the interest of ensuring the right to environmental participation and to permit inspection and surveillance by State entities,[36] limited solely by State secret, copyright laws[37] and the right to informational self-determination.[38] Owing to this, no criminal, civil or administrative responsibility is generated from the publication or transmission of information of public interest, or public documents in public registries or databases, and which has been obtained in conformance with the legal system and limitations established by the Congress.[39]

MOCUPP is supported by constitutional, criminal and administrative jurisprudence, as well as reports of the General Comptroller of the Republic and decisions of the Attorney General's Office.

According to constitutional vote 5616-2015, exercise of the right to information may be restricted for reasons of national security, mandatory provisions or to protect the rights of third parties, in cases and with the scope stipulated in applicable laws in this area, and by resolution of the competent authority, duly justified and motivated. Accordingly, no criminal, civil or administrative responsibility is generated by the publication or transmission of information of public interest, or public documents in public registries or databases, and which has been obtained in conformance with the legal system and the limitations established by Congress.

It can therefore be concluded that effective access to and dissemination of environmental information constitutes a State obligation to guarantee the right to environmental participation and permit inspection and surveillance by State entities. MOCUPP could thus be formally considered an instrument of public interest.

31. *The regulations of the Law on Citizen Protection from Excess Requirements and Administrative Procedures, through the principle of interinstitutional coordination, requires state institutions to share information selectively and in strict adherence to the criteria of pertinence. //Through Inspection Report DFOE-12-2014, the General Comptroller of the Republic ordered MINAE, SINAC and the National Geographic Institute to incorporate in the National Land Information System all standardized geo-referentiable information the Executive Power generates, administers and manages, and that agreed with other institutions in the preparation and approval of regulatory plans, and to provide access for users.*
32. *Article 3 of the Law on the National Archives System.*
33. *Constitutional votes: 2238-1996, 1518-2003, 6322-2003, 7789-2010 and 5615-2015 may be consulted.*
34. *Article 50 of the Organic Law on Environment and Articles 1 and 3 of the Water Law establish public domain over water; Articles 1 and 18 of the Forest Law establish domain over State Natural Patrimony; Article 6 of the Biodiversity Law establishes public domain over biological diversity and numeral 3 of the Law on Wildlife Conservation establishes domain over wild fauna.*
35. *The conservation and wise use of wetlands was declared of public interest through Article 41 of the Organic Law on Environment. Article 48 of that law and Articles 19, 33 and 34 of the Forest Law mandate sustainable use of forest on private land. Public interest in land use, management and conservation is stipulated in Article 53 of the Organic Law on Environment, and numeral 3 of the Law on Land Use, Management and Conservation; and lastly, wild flora is of public interest according to Article 7 of the Wildlife Conservation Law.*
36. *The right to petition is safeguarded by Articles 11, 27 and 30 of the Political Constitution, the Law Regulating Right to Petition and the regulations of the Law on Citizen Protection from Excess Administrative Requirements and Procedures.*
37. *Constitutional votes 1518-2003, 7789-2010 y 5615-2015 may be consulted, as well as article 273 of the General Public Administration Act.*
38. *The right to informational self-determination is regulated in the Law on Protection of the Individual Concerning Treatment of Personal Data and by constitutional vote 5615-2015.*
39. *Constitutional vote 5616-2015 may be consulted.*

V. MOCUPP's Linkage with the National Development Plan and the Long Range Vision of Sustainable Development in Costa Rica

Consolidation of monitoring of land use change within production landscapes linked with tenure (MOCUPP) as part of the National Environmental Information System is a way of achieving several expected outcomes of the Alberto Cañas Escalante National Development Plan 2014-2018 (NDP), It also contributes to achieving the Intended Nationally Determined Contribution (INDC) Costa Rica presented to the Conference of Parties of the United Nations Convention on Climate Change in December 2015.

MOCUPP is a vital tool for monitoring progress in the Emissions Reduction Program in reporting to the Forest Carbon Partnership Facility (FCPF), and exemplifies linkage between territorial, sectoral, public and private initiatives to reduce greenhouse gases. It also constitutes a tool to generate enabling conditions for sectoral greenhouse gas reduction, all of this while adhering to NDP stipulations.

The tool makes it possible to address result 1.4 of the NDP on land conservation under several governance models, since land-planning decisionmakers can verify forest cover on private properties. Specifically, it can help consolidate conservation in priority areas that ensures sustainable use and fair and equitable sharing of the benefits of genetic, natural and cultural patrimony. It does this by facilitating control of forest cover in those ecosystems each year. MOCUPP can also contribute to management and clean-up of the María Aguilar watershed, another focus of work in the NDP, using the watershed as planning approach by developing maps on forest cover loss and gain in the interurban biological corridor. This information explains how people affect vegetation along the riverbanks, which directly affects water quality and understanding of production practices.

MOCUPP can assist with the NDP 2018 goals of maintaining at least 300,000 ha of forest and plantations under the Payment for Environmental Services Program in continental territory, since it facilitates on-the-ground verification of cover for FONAFIFO and SINAC. By enabling publication of forest cover loss and gain through SNIT, the tool will help create forums for civil society participation aiding in processes of protection, control and surveillance of the country's biodiversity and natural resources This also represents a support for enforcing Executive Decree 39660 officializing policy and prioritization criteria for payment of environmental services in the country.

Elsewhere, MOCUPP facilitates achievement of NDP results pertaining to other strategic sectors, such as agriculture and rural development; or science, technology and telecommunications. One objective of the NDP is to increase agricultural value-added, fostering improved productivity and rural sustainable development. MOCUPP allows differentiation so that producers, at no cost, can demonstrate that their production units are free of deforestation, which enhances the country's agro-export competitiveness. MOCUPP also helps small and medium agro-exporters use digital technologies to create value chains in trade of goods and services.

In its INDC, Costa Rica reaffirmed its aspiration of aiming the economy toward carbon neutrality by 2021 as part of its voluntary actions prior to 2020. Under this early action, emissions generated in production landscapes must be lowered. The commitment to the international community is to adapt its lands to climate change using ecosystem-adaptation approaches and increasing forest cover to 60% of national territory. The intent is not to achieve this goal by expanding protected areas, but by generating more and better incentives and tools for expanding cover on private property. It is in this sense that a tool like MOCUPP would be useful to measure the progress of public policies and country efforts included in the INDC. This is also in line with the enhanced transparency framework decided and ratified in the Paris Climate Agreement.

MOCUPP coincides with and facilitates achievement of the country's long range vision, not just in the current NDP but other efforts initiated in previous government administrations on themes related to carbon neutrality, competitiveness and country brand image that depend on harmony between production and sustainability.

The international context obliges us to continue maintaining harmony in that relation and to inform trading partners about it. The New York Declaration on Forests of 2014 united governments, companies and civil society actors, including organizations of indigenous peoples, with the objective of halving annual loss of natural forests by 2020, and attempting to reach zero deforestation in 2030. As part of this process, the world's main commodities traders have established buying principles to eliminate deforestation in their production chains. This has repercussions on our development, so tools like MOCUPP are expeditious for our environmental competitiveness. MOCUPP can also serve as example for other countries with similar circumstances to comply with the New York Declaration.

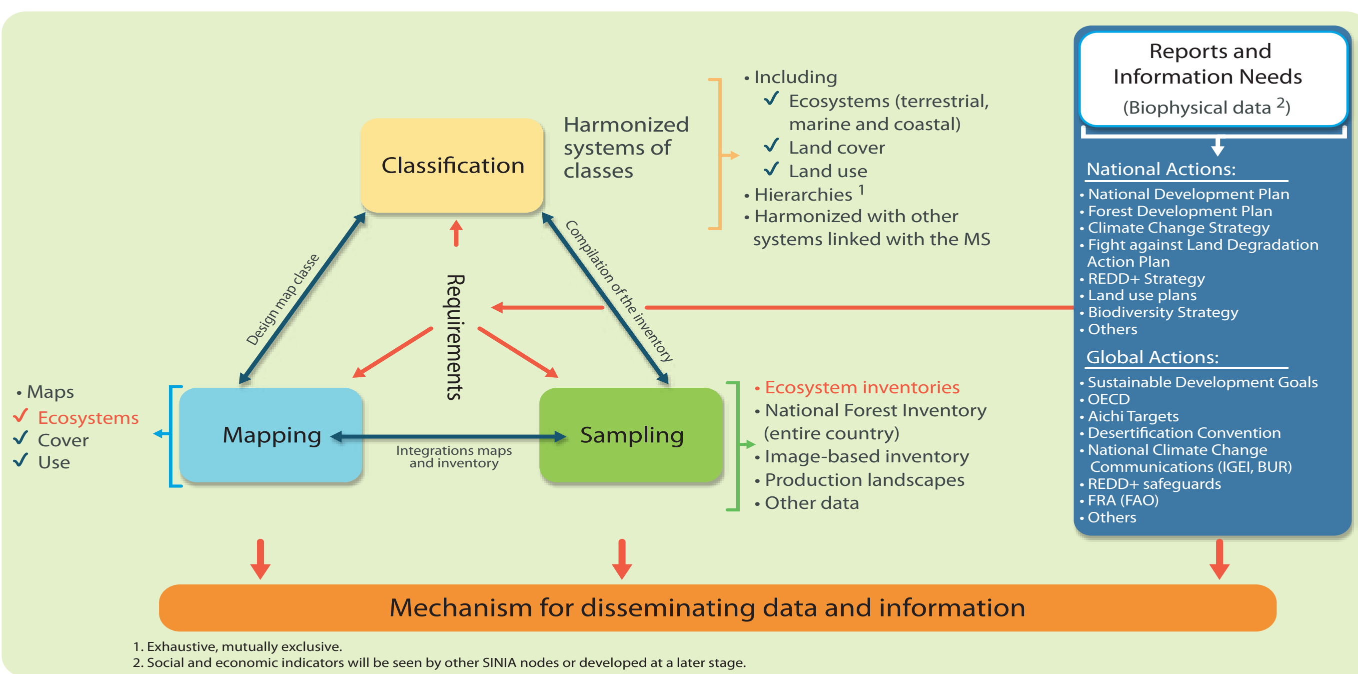
VI. MOCUPP as Part of the National Environmental Information System

The National Geo-Environmental Information System (CENIGA) was created in 2001 through Decree No. 29540, as a technical unit of MINAE promoting sound management of national environmental information. Its main task is to consolidate and coordinate the National Environmental Information System (SINIA). SINIA was constituted as official platform for institutional and sectoral coordination and linkage of the Costa Rican state, to facilitate management and distribution of national environmental information.

Directive DM 480-14 orders MINAE agencies to coordinate with CENIGA in identifying all statistical and geospatial information under the methodological standards defined by CENIGA. CENIGA is also responsible for maintaining representation of MINAE dependencies in the SINIA Institutional Information Committee. The directive also orders environmental institutions to coordinate with CENIGA on how the new projects for institutional information systems should interact.

In 2015, a new directive from the Minister of Environment (DM-417-2015) ordered CENIGA to develop a system for monitoring land and ecosystem cover and use (Sistema de Monitoreo de Cobertura y Uso de la Tierra y Ecosistemas-SIMOCUTE). In this way, MOCUPP became linked with SIMOCUTE and therefore SINIA (diagram 2). Originally arranged with UNDP support through the Green Commodities Program, MOCUPP was conceived as a specialized tool to verify compliance with the Forest Law in production landscapes with commodities for export. Operationally, MOCUPP and SIMOCUTE share the same geodatabase, making it possible to centralize highly important satellite information for the country. In addition, by taking the analysis to a finer scale, MOCUPP can verify SIMOCUTE results at national level, so the two systems give each other feedback and independent verification of the information.

Diagram 1: *Ministerial Directive DM-417-2015*
Monitoring System on Land and Ecosystem Cover and Use (SIMOCUTE)



VII. Strategic Framework of Monitoring of Land-Use Change in Production Landscapes to 2020

Objective:

Strengthen public sector capacity for land use planning and managing production landscapes sustainably, facilitating the country's positioning as a deforestation-free agro-exporter.

Specific Objectives:

1. Identify, total land cover for specific agricultural commodities in all national territory and the focal points of deforestation or forest regeneration within private land every year.
2. Differentiate deforestation-free production units at no cost to producers or buyers.
3. Provide maps of commodities land cover and forest cover loss and gain through the National Land Information System as a way to save costs for municipalities, Ministry of Environment and the private sector.

Indicators:

1. Maps of total national land cover of agricultural commodities that can be differentiated through remote sensing

Goals:

a. Total pineapple cover (based on 2015 as reference).
b. Total pasture cover (base year 2017).
c. Total sugar cane cover (base year 2018).
d. Total Palm oilcover (base year 2019).
e. From 2020 on, all commodities, every year.

2. Maps of forest cover loss and gain within production landscapes.

Goals:

a. By 2017, baseline for 2000-2015 forest cover loss and gain within pineapple production landscapes, and an annual analysis thereafter.
b. By 2018, baseline on 2000-2016 forest cover loss and gain within pasture (beef and dairy) production landscape, followed by an annual analysis thereafter.
c. By 2019, baseline on 2000-2018 forest cover loss and gain within sugar cane production landscape, followed by an annual analysis thereafter.
d. By 2020, baseline on 2000-2015 forest cover loss and gain within palm oil production landscape, followed by an annual analysis thereafter.
e. From 2020 onwards, maps of total forest cover loss and gain for the four aforementioned commodities, every year, using the previous year as reference

3. Pilot study on urban cover and forest cover loss and gain within the Maria Aguilar Interurban Biological Corridor, to determine the viability of annual monitoring of urban sprawl in the country as of 2020.

Goal: Study of viability and costs of monitoring urban area as part of MOCUPP

Means of verification: *Map viewer of the National Land Information System (www.snitcr.go.cr)*

<table>
<tr><th>Year</th><th>Pineapple</th><th>Pasture</th><th>Sugar cane</th><th>Palm oil</th></tr>
<tr><td rowspan="2">2016</td><td>Baseline 2000-2015 on loss and gain of forest cover on pineapple production landscape</td><td rowspan="2" colspan="3"></td></tr>
<tr><td>Total pineapple cover 2015</td></tr>
<tr><td rowspan="2">2017</td><td>Loss and Gain of forest cover on pineapple production landscape 2015-2016</td><td rowspan="3">Baseline 2000-2016 of forest cover loss and gain on production landscape with pasture and without trees</td><td rowspan="4" colspan="2"></td></tr>
<tr><td>Total pineapple cover 2016</td></tr>
<tr><td rowspan="2">2018</td><td>Loss and Gain of forest cover on pineapple production landscape 2016-2017</td></tr>
<tr><td>Total pineapple cover 2017</td><td>Total production landscape with pasture and without trees 2017</td></tr>
<tr><td rowspan="2">2019</td><td>Loss and Gain of forest cover on pineapple production landscape 2017-2018</td><td>Forest cover loss and gain in production landscape with pasture and without trees 2017-2018</td><td>Baseline 2005-2018 of forest cover loss and gain on production landscapes with sugar cane</td><td rowspan="2"></td></tr>
<tr><td>Total pineapple cover 2018</td><td>Total production landscape with pasture and without trees 2018</td><td>Total cover of production landscape with sugar cane 2018</td></tr>
<tr><td rowspan="2">2020</td><td>Loss and Gain of forest cover on pineapple production landscape 2018-2019</td><td>Forest cover loss and gain in production landscape with pasture and without trees 2018-2019</td><td>Forest cover loss and gain on production landscape with sugar cane 2018-2019</td><td>Baseline 2005-2016 of loss and gain of forest cover on production landscapes with palm oil</td></tr>
<tr><td>Total pineapple cover 2019</td><td>Total production landscape with pasture and without trees 2019</td><td>Total cover of production landscape with sugar cane 2019</td><td>Total cover of production landscape with palm oil 2019</td></tr>
</table>

Note:
MINAE has mobilized financing from the Global Environment Fund (GEF) for all outputs up to 2020, by then they are expected to be incorporated to the national budget.

VIII. Strategic Coordination between Partners with Complementary Roles and Jurisdictions

MOCUPP's functioning is based on the interaction of capacities, skills and mandate of three entities, described below. Each of these entities plays a role for achieving the described strategic framework for 2020. Therefore, MOCUPP is conceived as a system of three components. Each one operates independently, but together they generate services and products enabling the envisioned monitoring of production landscapes throughout the country. The financial strategy for MOCUPP's consolidation includes a separate budget for the tasks of each component. However, it is recommended that resources mobilized for the system contribute to all three components. Not only must land cover maps be generated each year; it is equally important for the country to continue moving forward in generating land tenure information available through online cadastral maps. Likewise, for MOCUPP to function correctly, the maps and cadastral information must be viewable and can be processed with an agile map viewer (SNIT). For example, MOCUPP is referenced in the National REDD Strategy. This means that REDD funding to the country for MOCUPP may be divided in three parts to cover components under the responsibility of the following:

Liaison Coordinator: The role of liaison, quality control and adherence to criteria for generating geospatial maps will be entrusted to MINAE's National Geo-Environmental Information Center (CENIGA). This entity has institutional responsibility for the National Environmental Information System, and will serve as MOCUPP's institutional referent.

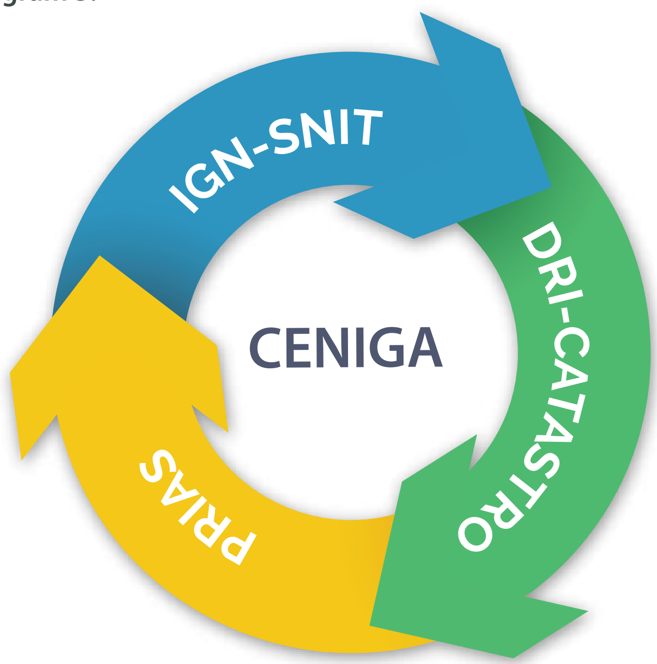
Component 1: The first component is the responsibility of Laboratory of the Airborne Research Program (Laboratorio del Programa de Investigaciones Aerotransportadas-PRIAS) belonging to the National High Technology Center (CENAT), which in turn forms part of the council of rectors of state universities (Consejo Nacional de Rectores-CONARE). PRIAS has trained human resources, technological resources and institutional experience, with part of its human and technical resources slated to yearly preparation of the maps as long as the required resources are transferred, as defined in the financial consolidation strategy for MOCUPP.

Component 2: The second component is the responsibility of the Directorate of Real Property Registration (Dirección de Registro Inmobiliario-DRI) which belongs to the National Registry and maintains the land tenure information that can be related to the maps PRIAS generates when these are published through the National Land Information System. It should be noted that not all private property may be identifiable through SNIT. This is because of a costly registration process to be gradually implemented throughout the country with contributions from the national budget and international support, such as the Cadaster and Registry Regularization Program.[40] Coordination with the DRI is strategic for MOCUPP's correct functioning and financial consolidation. This entails coordination of investments to increase the land area that may differentiate all private property in SNIT. For this reason, the role of DRI is to continue its regular registration work while at the same time coordinating with MOCUPP so that strategic districts producing the commodities to be monitored are registered. DRI will also receive part of the funds mobilized for MOCUPP's operation in order to advance land title registration within strategic agricultural production districts.

40. *Executed through co-financing with IDB, Law No 8154*

Component 3: The third component is the responsibility of the National Geographic Institute (Instituto Geográfico Nacional-IGN), specifically the unit that manages the National Geo-Environmental Information System (SNIT). This is an information node with an online viewer enabling map layer interaction with tenure records. This is crucial for the differentiation of deforestation-free production units, as well as for generating incentives and controlling deforestation. The correct functioning of the node and its growth to accommodate continual information on loss and gain and coverages of production landscape is key to MOCUPP's operation. The role of IGN-SNIT will be to provide viewer services on the web for maps generated by PRIAS so these may be related to land tenure. This is supported in the agreement between CENAT-PRIAS and the National Registry (Decision J272-2015). Requirements for SNIT to operate include training for existing human resources and optimization of the online viewer.

Diagram 3.



3 Important instances, Working together for The development of the country

IX. Component 1: Annual Generation of Maps on Agricultural Commodities Production Landscapes and Determination of Loss and Gain of Forest Cover

Component Leader: *PRIAS Laboratory*

The PRIAS Laboratory initially arose as a program of airborne research and remote sensing and in situ research. It was created as program on November 27, 2003, within the National Center for High Technology (CeNAT) under the Council of rectors of state universities (CONARE) and has an inter-university work team to carry out its activities. The objective of PRIAS is to promote, facilitate and execute research projects and academic dissemination, as well as business linkage in the field of geospatial industry, using airborne remote sensing and in situ measurements, geographic information systems and the satellite-based global positioning system.

PRIAS has carried out different missions and scientific projects in the country, most particularly Costa Rica Airborne Research and Technology Applications (CARTA) 2003 and 2005, in association with the U.S. National Aeronautics and Space Administration (NASA). The first CARTA mission laid the foundations for a national program in October 2003, to develop and promote airborne scientific missions on mapping with remote sensors and in situ and its applications, with cutting-edge technology in the country.

PRIAS Human and Technical Resources

PRIAS has experienced professional staff and in-house capacity for storage, processing and analysis of all types of satellite, aerial and field images and data (photographic, LIDAR, hyperspectral, and others). In addition, the team has experience in the deployment of airborne missions with conventional platforms and sensors, such as UAV[41] . Finally, the laboratory also has the hardware, software and physical and networking infrastructure to provide maximum security, robustness and efficiency in data custody and transport, both internally and externally.

Baseline Scenario on the Use of Remote Sensing for Monitoring Forest Cover within Production Landscapes

Worldwide, the study and analysis of land tenure and change in vegetative cover has gained momentum in recent years, and through their institutions, Latin American countries are attempting to collect and continually update layers of information on these areas. There are many permanent global forest monitoring programs, such as the FAO's Global Forest Resources Assessment. In the academic arena, another example is the 2013 study by Hansen et al., which mapped 2.3 million square kilometers worldwide, including tropical, subtropical, temperate and boreal forests in the

41. Agreement with Costa Rica's Ministry of Public Safety for the acquisition of images from unmanned airborne vehicles. (Convention in process)

2000-2012 period, using LANDSAT images. The Global Forest Watch of the World Resources Institute (WRI) also represents a global effort to monitor forest cover. It is based on the aforementioned data of Hansen et al. 2013, as well as auxiliary information such as early warning data in the tropics and Brazil. Global Forest Watch is global and aimed at detecting loss and gain in forest cover, although not interconnected with land tenure given its scale.

At regional level, studies in several Latin American countries reveal the different tools and services each country uses depending on the interest of those studies. These are important for recordkeeping so that changes in land cover and use can be determined over the years and thus avoid the impact such changes will have on the environment and human beings. For example, in Brazil, the National Space Research Institute (INPE) developed PRODES, a program that since 1988 has measured annual deforestation in the Amazon, also based on LANDSAT images. PRODES measures a minimum area of 6.25 hectares, which is useful for measuring deforestation in an area such as the Amazon, so includes monitoring of gross loss in large-magnitude forests.

In Mexico and Central America, the CABAL study used geographic information technologies, spatial analysis of available data on land use and vegetative cover at different scales to determine biodiversity hot spots under greatest threat due to climate change. (CABAL, 2010).
A similar study was conducted in Ecuador in 2010 , "Methodological Protocol for Generating the Map on Historical Deforestation in Continental Ecuador," an initiative of the Ministry of Environment and Forest Protection Program. The general objective was to "develop and validate methodology to construct the historical scenario of spatially explicit deforestation at national level."

These studies have been conducted by mapping classes of land use and cover, and utilizing optimal sensors for the study. In this case, LANDSAT TM, LANDSAT ETM+, and ASTER sensors were selected. Another methodology that can be helpful to this project is monitoring of coca crops in Bolivia by the United Nations Office on Drugs and Crime (UNODC) by the Bolivian Government in 2006. The main scope was "to establish methodologies for collecting and analyzing data on illegal crops, and improve governments' capacity to monitor them." (UNODC, 2007). The institutions in charge of land use planning in Bolivia mainly classified LANDSAT images to prepare a national map superimposed by the coca cultivation map for 2003 and 2004. This revealed the areas where the crop is harvested. (UNODC, 2007). PRIAS considered all of these methodologies in developing the procedure described further on.

In Costa Rica, consolidated studies on land cover mapping with remote sensing go back to the 1990s. Some of these include "Remote Sensing Applications for Surveying Land Use in the Coffee-growing Area North of the City of Alajuela, Costa Rica" (Hernández 1993) and "Land Use and Cover in Costa Rica in 1992: An Application of Remote Sensing and Geographic Information Systems" (Fallas 1996). A more recent study is entitled, "Analysis of Spectral Land Use Patterns and Hydrological Changes Based on Multisensor Data in Natural Spaces of Southern Costa Rica" (Esono 2015).

It is worth pointing out the experience of the National Forest Financing Fund (FONAFIFO), a public entity whose mission is to finance small or medium-scale producers of forest goods and services, in raising and administering national and international funding to support forest sector development. FONAFIFO has made several studies of Costa Rican forest cover in collaboration with other national and international entities that have been working on forest cover scenarios for the years 1990, 1997, 2000 and 2005 with Landsat ETM satellite images[42].

FONAFIFO and the Ministry of Environment and Energy conducted a study of forest cover for the years 2009-2010, which used images from the SPOT satellite that would span 88.18% of the country. Astor images were used for the remaining 11.82%.
The study's objective was to classify SPOT satellite images in order to determine forest cover in the country. This was based on processing, classification and interpretation of the satellite images selected for all of Costa Rica, into the sole categories of forest and non-forest, thereby obtaining forest cover.

The National Meteorological Institute (Instituto Meteorológico Nacional-IMN) also developed maps in 1978/80, 1997, 2000, 2010 and 2012 for the national greenhouse gas inventory. More recently, a map was made of types of forests in Costa Rica in 2013, based on RapidEye 2012 images. The aim was to guide forestland planning in decision-making about their management and administration and contribute to Measurement, Reporting and Verification (MRV) for the REDD+ Strategy, an essential tool for obtaining REDD+ results-based payments[43].

In summary, prior to 2014, Costa Rica produced several land cover and land use maps for varying purposes and done by different institutions. All of these maps were constructed using different methodologies, due especially to the differing ends.

In 2014, as part of the development of the National REDD+ Strategy, FONAFIFO initiated the preparation of a series of seven maps between 1986 and 2013, following the same methodology, to construct a baseline reference for REDD+. These maps were contracted to a consortium made up of the private Spanish companies Agresta S.A. and DIMAP, and two academic entities, the Technical University of Madrid and the University of Costa Rica; the latter acting as national implementing partner. The IMN adjusted the maps for use in the national greenhouse gas inventory, presented in the First Biennial Update Report to the United Nations Framework Convention on Climate Change in 2015.

These maps were constructed based on LANDSAT images and land cover for the entire country. Together they present a panorama of land use change in Costa Rica during the past 30 years. Ecological criteria were used for classification of the maps, but they were not associated with land tenure. In addition, based on these maps, FONAFIFO headed a study on deforestation and forest regeneration drivers in Costa Rica, identifying and ranking the most important factors behind land use changes in Costa Rica from 1986 to 2013.

However, these experiences have generally focused on forest cover, without making attempts to identify specific agricultural commodities or to determine forest cover loss and gain between time periods, which is both innovation and challenge, and so it requires an adaptive methodology. None of the experiences described earlier has endeavored to combine layers of information on deforestation with land tenure as MOCUPP does—an innovative exercise at global level and truly a land management tool that can be easily replicated in other countries.

42. (MINAET-FONAFIFO 2012).
43. According to the National Forest Office http://onfcr.org/

Procedure for Preparing Maps on Land Use of Agricultural Commodities for Annual Monitoring at National Level

The flowchart below shows the processing stages required to make maps on land cover of commodities for export, for annual monitoring of the entire country.

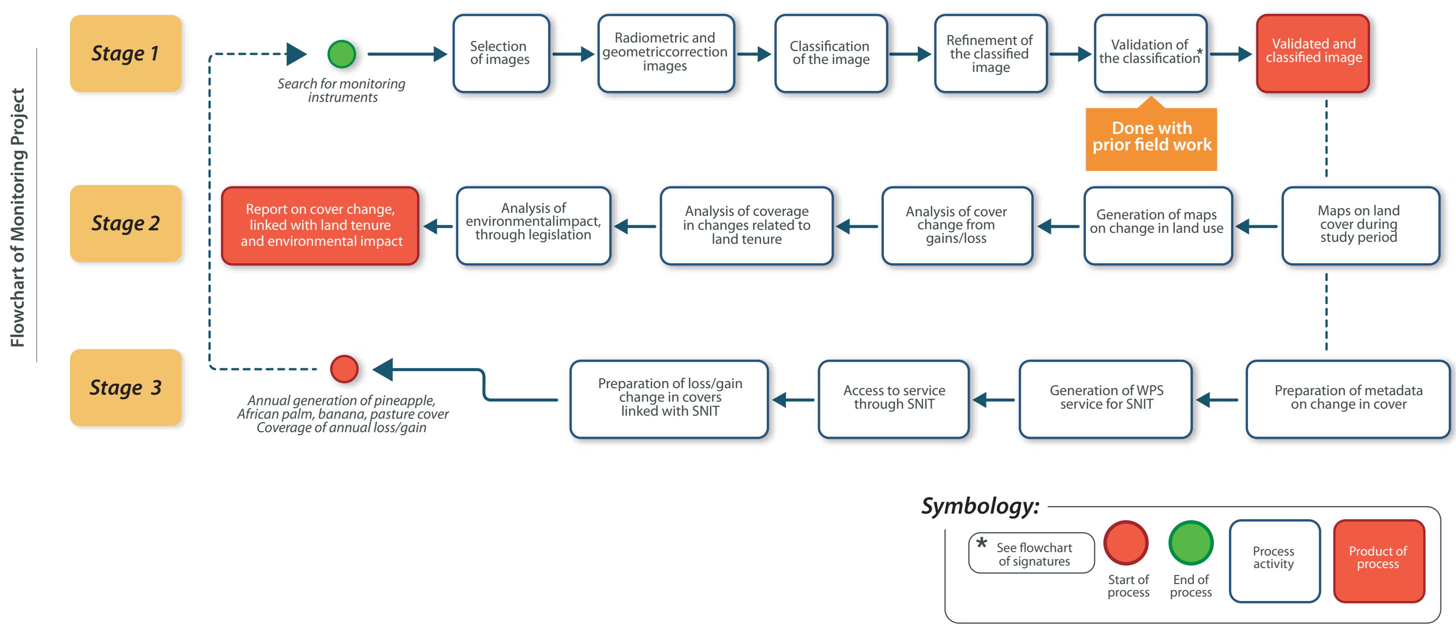


Figure 3: *Flowchart of agricultural commodities identification process based on LANDSAT 8 images*

Delimitation of Production Landscapes: Total Area of Annual Monitoring

MOCUPP is designed to identify annual cover of agricultural commodities that can be detected countrywide using selected remote sensing. It entails an ambitious monitoring of all national territory where agricultural activity is legal. This amounts to 60% of continental Costa Rica, since 25% is falls under some system of state protection and 15% corresponds to urban area and residential areas, considering all populated areas and those in expansion that can be mapped in the National Land Information System (SNIT) at a scale of 1:1000. This 60% of the nation where agricultural activity is legal is the area MOCUPP will monitor every year.

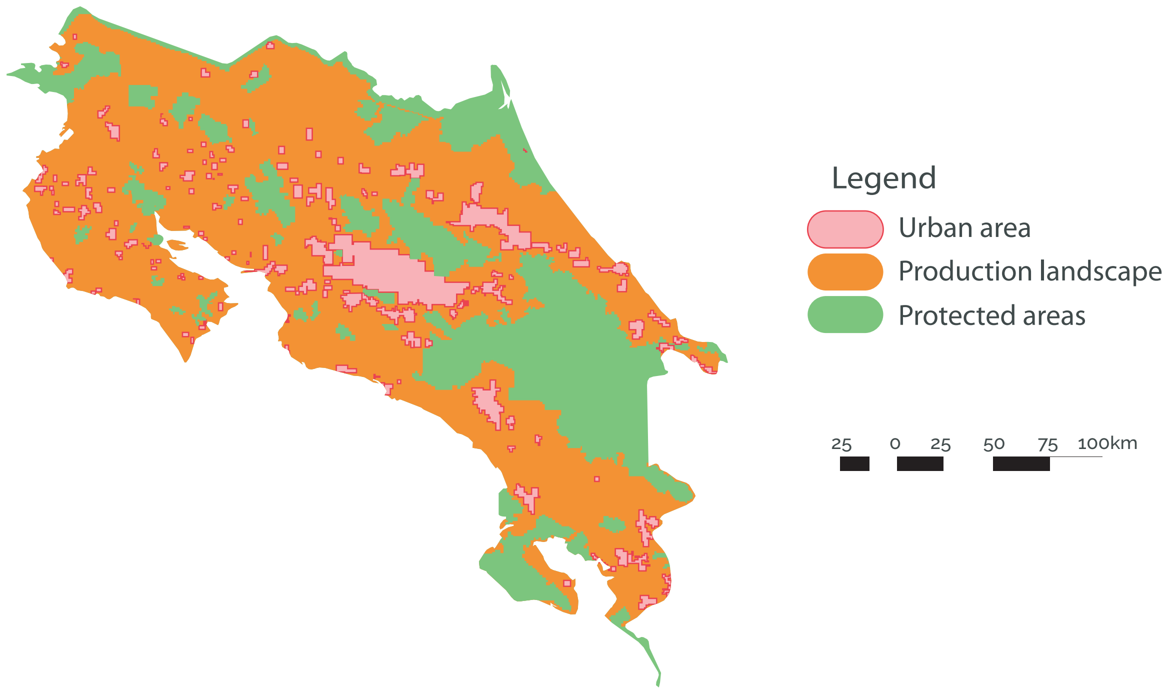


Figure 5: *Map of Estimated Extension of Production Landscape* [44]

An important phase in the delimitation of the cultivation area is a preliminary assessment of commodities land cover in the area to be monitored. PRIAS conducted a document review, examining the most recent agricultural census (2014) and existing land use maps, and consulting national experts about the commodity landscapes analyzed. Based on this review, the most important production areas are identified to generate polygons of the principal regions for a pineapple land cover map based on the use of remote sensors and fieldwork. For example, to prepare the 2015 Map of Pineapple Cover, four main production landscapes were identified: the North Huetar Region, the Caribbean Huetar Region, the Brunca Region and the Central Pacific Region. LANDSAT 8 images of these areas were obtained and a sampling was made of spectral signatures in order to identify the spectral behavior of the crop. General identification was done in the field to better locate pineapple plantations and have a preliminary distinction of neighboring land covers (CONARE, CeNAT 2016).

Selection of Principal Remote Sensing and Complementary Actions for Annual Monitoring.

Currently the market offers a variety of images obtained from sensors installed on satellites, providing extensive possibilities for processing images in Costa Rica.

The satellite images are generated by private corporations or government agencies that put them on the market, generally for a price, but in some cases, such as LANDSAT, they are free. Because of the way satellite orbits are programmed, images can have different coverages (large extensions). Images do not necessarily correspond to a specific coverage; to the contrary, users select images from the catalogue of those available to find those that suit their purposes and show the specific area of a given project.

44. By the author based on information published in the National Land Information System (SNIT)

Satellite	Sensors	Spatial Resolution	No. of Bands	Temporal Resolution	Price
GEOEYE-1	GEOEYE-1	MS: 2 m	4	3 days	25 $/km2
IKONOS	IKONOS	MS: 4 m	4	3 a 5 days	20 $/km2
KOMPSAT-2	KOMSAT-2	MS: 4 m	4	3 days	15 $/km2
RAPIDEYE	RAPIDEYE	6,5 m	5	1 day	1,08 $/km2
SPOT – 5	HRG	MS: 10 m	4	2,4 – 3,7 days	0,85 $/km2
LANSAT - 7	ETM +	MS: 30 m	8	16 days	---------
LANSAT - 8	OLI	MS: 30-15 m	11	16 days	---------
QUICKBIRD	QUICKBIRD	MS: 2,44 m	4	2 a 4 days	20 $/km2
TERRA	ASTER	15 a 90 m	14	16 days	0,09 $/km2
WORLDVIEW-2	WORLDVIEW-2	MS: 2 m	8	1 a 3 days	35 $/km2

Chart 1: *Satellites and Sensors Available in the Market* [45]

To carry out the planned task of processing images for MOCUPP each year, an agreement was made with the UNDP Green Commodities Program, entity responsible for developing the initial concept of this tool, to use low-cost, open source software and low-cost images to ensure long-term countrywide processing and monitoring easy to replicate in other parts of the world.

The technology makes it possible to capture specific images (ad hoc) of a study area.[46] While these can also be obtained by satellite (LANDSAT), usually they are taken from aircraft. Currently unmanned aerial vehicles (UAV), commonly called drones, can be used. Although images can be taken with the same type of sensors (entire electromagnetic spectrum), they are used more to capture visible light images, the typical blue, green and red.

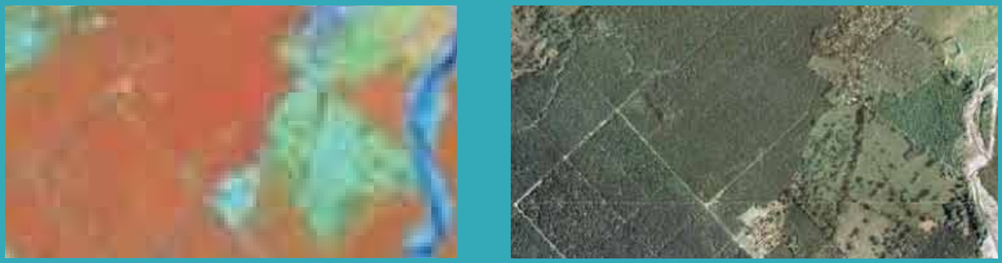


Figure 2: *Comparison of LANDSAT 7 image on red bands and visible light photography from an aircraft*[47]

45. Adapted from CONARE CeNAT 2015
46. Classical aerial photogrammetry is now considered digital capture, storage and support.
47. Adapted from (2013)

The information from different sources, as shown in the example in figure N° 2, may be combined and complemented to better identify land cover. Combining information provides versatility to achieve optimal coverage of the study or project area, and makes it possible to offset the effects of visibility (cloud cover in sectors), sensor affectations and other effects on the quality of data capture.

The satellite images used for implementation of monitoring in Costa Rica are mainly LandSat8, although other sensors can be used depending on the type of coverage and fitophenology. Landsat images are found at http://glovis.usgs.gov/. Information from satellite imagery has been collected from 1974 to the present, since this family of sensors allows researchers to take a look at the past through the extensive data collection on this web page.

In the case of Costa Rica, a 2001 image was identified as baseline information to detect changes that took place in the study area up to the current period.

Table 2: *Fundamental Characteristics of Landsat8 Satellite* [48]

LANDSAT 8 SATELLITE	
Characteristic	**Specifications**
Launch date	February 2013 by NASA
Orbit	Altitude: 705 km
	Temporal resolution: 16 days
Pixel	Size: 30 m. reflective (light). Possible 15 m. Panchromatic
Spectral Bands	Total 11. (Visible light, infrared (2), thermal (2) and panchromatic)

Once the information source for making the identification of land cover is defined, implicit conditions are established to determine the scope of monitoring. These must address the aspects that could become constraints during the implementation of monitoring actions.

In the specific case of Landsat 8 images for Costa Rica (and most tropical countries), there are two main aspects to take into account: i) the presence of clouds and ii) the resolution obtainable. For areas where clouds could be present, complementary ad-hoc image capture using unmanned aerial vehicles is highly available in the market. While this type of image has a cost, the technology available and PRIAS' experience in the area allows for these applications to be used. With respect to resolution, standard Landsat 8 has a pixel size of 30 meters, although with image fusion techniques this can be improved to 15 meters in the panchromatic band (Fallas 2016).[49]

48. Taken from http://landsat.gsfc.nasa.gov/?page_id=4071
49. See also http://desktop.arcgis.com/es/arcmap/10.3/tools/data-management-toolbox/create-pansharpened-raster-dataset.htm

The working premise concerning resolution is to determine extensions that considerably surpass the resolution (pineapple crops, for example). The point of analysis is to compare those coverages with other objects whose size could make them invisible due to the resolution. For this reason, the monitoring proposes integrating information from other sources in the cover identification obtained from Landsat 8 images. Comparison of object sizes will establish the type of analysis and scope of the results to which monitoring can be applied based on Landsat 8 resolution. In other words, the basic premise in carrying out monitoring is the resolution obtainable with Landsat images.

Radiometric Correction

This is required due to sensor flows that produce data errors in the images (pixels). On one hand, this entails the restoration of lines or lost pixels, and on the other, correction of image banding. Radiometric correction attempts to improve mechanical problems in the sensor that generate erroneous values for specific pixels. Generally, image providers deliver a product and receiving stations perform some type of correction at the moment the image is received. [50]

Atmospheric Correction

Atmospheric correction attempts to assess and eliminate distortions the atmosphere introduces in radiance values coming to the sensor from the earth's surface. It is thus based on more complex physics-based models to covert digital numbers (DN) stored by the sensor in radiance values. The objective of atmospheric correction is to recover the intrinsic radiance of the target obtained from the signal received by the sensor (total radiation of the sensor). To completely eliminate the effects of atmosphere, absolute correction is required. (Campos et al, 2012)

Geometric Correction

An image does not provide georeferenced information; each pixel is located in a system of coordinates. The georeferencing process consists of localizing each pixel in a system of cartographic coordinates (UTM, CRTM) so that the image can then be combined with another type of layer in a GIS environment. Georeferencing requires the use of control points to entwine the image with a system of coordinates. With the data from control points, software tools are applied to generate a new image in which the pixels are associated with the coordinates.

Image Classification

Based on the corrected image, an observer can identify land cover; this information makes it possible to construct a cover map. Identification of cover composition is done through image classification, a process whereby elements on the surface of the ground, objects and phenomenon are deduced from the total data of the image (pixels). This process is called classification, and with it information can be extracted, moving from visual analysis of the image to identification of objects. This involves multispectral analysis applying different techniques. Object identification is what then makes it possible to compare periods of behavior or dynamics of a specific cover.

50. http://www.um.es/geograf/sigmur/teledet

Generation and Reduction of Spectral Signatures

Phenological characteristics of the crop are considered, to test if that spectral data is in accordance with Landsat 8 resolution. Data to reduce spectral signatures is then captured at different sites of the plantation also taking into account the four stages identified. The distribution of some commodities makes measurement difficult, so to unify criteria a system of transepts was applied at the edges of the plantations in each stage.

The average values of pineapple spectral signatures in reflectance units are submitted to statistical testing to validate their normal distribution and homogeneity, for each of the stages and in each region. Shapiro-Wilks tests are applied and once the distributions found, the Kruskal-Wallis test, which does not assume normality in the data. Spearman's correlation analysis is also applied to examine the correlation of nutrients with spectral data.

Once spectral analysis takes place, spectral signatures are generated for each farm according to each stage studied. The statistical analysis does not normally show similarities in spectral signatures; to the contrary, many differences are found in the different spectral bands when studied through the Landsat 8 sensor and field spectroradiometer[51]. Spectral separation does not allow for a unique spectral signature to be defined at a national level. In the case of Costa Rica, spectral separation was found for each of the four distinct production landscapes. The spectral signatures generated were thus developed as spectral libraries. Figure 6 shows the results of the spectral signatures obtained for the four stages of pineapple cultivation in the Brunca region; each one of these libraries contains the average value according to each stage of the spectral signature scaled to the five bands of Landsat 8. (CONARE, CeNAT 2016).[52]

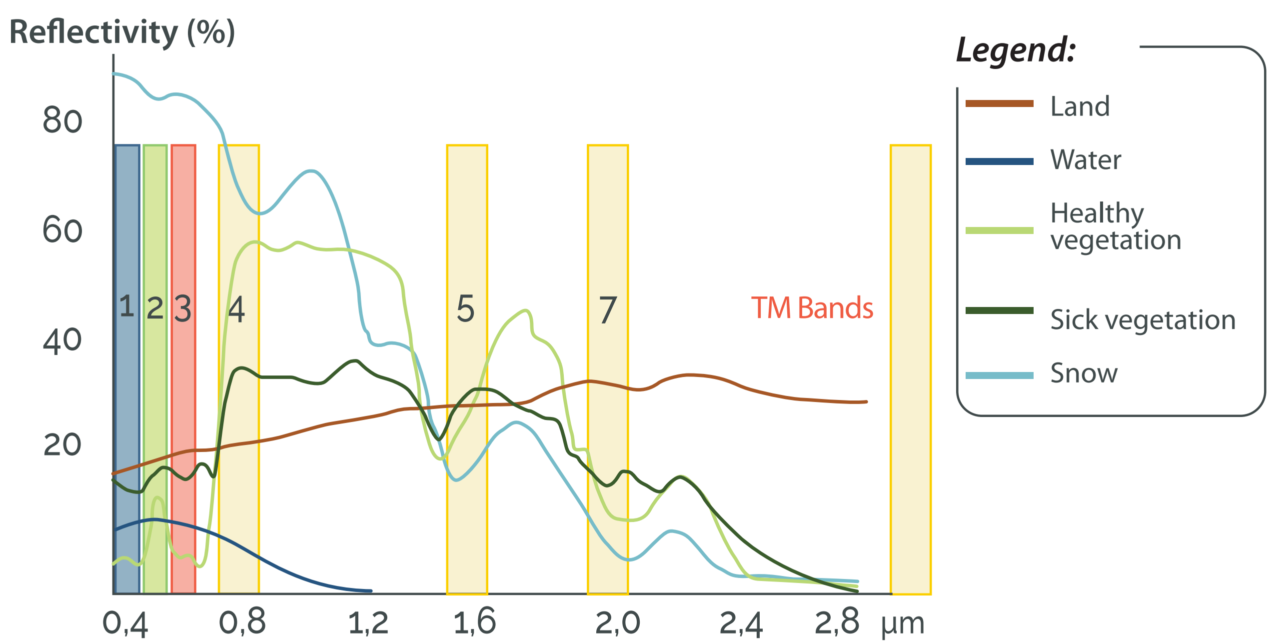


Figure 3: *Comparison of reflectivity (%) of different covers in LANDSAT bands.*[53]

51. Wavelength range of 325 nm to 1075 nm with a bandwidth of 1.6 nm, covers both the visible region (VIS) (400-725 nm) and short-wave near-infrared (NIR) (750-1075 nm)
52. Based on the use of ENVI software with the Build Spectral Library tool
53. http://www.scanterra.com.ar/

Automated classification (unsupervised)

This consists of applying an algorithm in software through which pixels are identified whose variance is minimal (according to algorithm parameters). This clustering makes it possible to identify classes since a map can be generated of pixels grouped by class. Classification does not relate the classes with objects or types of cover; this is achieved by comparing each class with field information.

Advanced Classification (Supervised)

In addition to applying an algorithm for identifying data (pixels) and relating them with objects or cover, this method requires knowledge of verification areas in the field (training areas) to relate the classes with objects or covers, such as pineapple. Selecting several areas in the field to obtain an adequate identification of each cover is sufficient. Multispectral methodology facilitates classification; it analyzes the spectral signature of the pixels and assigns them to classes based on similar signatures (libraries). The spectral signature is an identifying mark for the objects. It consists of a vector whose components (n) have the reflectivity response that the predominant material in that class produces in each one of the bands (n) of a sensor.

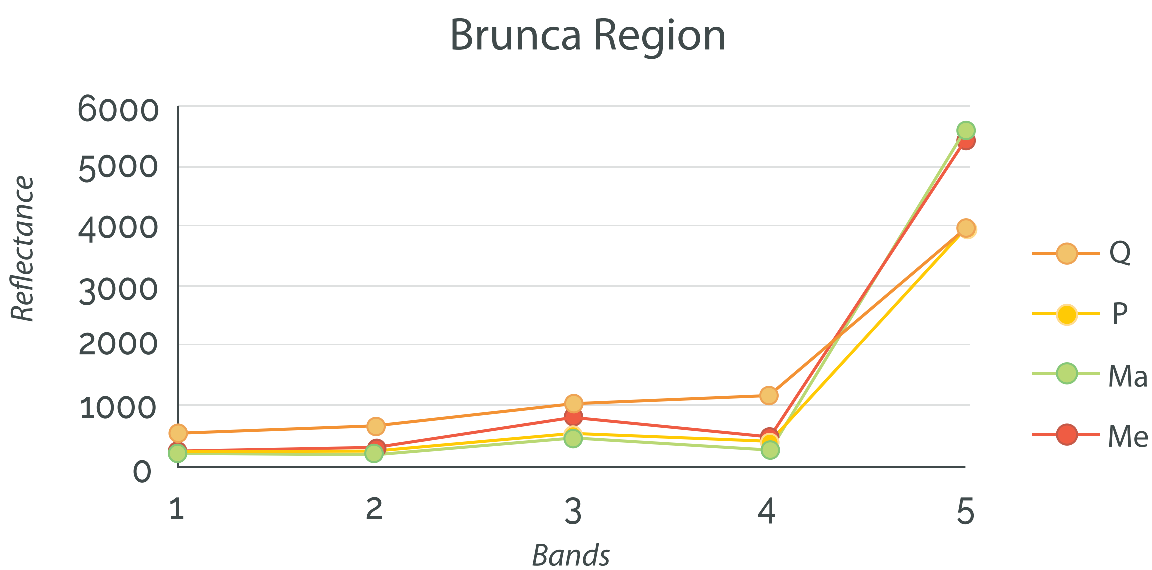


Figure 6: *Spectral signatures reduced for LANDSAT 8 in the four stages in the Brunca region*

Application of the spectral signature allows efficient classification of images in large extensions, reducing time and significantly, effort and inspection in the field.

The spectral signature is considered to trace out the training areas, and thereby generate identification of the different stages. Image classification for this process is done by applying a classification algorithm through decision trees known as "See5". This algorithm comes from machine learning techniques. Informatics engineer John Ross Quinlan is recognized as its developer, with the application geared to data mining. It has multiple applications in fields as diverse as finance, insurance and flight simulators. In the case of image processing and classification, this algorithm has been incorporated or programmed in specialized applications .[54]

Validation

Once classification has been done and the commodity cover is obtained, classification is validated. For this, previously separated points collected in the field are employed and compared with a grid of random points. The statistical system is applied aiming for a 95% probability of error, and were none of the production landscapes is over 5%.

Representation

To obtain adequate representation at the level of use cover map, the classified information from the image (raster) must be converted to a vector format facilitating its analysis and publication on different platforms, or raster format. The ESRI Shapefile[55] is recomended.

Generation of Maps from Images

Based on the supervised classification method, pixels are related to classes and objects or covers are identified through spectral data and field inspection. This representation can be displayed in a defined cartographic format, generating a cover map.

Applying the aforementioned procedures the commodity total land cover map may be obtained. For example, a baseline map of pineapple cultivation was obtained for three study regions in Costa Rica for 2015. This map, shown in Figure 7, will serve as initial tool to promote monitoring of pineapple cultivation in the country. A total of 58,442 hectares of pineapple were found, distributed in the three study regions in Costa Rica. The greatest presence of pineapple cultivation by area is in the North Huetar region, with 37,718 ha, followed by the Caribbean Huetar region with 11,579 ha, the Brunca region with 8,030 ha, and lastly, the Central Pacific region with 1,100 ha of pineapple.

Image analysis included the areas cultivated with pineapple and areas with land prepared for its cultivation as the study's area of interest. It was necessary to use different classes to prepare the training areas to be used in the classifier. The classes[56] used were: natural forest, forest plantation, scrubland, crop, pasture, clouds, cloud shadows, infrastructure, bare ground, water bodies, pineapple and prepared land.

54. ENVI/Erdas applications
55. Known and established as de facto standard for Geographic Information Systems applications.
56. Purge of the classes was based only on the areas of interest for pineapple, so the values of the other classes mentioned were not purged or validated, nor were they included as part of the results of this project.

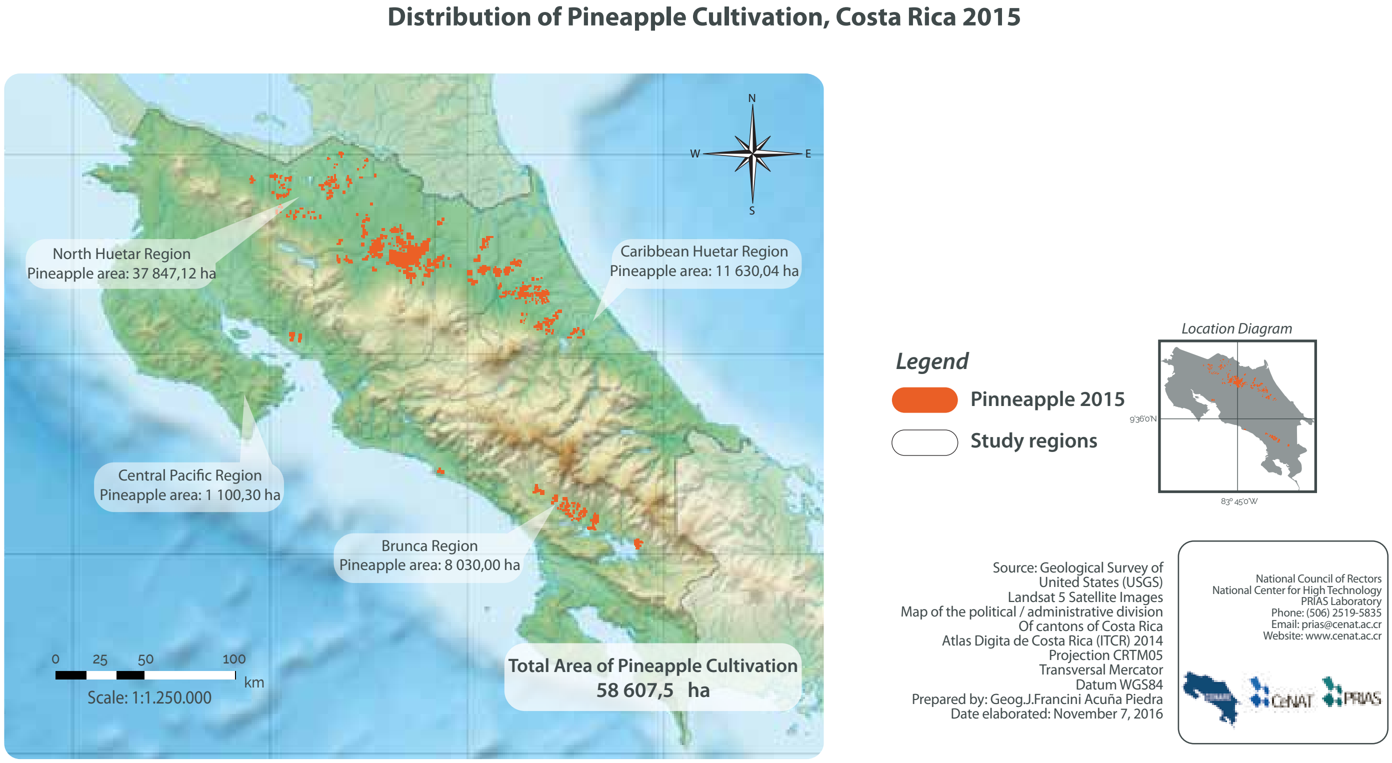


Figure 7: *Result, baseline map of pineapple cultivation, 2015*

Determination of Cover Loss and Gain

Knowing cover on a regular basis makes it possible to determine loss and gain between the periods of processed images. With the results obtained in the future compared to previous periods, pineapple evolution can be determined. As part of the development of strategy to establish Monitoring of Land Use Change within Production Landscapes, a pilot was conducted in control areas of the cultivation regions.

Images and Processing

PRIAS proposes the combination of images from different sources that have been verified in the field. The images correspond to Landsat 7 (2001) and RapidEye (2012) for a plantation in the Caribbean Huetar Region.

Figure 9 shows the images obtained from Landsat 7 and RapidEye for the same cultivation area. Based on these, a cover map was made identifying pineapple cultivation.

Figure 9: *Landsat 7 2001 images (left) and RapidEye 2012 (right) for a cultivation area*

For image processing the usual methods are applied, broadly extended and previously documented. Atmospheric, radiometric and geometric corrections are also made and verified, as well as image filtering to obtain better quality.

In addition to supervised classification, verification was done on the ground.

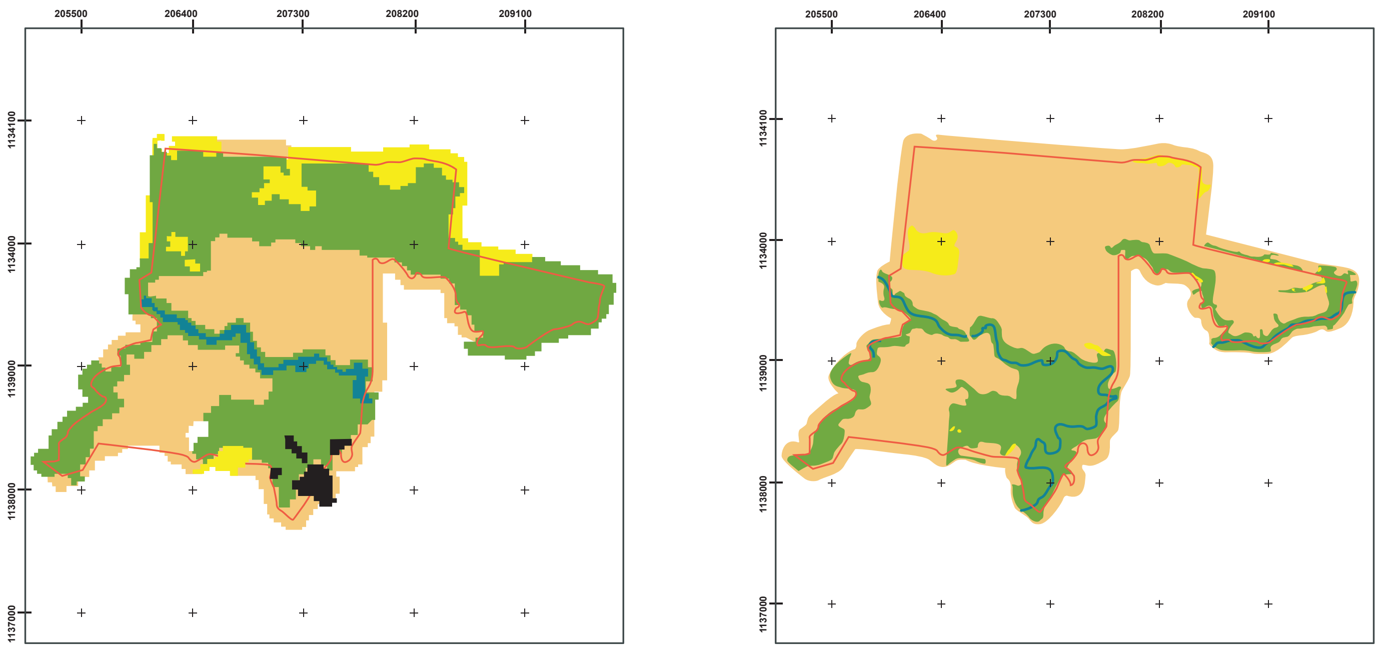


Figure 10: *Landsat 7 2001 (left) and RapidEye 2012 images (right), corrected and classified.*

Figure 10 shows the outcome of processing Landsat 7 2001 (left) and RapidEye 2012 (right) images, corrected and classified. In both cases, green corresponds to forest, yellow to pasture, blue to watercourses and orange to pineapple cultivation. The contrast in land use change between the dates of the images is evident. For monitoring purposes, the differences in the area of land uses in the two periods must be quantifiable numerically (not perception).

Analysis of Change in Land Cover

Once the satellite images are processed and the supervised classification is done, maps of land cover change are prepared. This is based on two scenarios: One for the balseine year of analysis (starting point) and one for the year of study (end point). In Costa Rica one was taken from the Landsat 7 images for 2001 and the other from RapidEye images for 2012. This analysis requires the supervised classification of each year to perform mapping algebra permitting analysis of what was gained or lost for each variable.

With this, a result is obtained showing cover behavior for this period, whether decreased or increased.

The numerical analysis is done with GIS software tools known as raster or image analysis.

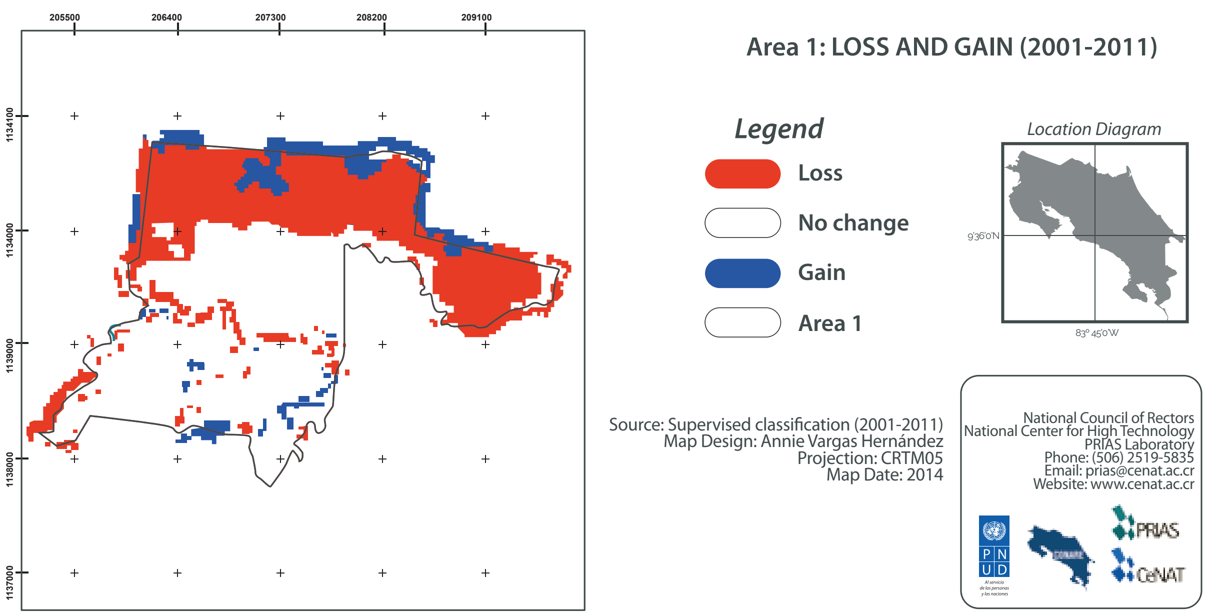


Figure 11: *Map of forest loss or gain from classified satellite images.*

Figure 11 is a map formed on a GIS platform. Forest cover loss appears in red, associated with conversion of forest to pasture or forest to pineapple cultivation. Forest cover gain is shown in blue and refers to conversion of pasture to forest or pasture to pineapple cultivation. Areas in white show regions where there was no change in land cover.

Analysis of Legal and Environmental Restrictions. Forest Law

Once supervised classification has been done, covers can be identified and compared with one another in a same period[57] to discern possible conflicts in land use with respect to environmental protection legislation.

Figure 12 shows how the identification of crop cover can be compared to hydrological elements that have some protection status due to their characteristics. This can be verified by analyzing the information in a geographic information system.

With this methodology for identifying cover, a monitoring strategy can be implemented that takes the specific country's legal framework into account, making it easier to control restrictions and conflicts over plantations with State natural patrimony,[58] and protected areas.

Figura 12:
Image of the study area with hydrographic and wells cartography superimposed

57. This analysis is grounded in the definition of forest in the Forest Law N°7575: "Native or autochthonous ecosystem, altered or not, regenerated through natural succession or other forestry techniques, that occupies two or more hectares, characterized by the presence of mature trees of different ages, species and stature, with one or more canopies covering more than seventy percent (70%) of that extension and where there are more than sixty trees per hectare measuring fifteen or more centimeters in diameter measured at chest level (DAP)".

58. "The natural patrimony of the State shall consist of forests and forested lands in national preserves, areas declared inalienable, properties registered in its name, those belonging to municipalities, autonomous institutions and other entities under Public Administration, except real property used as guarantee for credit operations with the National Banking System and which become part of its patrimony. The Ministry of Environment and Energy will administer the patrimony". Article 13, Forest Law N° 7575

Table 3: *Legal Restrictions that can be Controlled through Monitoring of Use Cover in Costa Rica.*

LEGAL BASIS	PROTECTION AREA	RESTRICTION
Law N° 7575. Article 33, section a)	Permanent springs	100-meter radius measured horizontally
Law N° 7575. Article 33 section b)	Sides of rivers, streams or creeks	15-meter strip in rural areas and 10 meters in urban areas, measured horizontally if the terrain is level and 50 meters measured horizontally if the terrain is uneven. [59]
Law N° 7575. Article 33, section c)	Sides of lakes and natural or artificial reservoirs constructed by the State and its institutions	50-meter area measured horizontally
Law N° 7575. Article 33, section d)	Recharge areas and aquifers of springs whose limits will be determined by the competent bodies as established in the regulations of this law	Determined by the competent bodies as established in the regulations of this law
Law N° 276 1942. Article 31, section a)	Land surrounding catchment areas or intakes for potable water supply	In a perimeter with at least a 200-meter radius

The monitoring strategy makes it possible to supervise restrictions. This control depends on the resolution of information sources applied to determine use cover and the objects or elements that generate restrictions. Integrating information from different sources is consequently indispensable, as evident in Figure 12.

The monitoring strategy accounts for changes in laws and new restrictions established by new laws insofar as these are established in terms that allow cartographic representation or are based on elements that can be mapped, such as wells and springs.

59. Terrain with over 40% average slope. Article 2, section v) Decree N° 25721.

Forest cover loss within pineapple production landscapes 2000-2015

The maps in this section show the main areas of forest cover loss within productive pineapple landscapes in the country for the following regions: Huetar Norte, Huetar Caribe, Brunca, and Central Pacific. It compares satellite images of productive pineapple landscapes between the years 2000 and 2015. The analysis was carried out by the PRIAS Laboratory from National High Technology Center, as part of the formulation process of the Project Conservation of Biodiversity in Productive Landscapes of Costa Rica of MINAE- UNDP.

These images can be analyzed by any user of the National Territorial Information System (www.snitcr.go.cr). This allows public institutions, buyers and pineapple producers to relate the location of loss of forest cover with land tenure records, which are also accessible by the SNIT. This allows users to determine in which properties the Forestry Law that Prohibits change in the use of forest cover was infringed. These images constitute the baseline of loss of forest cover associated with the pineapple crop for MOCUPP.

Between the years 2000 and 2015 there was a total loss of forest cover within productive pineapple landscapes of 5565.98 Ha. This is distributed in the following way: 3192.70 Ha. North Huetar region; 545.26 Ha. Huetar Caribbean region, 1789.71 Ha Brunca region; 38, 31 Central Pacific region.

NORTH HUETAR REGION

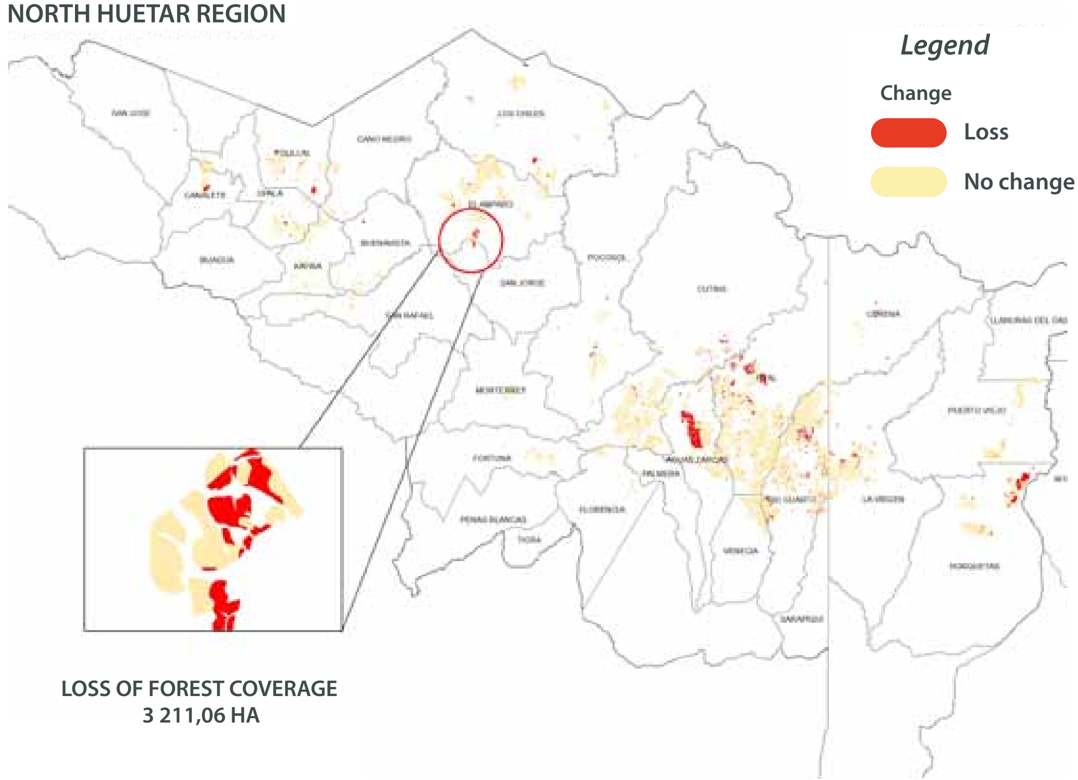


Figure 13: *Loss and gain of forest cover within pineapple production landscapes in North Huetar Region of Costa Rica between the years 2000 and 2015. Total loss: 3192,70 Ha.*

CARIBBEAN HUETAR REGION

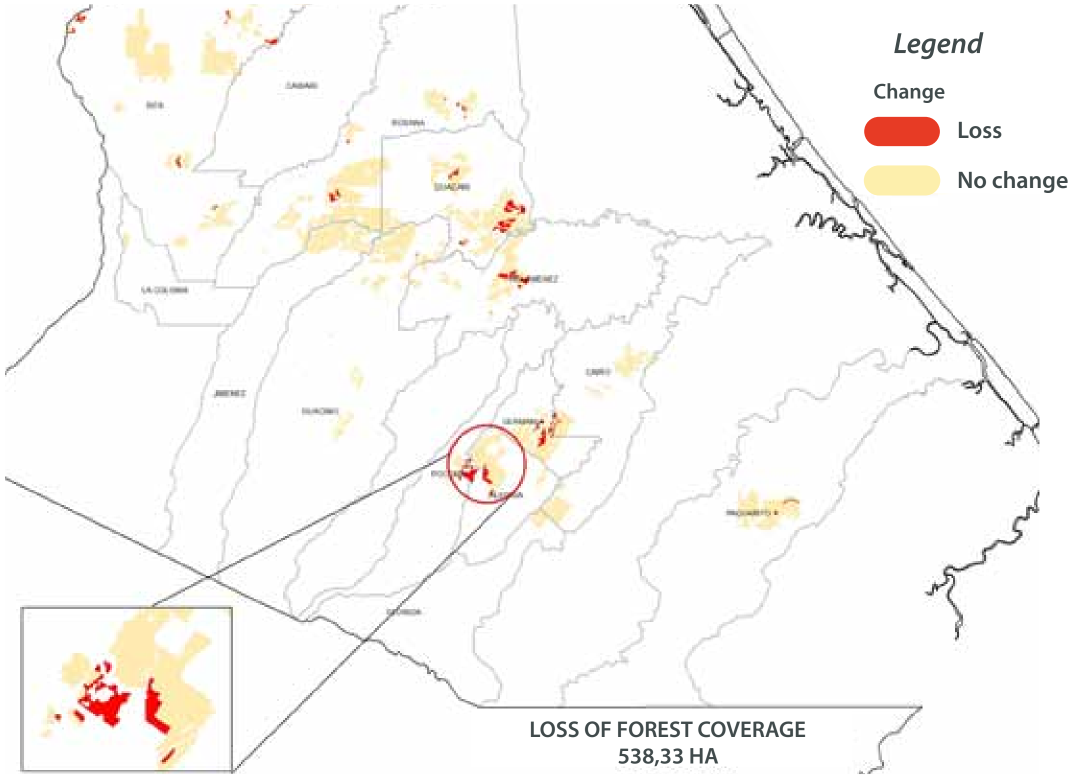


Figure 14: *Loss and gain of forest cover within pineapple production landscapes in the Caribbean Huetar Region of Costa Rica between the years 2000 and 2015. Total loss: 545,26 Ha*

BRUNCA REGION

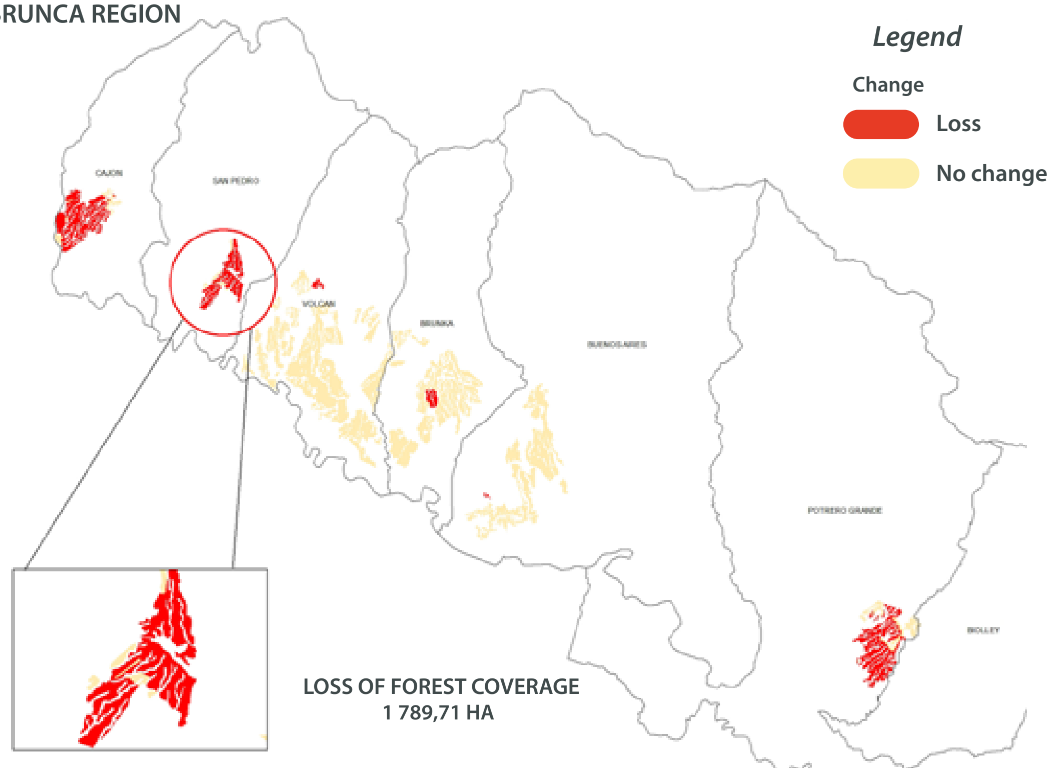


Figure 15: *Loss and gain of forest cover within pineapple production landscapes in the Brunca Region of Costa Rica between the years 2000 and 2015. Total loss: 1789,71 Ha.*

CENTRAL PACIFIC REGION

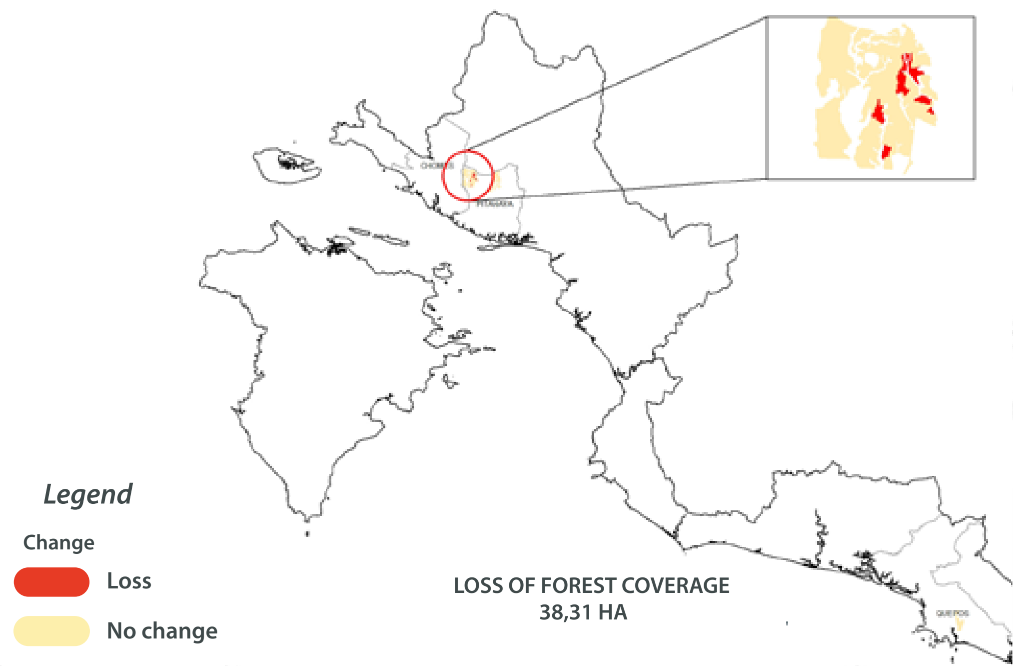


Figure 16: *Loss and gain of forest cover within pineapple production landscapes in the Central Pacific of Costa Rica between the years 2000 and 2015. Total loss: 38,31 Ha.*

X. Component 2: Generation of Land Tenure Information Available Through Online Cadastral Maps

Component leader: Directorate of Real Property Registration and the National Registry

Real Property Registration, under the National Registry, is the institution in charge of managing all cadastral and registration matters involving real estate property in Costa Rica and has been under the Public Registry since its beginnings. The Public Registry was created with the Mortgage Act of October 31, 1865, an adaptation of the Spanish Mortgage Act of 1861. It was issued prior to the Civil Code of 1886. In 1916, under Law Nº 70, the General Cadaster Office was created and set up in order to make a plan of public highways, roads and byways, railways and rivers serving to delimit areas or regions of national territory.

This is similar to other developing countries where land tenure information is not easily available nationwide. This is why MOCUPP is a replicable tool in other countries. The strategy is to establish land use change monitoring within all of its national production landscapes, and as the system grows and becomes consolidated, and as commodity sector and institutional partners found value in its yearly products, more partners may be chandelled to the activities aiming to increase total area of digitalized cadaster, so that all images may be tied to land tenure.

The purpose of real property registration is to strengthen registration security through the legal effects of its publicness, as well as effectiveness and efficiency in processing the documents presented. Implicit in the Real Property Registration's creation are a series of technological transformations related to human resources, finance and service, but which primarily makes Costa Rica one of the few countries with a unified system that provides legal security through custody of registration and graphic information about property.

Registration System in Costa Rica

The property registration system in Costa Rica is a consolidated part of the country's culture and economic dynamics. Recent data, the result of cadastral surveying, indicate that over 90% of properties are registered, meaning that in general and notwithstanding the presence of some conflicts, land tenure is under the domain of registered owners- in other words, a legal reference exists as to the person or entity responsible for land use.

The consolidation of the registration system stems from the constitution of the Public Registry as of 1865. Over the years, this institution has enjoyed the respect of government authorities and society in general. Thanks to its administration, the system has been modernized, mainly in technological aspects, with registry information now on computerized databases.

In 1916 a Cadastral Office was created within the Registry as complement for property description and physical location. This orientation was not always maintained, and it was not until 1981 that the National Cadaster was created to consolidate the aim of having a description and the exact location of each property.

Under the administration of the National Registry, two institutions were maintained with jurisdiction over the same good. The Public Registry of Property has been in charge of the subject, meaning the owner and owner condition, while the National Cadaster is responsible for the object, or description and physical location of the property.

Nonetheless, because data is kept in two different institutions and under different legal systems, weaknesses became evident when incongruences arose in the data registered for some properties. Another weakness was that the physical description registered in the cadaster was only for the individual property, with no description available for the entirety of all properties.

In 2009, Law Nº 8710 created "the Real Property Registry, which includes: real estate property, mortgages, mortgage bonds, condominium properties, maritime terrestrial area concessions, concessions in the Gulf of Papagayo, registration of tourism marinas and the National Cadaster."

According to its regulations,[60] with this modification cadastral and property registration functions are integrated, while respecting the principle of each one's specialty area. In addition, the cadastral map is defined as graphic representation showing the location, identity and official boundaries of the properties.

Because the Real Property Registry was created only recently, full integration of registration and cadastral data and the officialization of the cadastral map are still in process.

Cadastral Progress in the Publication of Tenure Data.

While the cadastral map is the official document showing the location, identification and official limits of properties, it has not been formed for the whole country. Still, given the needs of the land cover monitoring system, the cadaster has information on a considerable portion of the territory.

Figure 12 shows the map of Costa Rican territory and cadastral coverage. The minimum administrative units (districts) can have three types of status: "officialized," "in process" and "without information." In districts where cadastral surveying has been officialized (101 – 21%), the official description of the property appears on the cadastral map. There is a considerable number of districts (221 – 46%) where this is in process at the different stages of formation, public disclosure or on hold prior to its officialization. This process has not yet been initiated in other districts (161 – 33%) and information under cadastral map criteria does not exist, just a description in the form of individual cadastral plans

60. Executive Decree Nº 35509-J

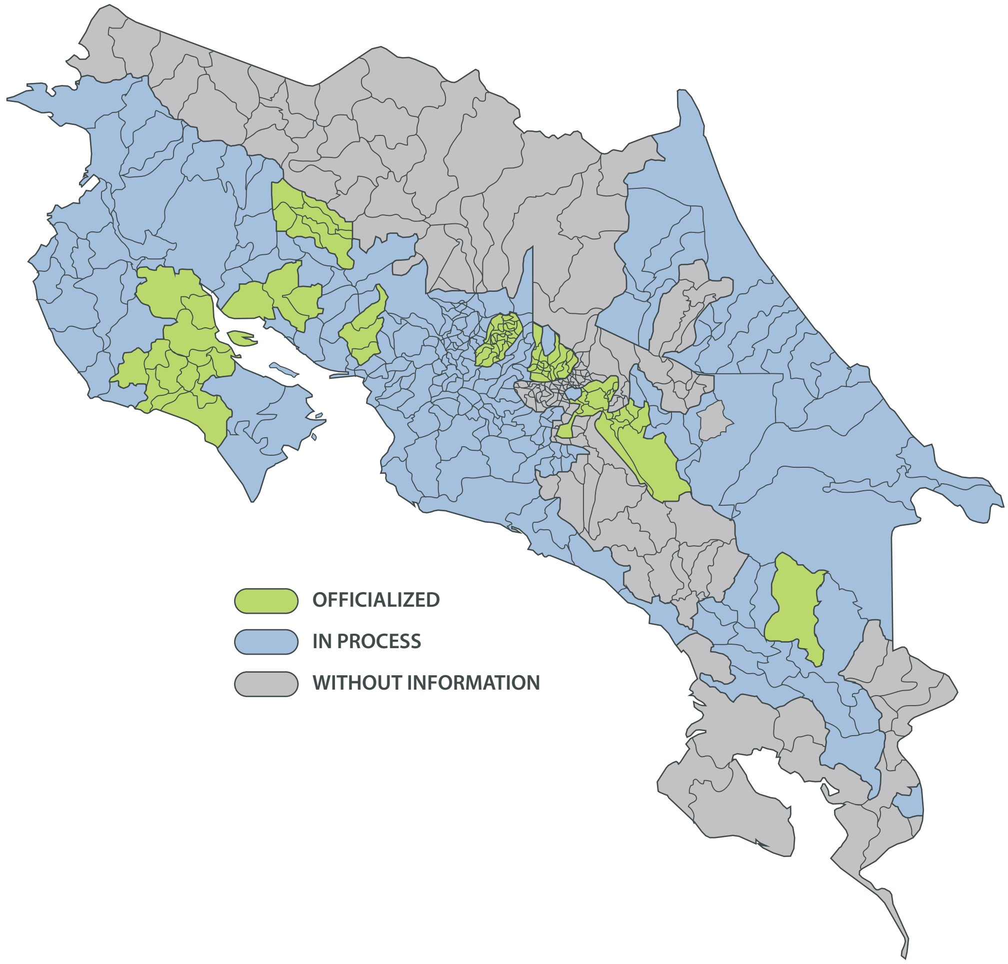


Figure 12: *Coverage of cadastral survey by districts* [61]

To date, 67% of the districts have cadastral data formed with a data model (cadastral model) aimed at the description of the registered property (legal object). In addition to the location of the property in the country, it also indicates the owners and types of rights associated, as well as affectations of those rights.s.

In this model,[62] the cadastral map is considered as a series of digital "information layers" together describing the physical situation of the lands, such as tenure, rights, restrictions, affectations, land use and other aspects. One of these information layers provides the description of the properties, with each one represented as a polygon, and corresponds to the physical description of a registered property (farm), one that is unregistered, or one that is public domain. The cadastral map or cadastral cartography is understood as the layer of information that describes the properties, identified through field or office work.

Cadaster coverage in terms of the total surface of the country is shown in Figure 13, again classified as officialized, in process or without information. Here the percentage without information is somewhat greater than by administrative units (districts).

61. By autor with data of the Real Property Registry
62. PRCR (2013)

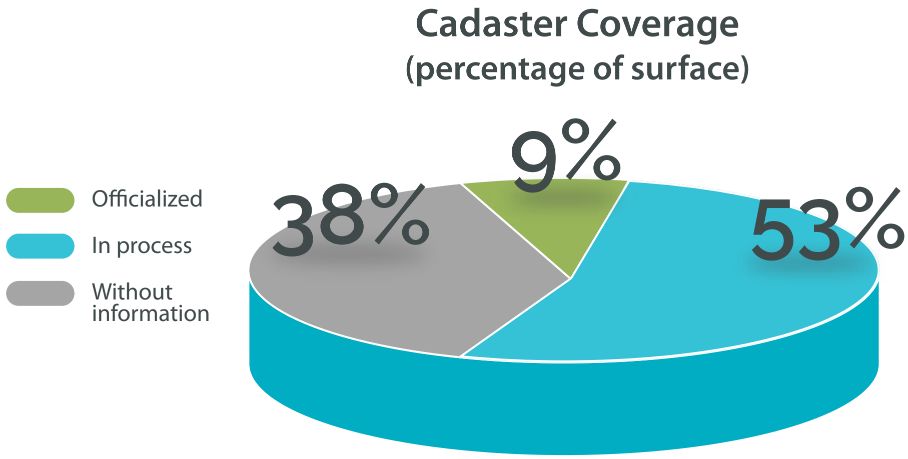


Figure 13: *Cadaster coverage by districts*[63]

The formation of the cadaster with the result of the cadastral map is essential for the monitoring system as a simple way of contrasting property data with land use covers. Figure 14 shows a section of the cadastral map where each property is individualized using a unique identifier. If that identifier corresponds to a registration entry, property data, rights and associated notations can be known.

Figure 14: *Sección del Mapa Catastral del Distrito Mansión cantón Nicoya*

As can be seen in Figure 14, the Cadastral Map (understood as geospatial database) makes it possible to integrate information layers contained in the cartographic base or reference prepared at a scale of 1:1000 for urban and residential areas, and 1:5000 for rural areas. In this way, a property is defined and individualized by its unique identifier. The layer of the cadastral map can be overlaid with the base cartography that describes public throughways and watercourses. It can also be integrated with the orthoimage from which land cover and use can be interpreted and deduced.

This characteristics of the cadastral map as geospatial database also permit its publication through map service applications that can be implemented in both licensed and open source software. For the land use cover monitoring system, this allows integration with tenure data and cover and land use data to be generated by other stakeholders, as PRIAS does for agricultural commodities.

63. By author with data of the Real Property Registry

XI. Component 3: Map Viewer that Relates Maps of Land Cover in Production Landscapes with Tenure Information on a Periodic and Public Basis

The strategy of the monitoring system focuses on showing data on forest cover loss and gain integrated with land tenure and legal environmental restrictions on land use. Tenure data are contributed by the cadaster and loss and gain data are periodically generated based on spectral analysis of images. Once data is available, their integration and publication is carried out on the platform of the National Land Information System (SNIT).

The National Land Information System was generated as product of a program to regularize cadaster and registration in Costa Rica (Programa de Regularización de Catastro y Registro de Costa Rica-PRCR)[64] in order to manage the country's unified cadastral-registration database on which different geographic information systems can be mounted. SNIT's administration was transferred to the National Geographic Institute (IGN) as the entity in charge of producing official cartography and its publication and distribution.

The National Registry is the administrative superior of two institutions key for achieving the objective of publishing information from the monitoring system: the National Geographical Institute, in charge of SNIT, and the Real Property Registry responsible for the formation and publicizing of the cadastral map delimiting property. For this reason, actions taken by the Real Property Registry are fundamental for the publication of SNIT information.

Legal and Technical Foundation for SNIT's Development. Decree 37773

The fundamental legal basis for the SNIT lies in Executive Decree 37773, published in Diario Oficial La Gaceta no. 134 of 12 July 2013. According to this decree, its general objective is to promote the generation of georeferenced products, services and geographical information with national, regional and local coverage. It is also responsible for integrated and georeferenced publishing of land information produced by government agencies, individuals and private sector entities, and harmonizing standardized geospatial information in the frame of an infrastructure of common data.

This concept of common data infrastructure is the fundamental and functional basis underlying SNIT, and corresponds to the widely established concept[65] that defines a spatial data infrastructure (SDI) as an informatics system made up of an array of resources (catalogs, servers, programs, applications, web pages, etc.) permitting access and management of datasets and geographic services (described through its metadata) available on the Internet, that complies with a series of rules, standards and specifications that regulate and guarantee the interoperability of the geographic information.

64. Executed through loan agreement between the State and the Inter-American Development Bank, and approved through Law Nº 8154 of 01 December 2001
65. See INSPIRE directive: http://inspire.ec.europa.eu/

It is also necessary to establish a legal framework (policies) ensuring that the data produced by the institutions will be shared by the entire administration and citizens are encouraged to use them."[66].

In practice and functionally, an SDI is a network of nodes that operate with connectivity on the Internet and through rules (usually agreements) and standards, transparently exchange geospatial information. In principle, all of the nodes could be considered equal, but usually there is one called a central or main node through which publication is materialized on a geoportal that provides access to services of viewing, localization by metadata and localization by geographical names or locations. In other words, the geoportal basically has a viewer and a search catalog. Figure 15 illustrates the architecture of an SDI with a central node.

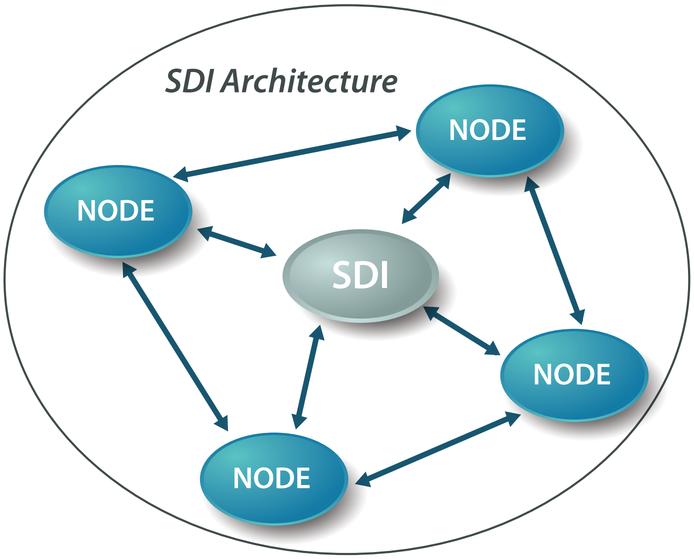


Figure 15: *Architecture of an SDI (Central Node)*

In this architecture system, it is understood that the technical and policy leadership of an SDI is performed from the managers of the central node; in other words, along with administering the geoportal as technological platform, it prepares and disseminates technical rules and promotes the production and publication of standardized, integratable geoinformation. SDIs as infrastructures are comparable to highway networks, and like them, can be categorized, whether by their emphasis, themes or coverage. Figure 16 shows the typical grouping of SDIs in three categories, which follow a pyramid regime.

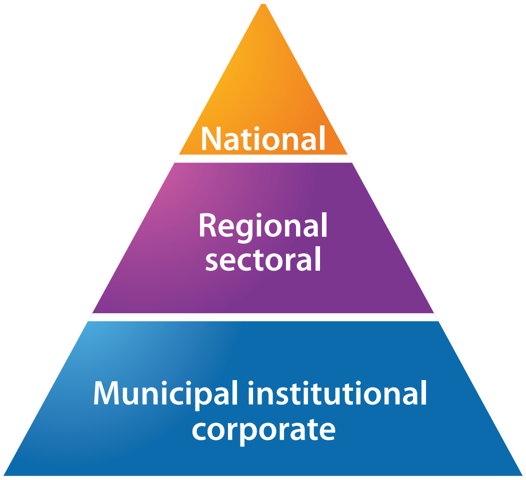


Figure 16: *Relation between SDIs in a country*

66. http://www.idee.es/. Spatial Data Infrastructure of Spain

At the base of the pyramid the cases involving specific themes, the data of a municipality, an autonomous institution or public enterprise[67]. At the top we find be SDIs responding to a greater geographic space, such as regions of municipalities or sectors such as environment, energy, health and education, grouping some institutions with related fields of action or jurisdictions, as CENIGA could be considered. Finally, the national level defines policies and integrates the information and other SDIs in overall form.

As presented and established in Executive Decree No. 37.773, SNIT corresponds to the SDI concept. From the definition of its initial content as official topographical and cadastral cartography,[68] it can be considered a sectoral SDI since it contains the information that is generated by two institutions attached to the National Registry[69]. Nonetheless, the same decree establishes that the National Registry, the entity in charge of the direction of SNIT, will promote the establishment of a national geospatial data infrastructure. In addition to publishing geoinformation, SNIT is assigned the definition of standards and promoting the use of systems integrating geoinformation.

These additional competences on top of the publication of geoinformation are to be interpreted as the basis for developing the national SDI, which is reinforced by the decision of the National Registry to entrust SNIT administration to the IGN, the institution responsible for producing official country cartography.

Actions by State institutions recognizing the governing function of SNIT should be indicated. The Comptroller General of the Republic ordered MINAE, SINAC and IGN to integrate in SNIT information about the formulation and approval of regulatory plans. Likewise, the National Land Use Plan (Nacional de Ordenamiento Territorial-PLANOT 2014-2020) ordered the strengthening of SNIT and assurance of universal access to information on territorial management.[70] These actions reveal the preeminence SNIT can have with respect to land information.

However, based on the country's experience in and knowledge of the use of geoinformation, it can be stated that to date, only a minimal amount of the data available in the country has been integrated. In part, this can be explained by the fact that SNIT was only recently created and because it represents the first official attempt to consolidate an SDI. Nevertheless, there is an evident need for promoting institutional policies on publishing and integrating information, as well as actions publicizing the usefulness of consolidating the SNIT.

Given the proposed objectives and reach of MOCUPP, SNIT represents the ideal legal means and platform for dissemination of the commodities total land cover, gain and loss of forest cover, and land tenure records. The decree of its constitution requires the Executive Power entities to publish through that system all of the standardized georeferenced land information all institutions generate, administers and manages, with the capacity to make arrangements with autonomous and semiautonomous institutions, municipalities and public enterprises for the publication of standardized georeferentiable information that they administer, manage and construct.

67. In general, the theme of SDI is approached from the public focus; however, in this same scheme private business can be considered at the corporate level.
68. Article 1. Executive Decree Nº37.773
69. Laws Nº 8.710 and Nº 8.905
70. See consultancy report by Mario Peña Chacón.

Technological Infrastructure and Installed Capacity

Currently SNIT operates with an infrastructure made up of only one server (2GHz-12Gb) and access is provided through a 40 Mbps communication channel.

The proposed hardware includes a structure of five servers (2GHz-12Gb) with redundancy, two for the geospatial database, one for applications, one for a data catalog and one for web publication and the viewer. A storage area network (SAN 4Tb) is planned for data. This system follows what can be called standard for geospatial data publication. Figure 17 provides a schematic illustration of the infrastructure of the hardware platform.

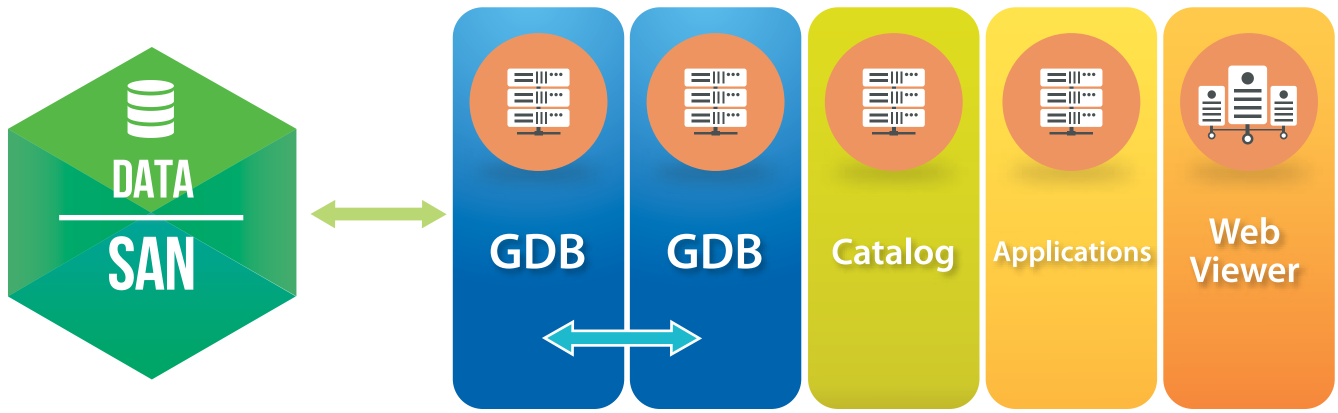


Figure 17: *SNIT Technological Infrastructure*

Concerning communications, it is now being proposed that SNIT operate with a bandwidth higher than the current 40 Mbps, dedicated and without restrictions on period of time. Platform renovation will clearly improve SNIT performance. This means that once the new platform is implemented, there will be better performance in its main functionalities of map viewer or geoportal and response to requests for geoservices[71].

Response Capacity

With respect to response capacity (present and future), this will always depend on user demand and the type of consultations required. Response by systems like SNIT can be measured according to performance in three basic functionalities I) online display through viewer, II) response to GeoService and III) downloading services. SNIT currently performs the first two of these functionalities.

Regarding the user, consultation through viewer (online consultation) using a home bandwidth connection of 2Mbps on a work day gives average 2-second response times to display a zoom in a given region of the territory with orthophotography. As for response for consumption of geoservices, with the same type of connection, loading vector hydrography or cadastral map information has response times slightly better than two seconds.

71. *GeoService: a web service (user access to information on remote servers) for exchanging information with spatial representation characteristics (geoinformation). Specific languages and standard protocols defined by OGC are used for the generation and use of GeoService.*

These response times can be considered appropriate, but some parameter of comparison is needed. It is thus valuable to consider the geoportal of Navarre's Territorial Information System[72] (Spanish acronym SITNA) http://sitna.navarra.es as reference. This system operates in its geoportal with three servers (2.4 GHz-72Gb) and 7 Tb storage.

For the same types of consultations in viewer and geoservices, while in some cases SITNA responses close to a second have been observed, generally no substantial differences are noted between SNIT and SITNA in the two parameters analyzed. It should be pointed out that in SITNA no access was obtained to orthophotography geoservices.

Statistics

Another way of assessing SNIT performance involves use parameters, statistics that measure use behavior over time. Eighteen-month data have been collected on hits, from which important parameters can be drawn.

The number of hits per month ranges between 7,000 and 15,000, with 18,000 in September 2015. This last month represents a homogeneous distribution averaging 20 hits an hour; in a concentrated distribution there could have been work days when up to 100 hits an hour were responded to. For the month of September hits have taken place from 5000 identified IP addresses- in other words, SNIT can be considered to have 5000 localized users who regularly request information.

Concerning geoservices, in September there were more than eight million petitions[73] for geoservices. On average, consultation for data on a farm and the orthophoto requires twenty petitions; demand for geoservices would be estimated at five hundred consultation hours an hour.

Table 4: *Main Statistics on Hits in SNIT*

Parameter	18 –Month Average	September 2015
Geoportal hit-count	12000	18000
IPs recorded	3000	5000
GeoService petitions	5.000.000	8.000.000
Data download (Gb)	75	20

Source:
Presentation by
C. Jonnathan Jiménez

72. *Autonomous Community of Navarre. Extension 10,000 km,2 population of 650,000 inhabitants.*
73. ***Petition:*** *Each request for information at an Internet site that recovers content correctly. A petition can be associated with each user action that leads to one of more downloads of information from the server.*

Another statistic of interest is the information downloaded from the SNIT viewer, measured as data rate according to the hits logged. This data rate is between 50 Gb and 200Gb per month, indicating that on some dates the rate reached 10 Gb.

Figure 18 shows SNIT behavior with respect to downloads in the first nine months of 2015. A monthly rate of 150 Gb (August 2015) signifies an average 20 displays or viewer responses per minute.

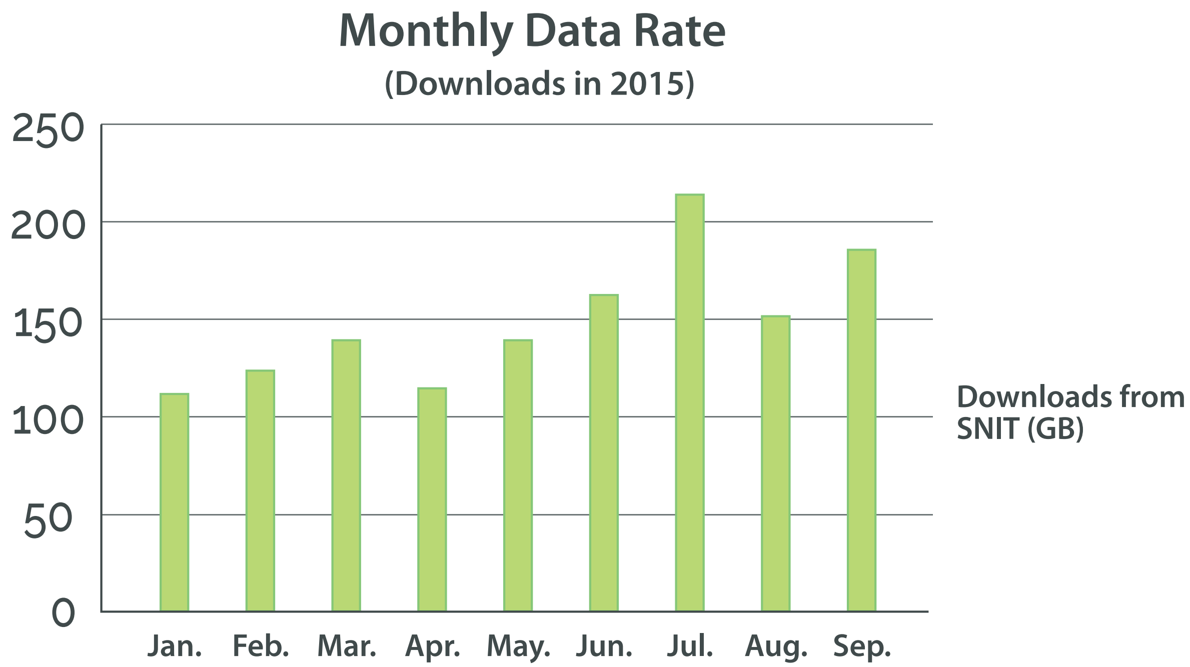


Figure 18: *Monthly Output of the SNIT in Gb of downloads*

As reference, estimated monthly download in SNIT for 2014 was 130 MB. This shows that SNIT data publication and distribution capacities are acceptable, and should improve with the renovation of the technological platform.

Demand

It should be noted that demand has been growing over time. Compared to data for September 2015, in January 2014 8,000 hits were logged from 2,500 IP addresses.

Demand is generated by users and has been rising. While performance is comparable with other similar systems, user demand can surpass capacity. This "greater" demand on current performance can respond to user expectations, hence it is important to pin this down.

Informal consultation with a group of users knowledgeable about GIS shows that in general, the SNIT is recognized as a platform that contains and provides access to quality land information generated by the National Geographic Institute and other institutions. In different roles, these same users periodically consume SNIT information and consider it a useful platform, but one in process. The main limitations identified are the small amount of information available, the resolution and display speed of the viewer, and that access is impossible from some institutions.

Other limitations have been found include: a maximum download permitted per person, the absence of bulk downloading and feature service, and publication of geoservices without adequate functionality.

Information Published. Internal and External Generators

To date the SNIT has been able to compile, describe and address geospatial information from 12 State institutions. The information complies with the characteristics to be integrated under the standards required in the concept of an SDI. Of this information, some is integrated in viewer (geoportal) and other information is addressed for use (consumption) through geoservices.

Between all twelve of the information-generating institutions, 176 maps or layers of information are available in geoservices (WMS)[74]. Of all those geoservices, 31 are published on the viewer of the SNIT geoportal and can be accessed immediately by any user over the Internet.

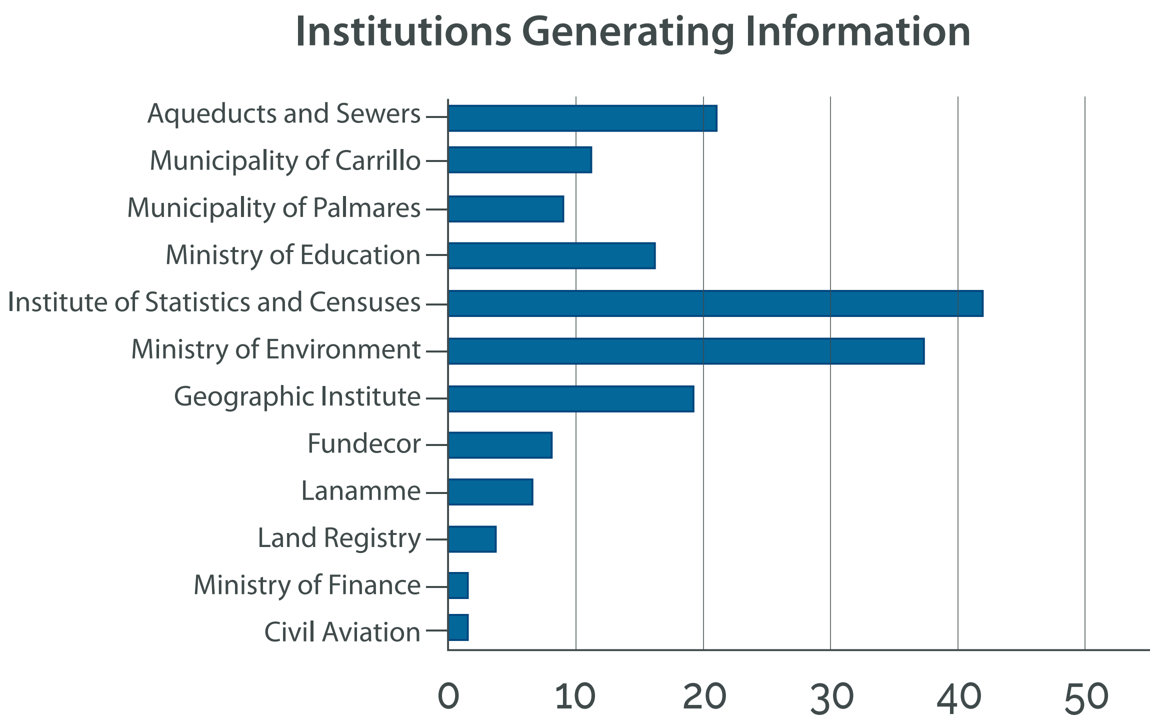


Figure 19: *Institutions Generating Geoinformation*

An important aspect to note is that each institution is responsible for ensuring that its information is accessible and updated, and must implement the corresponding measures. The functional basis of SNIT as SDI is not only to publish information; this involves responsibilities.

Examining the institutions that publish information, it is easy to identify sectors that are not participating despite their strategic importance in the economy, such as health, agriculture, tourism and culture, fundamental in terms of infrastructure. One would particularly expect more participation from the municipal sector to make zoning derived from land use regulations available. Apart from those included in the inventory, several municipalities have made

74. Web Map Service. Open Geospatial Consortium (OGC) standard for map publication.

significant efforts and advances to publish geoinformation[75], but not all of these have envisioned an SDI that is neither local nor external. This creates barriers to fully exploiting the potential of the information.

The information available is valuable and allows for an effective integration, thereby acquiring value-added. From the viewer, ownership of the land and its tax value can be determined,[76] and whether or not it is located within some type of protected wildlife area.

Figure 20: *Integration of information in the viewer of the SNIT geoportal.*

Figure 20 shows how, from the viewer in the SNIT geoportal, the integrated cadastral map can be displayed of the Buenos Aires district, canton of Buenos Aires, with the identification of the property (green line) and part of the area cultivated with pineapple in the Brunca region on the orthography. The integrated information corresponds to institutions with different responsibilities: the National Geographic Institute (orthography), Real Property Registry (cadastral map) and PRIAS (pineapple cultivation).

While the SNIT initiative is recent and can be considered an advance due to the amount of information published on a single platform, it is also true that a considerable number of sectors have not yet published information. The need for publishing information must be extended to other sectors, based on Article 5 of Executive Decree 37773, establishing that "the Executive Power will publish all standardized georeferentiable territorial information that it generates, administers and manages in the National Land Information System."

The SNIT platform provides two means of publishing information online: previously configured from a map viewer and through configurable map servers (WMS) that are consumed and configured by a GIS client.

The map viewer is an application with a configuration of displayable information layers about which attributes can also be consulted. Figure 21 presents the map viewer with the superimposed orthoimage, with base mapping of the road network that differentiates primary routes from secondary roads, and also watercourses.

75. Municipality of San Jose http://mapas.msj.go.cr:1024/SistMap/. Municipality of Escazú http://gis.muniescazu.go.cr:8399/GRL/mapviewer.jsf. Municipality of Cartago http://gis.muni-carta.go.cr/flexviewers/gisweb/.

76. Only for some cantons to date. See section 3.3

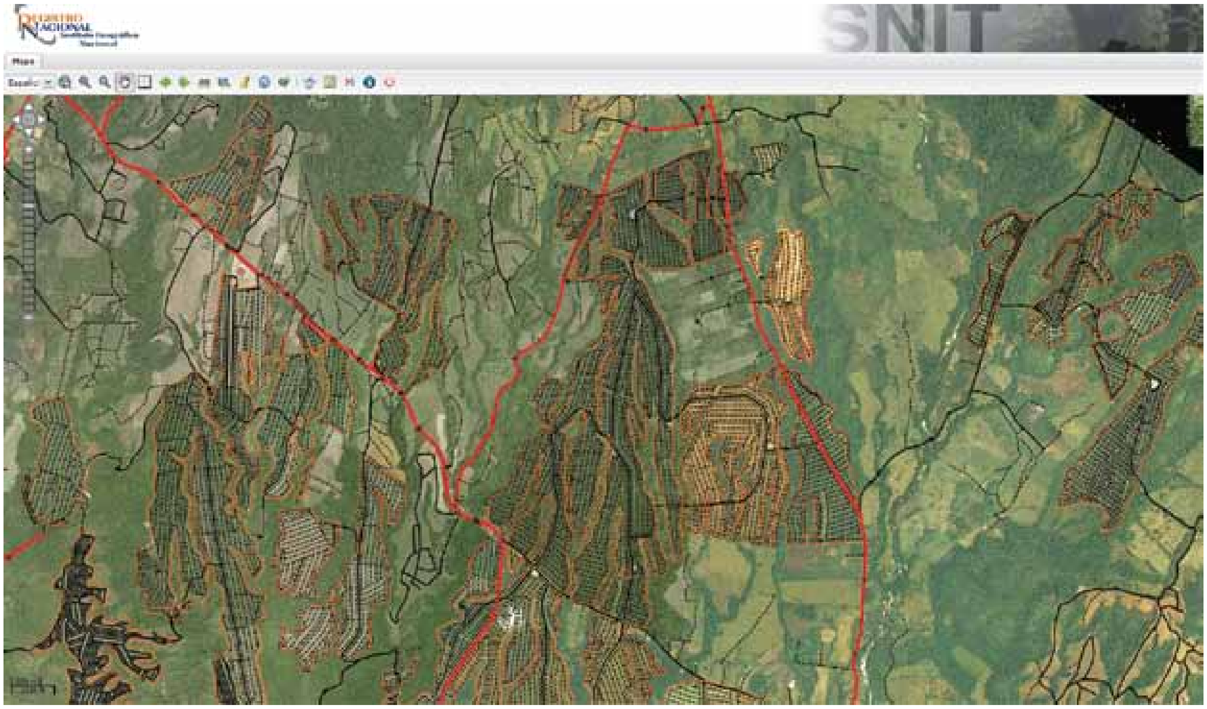


Figure 21: *SNIT map viewer* [77]

The SNIT information published through map service can be easily included in the user's composition of maps by bringing in information layers published as a web service. In this way, the generation of a land cover map can be integrated with other information. Figure 22 shows the interface of a GIS application (based on open source software) in which the web service of the SNIT orthoimage is integrated with the land cover map obtained from supervised classification of images.

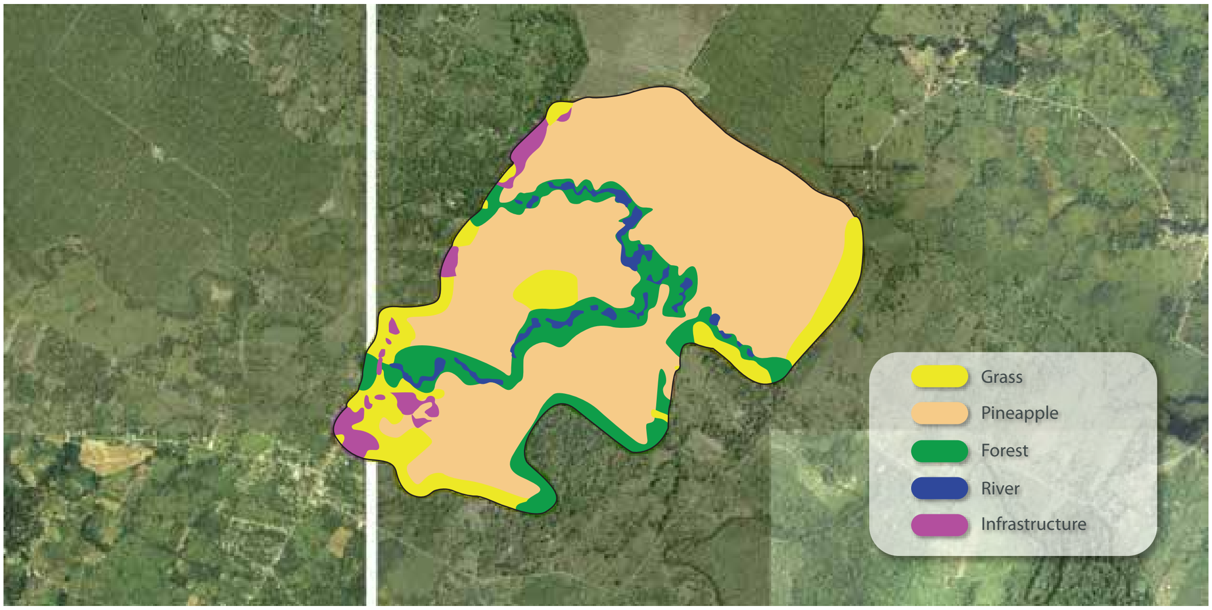


Figure 22: *Integration of the cover map with SNIT's orthoimagery service.*

77. *Captured from www.snitcr.go.cr*

As shown in figure 23, the same information from the land cover map can be integrated with base cartography, which makes it easier to identify possible crop affectation on hydrological elements.

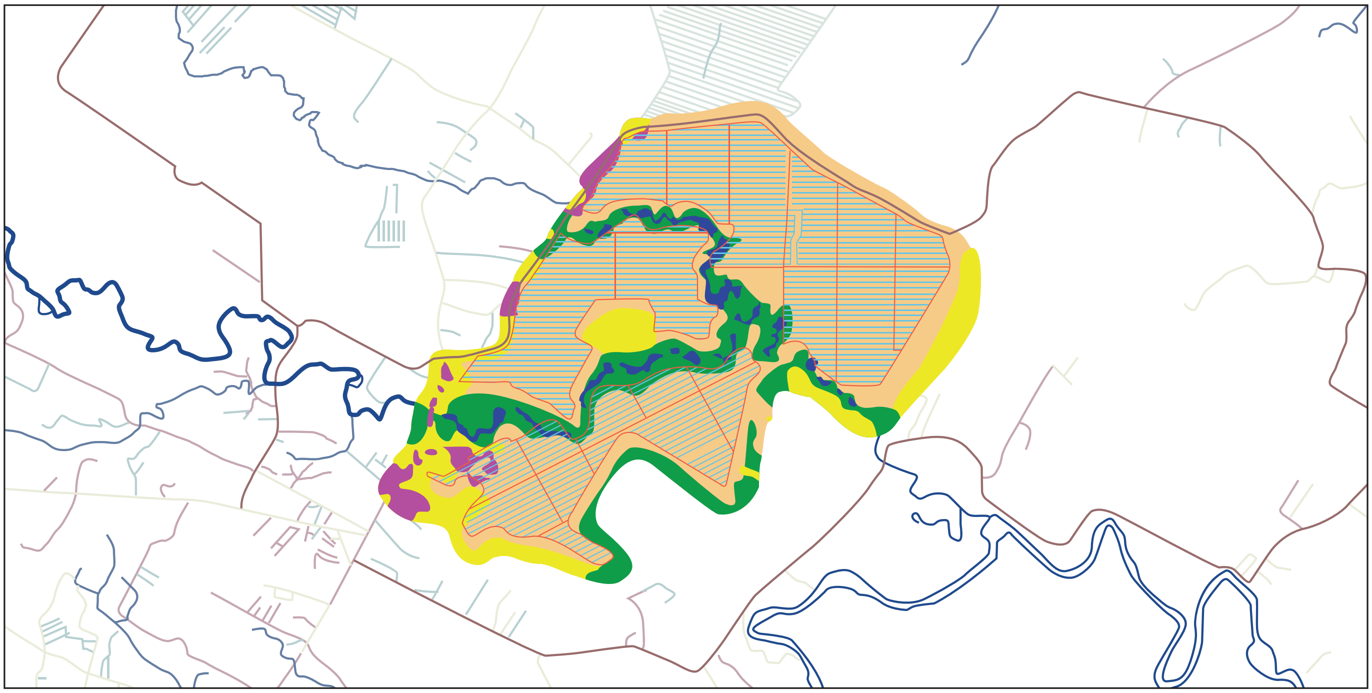


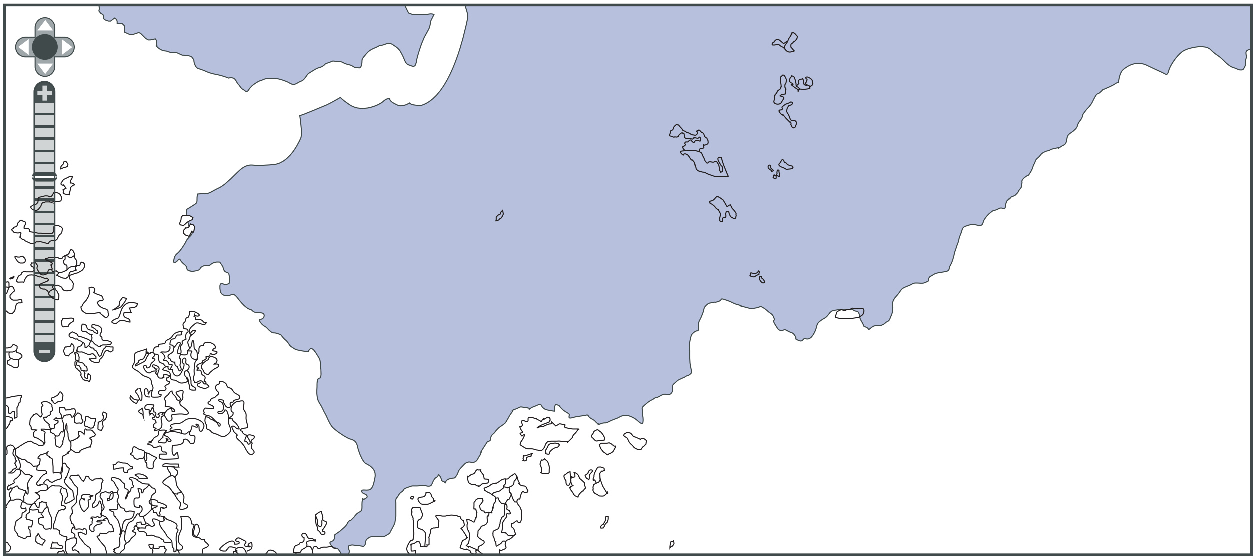
Figure 23: *Integration of the cover map with SNIT's base map service.*

As noted in the examples above, the SNIT is a platform in operation that facilitates the integration of geospatial information, thereby achieving two basic objectives of the system for monitoring land cover in production landscapes (MOCUPP). First, by publishing cadaster data in SNIT, cover maps are integrated with land tenure data. In addition, the SDI concept on which the SNIT is based allows integrated information to be publicized to all stakeholders.

XII. Benefits and Comparative Advantages of MOCUPP

Identification of Illegal Expansion of the Agricultural Frontier

With maps of specific commodities land cover, it is possible to identify exactly where they are located. When published through the National Land Information System (SNIT), this can be related to other layers of information. For example, the following figure shows the SNIT map viewer relating two layers, pineapple cultivation in 2015 and protected wildlife areas, generated by SINAC. By zooming in, patches of pineapple can be clearly identified within the Maquenque Mixed Wildlife Refuge.



SNIT map viewer showing protected wildlife areas and pineapple detected within the protected area.

Photo of pineapple located within the Maquenque Mixed Wildlife Refuge in October 2016. This plantation was located using the 2015 pineapple cover map published on SNIT, and later verified in the field by officials of SINAC (Carlos Quesada León) and UNDP (Carmen Umaña).

Monitoring of Forest Cover Loss and Gain from Urban Sprawl

Currently, loss of biodiversity in the country due to the elimination of habitat is associated with expansion of the agricultural frontier and of urban areas. It is thus strategic to take advantage of the interaction between PRIAS, DRI and IGN to address this environmental threat in urban areas, as well.

The procedure used to generate images of forest cover loss and gain associated with commodities that can be teledetected can be replicated in urban settings to verify compliance with the Forest Law, but in residential areas.

In this case, MOCUPP could generate two additional outputs: first, maps of total urban sprawl that indicate the total extension of residential and inhabited areas year by year; and second, maps showing whether specific urban patches eliminate forest cover (violating the Forest Law and several municipal provisions) or to monitor annual increase in forest cover alongside rivers that run through cities.

Through the project, Conserving Biodiversity through Sustainable Management of Production Landscapes in Costa Rica, funded by the Global Environment Fund, MINAE will invest in a pilot project involving the Maria Aguilar interurban corridor and determine its usefulness for urban land use planning and municipal management.

The following table shows the outputs expected in the next five years. When this pilot process concludes, resources will be available for annual mapping of the country's entire urban area, documenting its uses and the savings to be generated in State and municipal management. With this systematization of uses and costs to 2020, the government will be able to make the budgetary decision on including yearly monitoring of urban sprawl and associated forest cover loss and gain as part of MOCUPP. This decision and budgeting can take place in 2020.

Date of publication by SNIT	Urban Sprawl (CIUMA/ACLAP)**
2017	**Baseline** 2000-2016 of forest cover loss/gain in the urban area of CIUMA and ACLAP
	Total cover of urban sprawl of CIUMA and ACLAP 2016
	Loss and gain in forest cover in nationwide urban area 2016-2017 16-2017
2018	**Loss and gain** of forest cover in urban area CIUMA/ACLAP 2017-2018
	Total cover of urban area CIUMA/ACLAP 2018
2019	**Loss and gain** of forest cover in nationwide urban area CIUMA/ACLAP 2018-2019
	Total cover of urban area CIUMA/ACLAP 2019
2020	**Loss and gain** of forest cover in nationwide urban area CIUMA/ACLAP 2019-2020
	Total cover of urban area CIUMA/ACLAP 2020

Certification of Deforestation-Free Production Units

The New York Declaration on Forests of 2014 united governments, businesses and civil society actors, including organizations of indigenous peoples, around the objective of reducing annual loss of natural forests in half by 2020, and making efforts to reach zero deforestation by 2030. As part of this process, the world's main traders in commodities have established purchasing policies to eliminate deforestation from their production chains. This has repercussions on our development, so tools like MOCUPP are expeditious for our environmental competitiveness.

The fact that the country generates annual maps of forest cover loss and gain and that these are published on a public access map viewer that links these maps with land tenure information, means that international buyers of commodities can ascertain, at no cost whatsoever, whether or not the farms where they acquire their commodities comply with forest legislation.

It also means that a producer can demonstrate to his market that the farm remains free of deforestation, or even better, that it maintains or increases forest cover.

Given the previously mentioned New York Declaration and other market trends toward eliminating deforestation from value chains, this tool will become a key ally of commodities producers aiming to differentiate themselves.

The project Conserving biodiversity through sustainable management of production landscapes in Costa Rica will invest in the development of a certification system for deforestation-free production units taking advantage of MOCUPP. This certification is expected to be ready in 2018.

Comparison between Landsat 2001 and RapidEye 2011 to obtain loss and gain

Reduce State Costs of Verifying Compliance with the Forest Law

Currently, violations of the Forest Law are mainly processed by SINAC and MINAE officials who file complaints with the Environmental Administrative Tribunal and the Public Ministry. This requires a visit to the site, often in response to community complaint. As a result, many violations of the Forest Law can go undetected or, considering the workload of MINAE officials in rural areas, may be denounced but never processed before the Environmental Administrative Tribunal or Public Ministry because not all of the required inspection visits to process the cases are scheduled. MOCUPP offers a way to enhance responsiveness and lower the cost of processing environmental images for the entire public sector.

XIII. Strategy for Long-Term Financial Consolidation

Long-term consolidation of the System for Monitoring Land Use change in Production Landscapes is achieved through a flow of technical actions that must be carried out in different settings and by different actors, and making those actions sustainable. Basically, they must be undertaken by those responsible for cadaster, those responsible for SNIT and the agencies in charge of generating data about land cover and land use.

On the part of the agencies responsible for producing land cover and use maps, it is necessary to consolidate technical staff and equipment ensuring that cover data is acquired in the periods established. This will also include developing methodologies for the classification of images and interpretation methods for the description of different crop covers.

Concerning those responsible for cadaster, they must make data official for the entire territory and implement permanent updating mechanisms.

In addition, those responsible for SNIT must promote its sustainability, mainly through the dissemination of policies for producing information under standards that ensure integration of all country-produced geospatial data in the SNIT.

For the system's consolidation and sustainability, support for each component of the monitoring system must be borne in mind. It is considered that a five-year support strategy would achieve the system's consolidation and accomplish the objective of publishing annual loss and gain maps.

The component of preparing land cover maps and determining loss and gain in agricultural production landscapes should take the following aspects into account:

Training. To obtain response and annual publication, more staff need to be trained, proceeding from the knowledge base already existing in the country.

Technological platform. Includes a suitable technological platform for image processing and Geoservice publication.

Images. An important support to the system would be to have higher-resolution images to Landsat 8; with them, the objective of annual publication is assured.

Logistical support. An organization like PRIAS requires support for fieldwork and logistics needed to prepare the annual land cover maps and land use change.

Table 5: *Budget of Component1*

Component 1	Year			
	1	2	3	4
Training	USD 30.000,00	USD 15.000,00	USD 15.000,00	USD 15.000,00
Tech platform	USD 400.000,00	USD 100.000,00	USD 100.000,00	USD 100.000,00
Rapid Eye images	USD 70.000,00	USD 70.000,00	USD 70.000,00	USD 70.000,00
Data capture in the field	USD 30.000,00	USD 30.000,00	USD 30.000,00	USD 30.000,00
Update maintenance	USD 83.666,00	USD 83.666,00	USD 83.666,00	USD 83.666,00
Technical staff	USD 80.000,00	USD 80.000,00	USD 80.000,00	USD 80.000,00
Rentals	USD 30.000,00	USD 30.000,00	USD 30.000,00	USD 30.000,00
Subtotal	USD 723.666,00	USD 408.666,00	USD 408.666,00	USD 408.666,00
Contingencies (15%)	USD 108.549,90	USD 61.299,90	USD 61.299,90	USD 61.299,90
Administrative costs (5%)	USD 41.610,80	USD 23.498,30	USD 23.498,30	USD 23.489,30
Total	USD 873.826,70	USD 439.464,20	USD 439.464,20	USD 439.464,20

With support for capacity building and systematization of the production of maps for different crop covers, information about loss and gain of the commodities and forest cover is expected to be obtained in five years as planned.

The following table presents estimated time for obtaining loss and gain and forest cover maps for each selected agricultural commodity.

Table 6: *Estimated outputs on loss and gain per agricultural commodity*

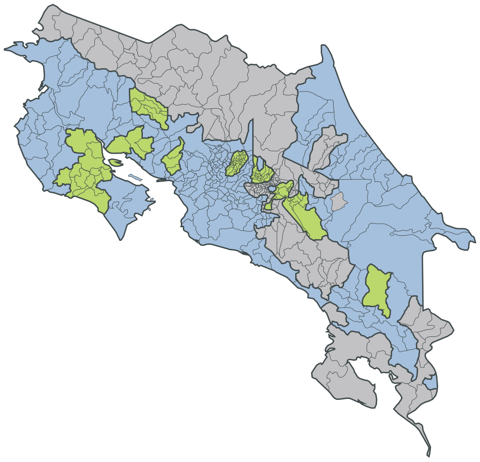
Year	Amount	Pineapple	Pastures	Sugar Cane	Palm Oil
2016	Financed by UNDP (Green Commodities) & UNREDD TS2 CR	**Baseline** 2000-2015 on loss and gain of forest cover on pineapple production landscape			
		Total pineapple cover 2015			
2017	USD 873.826,70	**Loss and Gain** of forest cover on pineapple production landscape 2015-2016	**Baseline** 2000-2016 of forest cover loss and gain on production landscape with pasture and without trees		
		Total pineapple cover 2016			
2018	USD 493.464,20	**Loss and Gain** of forest cover on pineapple production landscape 2016-2017			
		Total pineapple cover 2017	**Total production** landscape with pasture and without trees 2017		
2019	USD 493.464,20	**Loss and Gain** of forest cover on pineapple production landscape 2017-2018	**Forest cover loss and gain** in production landscape with pasture and without trees 2017-2018	**Baseline** 2005-2018 of loss and gain of forest cover on production landscape for sugar cane	
		Total pineapple cover 2018	**Total production** landscape with pasture and without trees 2018	**Total cover** of production landscape with sugar cane 2018	
2020	USD 493.464,20	**Loss and Gain** of forest cover on pineapple production landscape 2018-2019	**Forest cover loss and gain** in production landscape with pasture and without trees 2018-2019	**Loss and gain** of forest cover on production landscape with sugar cane 2018-2019	**Baseline** 2005-2016 of loss and gain of forest cover on production landscapes with palm oil
		Total pineapple cover 2019	**Total production** landscape with pasture without trees 2019	**Total cover** of production landscape for sugar cane 2019	**Total cover** of production landscape for palm oil 2019
Total	**USD 2.354.219,28**				

The component of information on land tenure and ownership, support involves two key aspects, completing the corrections and officialization of 168 districts where cadaster surveying has been done and certain processes are still pending, and surveying in 161 districts; no cadastral surveying process has been carried out in 33% of these districts.

Component 2	Complete cadaster surveying					
	Year 1	Year 2	Year 3	Year 4	Year 5	Totals
Processes underway	USD 2.000.000,00					USD 2.000.000,00
Updates in 110 districts		USD 750.000,00				USD 750.000,00
Corrections in 59 districts			USD 1.250.000,00			USD 1.250.000,00
Surveying in 161 districts			USD 8.500.000,00	USD 8.500.000,00	USD 8.500.000,00	USD 25.500.000,00
Sub total	USD 2.000.000,00	USD 750.000,00	USD 8.500.000,00	USD 8.500.000,00	USD 8.500.000,00	
***Budgeted and contracted by the National Registry**					**Subtotal of the Component**	**USD 29.500.0000,00**

Table 6: *Budget for the Consolidation of Component 2 by 2020*

Concerning the component of publishing land cover and loss and gains maps, the consolidation and sustainability strategy centers on a more solid institutional setting for SNIT. An institutional analysis is proposed, culminating in a modification of its regulations to establish authorities for governing and promoting publication and geospatial information.



Complementarily, support is proposed for internal capacity building and a dissemination strategy to promote the functionality concept of a spatial data infrastructure.

Component 3	Publication of maps in SNIT					
	Año 1	Año 2	Año 3	Año 4	Año 5	Totales
Training	USD 25.000,00	USD 25.000,00				USD 50.000,00
Support for capacity building	USD 35.000,00	USD 15.000,00				USD 50.000,00
Legislative reform	USD 25.000,00	USD 15.000,00				USD 40.000,00
Dissemination strategy	USD 25.000,00	USD 25.000,00	USD 25.000,00			USD 75.000,00
Sub total	USD 11.000,00	USD 80.000,00	USD 25.000,00	USD 0,00	USD 0,00	
					Subtotal of Component	**USD 215.0000,00**

Table 7: *Budget of Component 3*

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MOCUPP

MONITORING LAND USE CHANGE WITHIN PRODUCTION LANDSCAPES

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Link to 4 minute video describing the MOCUPP
https://vimeo.com/125056174