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INVENTORY OF DATA ON ECONOMIC ACTIVITY AND DEFORESTATION IN THE AMAZON BASIN

Summary

INVENTORY OF DATA ON ECONOMIC ACTIVITY AND DEFORESTATION IN THE AMAZON BASIN

Introduction

The health of the world's forests has drawn global attention as national governments, businesses and philanthropic groups look to natural biomes to slow greenhouse gas (GHG) emissions and reverse the effects of a warming world. Central to this discussion is the threat of deforestation in the Amazon rainforest, an area spanning roughly seven million square kilometers. However, much of the current debate only scratches the surface. Measuring the rate of illegal Amazon deforestation – as much as 95% of all forest clearance is illicit – is only one part of wider international efforts to track the health of forests (Valdiones, 2021). In this technical note, we shine a light on a series of interrelated factors that threaten the Amazon and further jeopardize the role of the world's largest tropical forests as crucial assets for the climate agenda.

There is growing interest among countries of the Amazon Basin - and international partners - to leverage reliable and comprehensive information to prevent and reverse deforestation and restore forests and biodiversity. A wide range of data-driven initiatives to monitor the rainforest and measure the effects of specific types of economic activity are already underway. Notwithstanding enthusiasm for deploying satellites and drones to map deforestation and degradation, cross-sectoral and cross-national data availability and accessibility are uneven and often patchy. Accurately monitoring and measuring the Amazon flora and fauna begins with obtaining quality data, which in turn is essential for the prudent management of one of the world's most important tropical biomes.

This technical note provides a comprehensive review of comparative sources of data on deforestation (loss of forest cover and land degradation) and GHG emissions in Brazil, Colombia and Peru. It also assesses available data on how cattle ranching and agriculture development are encroaching on the rainforest. While considerable work is still to be done, the review highlights prominent databases and relevant indicators. A cross-country comparison of datasets provides insight into the economic activities that are pushing the agricultural frontier into Amazonian territories and compromising conservation efforts.

In order to detect, deter and disrupt criminal activities driving deforestation, public and private authorities require greater clarity about the type, coverage, timeliness and quality of available data. This is because access to accurate and granular information can improve efforts to measure the impact of economic activities on Amazon deforestation,

degradation and GHG emissions.[1] This note focuses specifically on the two sectors that are considered to be most harmful to the Amazon biome: cattle ranching and agriculture.[2] It features a preliminary inventory of 55 public, private and non-governmental datasets. The first section provides an overview of open-source databases on deforestation and GHG emissions in the three countries. It considers the availability of data in terms of geographic scope, time periods and public access for download. The second section provides an inventory of data on ranching and agriculture. A brief conclusion brings the note to a close.

Database inventory and sources

Multiple factors shape land change and land use patterns in the Amazon Basin. This note aims to identify data sources for two specific phenomena: changes in land cover and GHG emissions. It also considers key economic sectors that accelerate deforestation including livestock and agricultural development. To this end, the focus is on available data sources across three countries with an analysis of their geographic scope, depth of detail, and the frequency and periodicity with which they are reported. A summary of available information, elements of geographic and time coverage, and downloadable files for each country can be found in Annex 1.

1. Deforestation

1.1. Land cover by forest and forest change

Loss of vegetation is the most common and widely-used indicator of forest health and environmental conditions. This metric is listed in the UN Sustainable Development Goals (SDGs) as indicator 15.1.1. (LandPortal, 2022).[3] The Food and Agriculture Organization (FAO) is responsible for monitoring this indicator at a global level and proposes standardized categories for evaluation as part of the Global Forest Resources Assessment. Country reports prepared by national governments and

1 This is a descriptive article intended to propose a preliminary hypothesis and basic indicators to gain a better understanding of how economic activities impact the Amazon. It does not seek to develop statistical models that establish the main drivers of deforestation and GHG emissions.

2 The Igarape Institute's typology of environmental crime related to economic activities includes cattle ranching, agriculture, illegal drug cultivation, forestry, wildlife trade, energy and mining, public utilities and infrastructure (Igarape Institute, 2020). Other activities rather than cattle ranching and agriculture would be reviewed in further research by Igarapé Institute.

3 The official formula used by the UN to calculate the percentage of forest area for a given year is forest area divided by land area, multiplied by 100.

remote sensing conducted by FAO together with national focal points and regional partners provide estimates through 2020.

The FAO defines forest as "land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*." The definition does not include land that is "predominantly under agricultural or urban land use." Land area, in turn, is defined as the "country area excluding area under inland waters and coastal waters."[4] This information is used for the calculation of changes in land cover and deforestation rates.

In Brazil, at least four sources of land cover data are available. The official statistics agency (IBGE) provides detailed information with a four-year delay (the lastest dates to 2018). The National Institute for Space Research (INPE) is another important provider of land cover and deforestation rates, publishing satellite-based data with a one year lag. An alternative data source for more timely data is MapBiomas, a collaborative nonprofit network that provides a sharper picture, leveraging satellite data from Planet with a resolution scale of 1:1,000,000. Several additional Brazilian sources provide shapefiles of vectors for download with detailed information.

In Colombia, the national agency (IDEAM) monitors land cover and deforestation rates, albeit with a two-year lag. The website currently has many outdated links; the most recent files were made available only by request. At the regional level, the Amazonian Scientific Research Institute (SINCHI) manages the Territorial Environmental Information System of the Colombian Amazon (SIAT-AC) with information of land cover at a 1:100,000 scale using Landsat satellite information up to 2020. SIAT-AC also provides maps of forest change up to 2020 (preserved forests, recovered forests, lost forests and other coverage).

Peru also suffers from non-timely data; the latest land use information from the Ministry of Environment was only released in 2018. An alternative source in Peru is Terra-i, a consortium led by the International Center for Tropical Agriculture (CIAT) that provides publicly-available georeferenced satellite data with 250m resolution and a three-month delay. All told, all three countries host a variety of organizations and methodologies involved in measuring and monitoring land cover. Government agencies, university groups, and civil society organizations obtain forest and vegetation cover data via remote sensing technologies from LANDSAT, while regional and global projects access information from satellite imagery vendors such as DigitalGlobe (Maxar)[5], Planet[6] and Sentinel.[7]

A common challenge highlighted in this review is the substantial two- to four-year lag time between when government agencies such as IBGE for Brazil, IDEAM for Colombia and Ministry of Environment (MINAM) for Peru, collect national data on land cover and deforestation and publicly release official consolidated findings. Considering the lack of detailed and comparable data on land cover and deforestation across the region, civil society organizations have stepped up to provide relevant information in a more timely manner. For example, the Global Land Analysis and Discovery (GLAD) Initiative's Global Forest Change, from the University of Maryland, and the Monitoring of the Andean Amazon Project (MAAP), run by the NGO Amazon Conservation Association, apply remote sensing tools to identify potential causes of forest loss in near real-time. Both entities have proven they can deliver faster, cheaper and more timely information than official providers.

4 See FAO, indicator 15.1.1. - forest area as a percentage of total land area.

5 https://www.maxar.com/products/satellite-imagery

6 https://www.planet.com/markets/forestry/

7 https://sentinels.copernicus.eu/web/sentinel/thematic-areas/land-monitoring

Regional projects such as Terra-i Peru, MAAP and the Amazon Network of Georeferenced Socio-Environmental Information (RAISG), together with global efforts including GLAD and the Global Forest Watch, offer user-friendly databases and data visualizations with disaggregated information of land cover and forest change. These civil society initiatives, tapping mainly satellite systems, also generate timely information critical to understanding the underlying causes and impacts of forest change.

1.2 Early Warning Systems for Deforestation

National agencies in all three countries are scaling up more agile and flexible systems to quickly identify and map near real time land use changes, including deforestation. Early warning systems are tapping cutting-edge technology to analyze satellite imagery on demand to detect even subtle changes in forest cover. These systems are perhaps the fastest and most effective tools for detecting and responding to recent changes in forests. They are programmed to flag imminent deforestation and send alerts to law enforcement, indigenous communities, and other groups in or near affected areas (Global Forest Watch, 2018).

They also provide complementary information to independent projects regionally and globally; one example is MAAP's "hotspot" alerts which highlight risks of deforestation in specific areas and possible drivers of deforestation. Brazil and Peru provide timely information available for download as well as informative visualization platforms. By contrast, although Colombia's IDEAM claims that its early warning bulletins are posted weekly, the latest available report posts data only to March 2021. (The website went offline in March 2022.) The frequency of early warning reporting makes the system a priority resource for regulatory and enforcement agencies, as well as other stakeholders, to take stock and act.

It is important to consider that early warning systems are designed to prioritize institutional response from governments. The timely reporting and information that these systems deliver are critical to complementing the process of mapping land cover and land use changes. All three countries have developed consistent databases to access and download the relevant information.

In Brazil, for example, INPE operates the DETER system, which generates daily alerts on felling, forest degradation, and timber extraction in the Amazon forest. This is public information, released with a two-week delay, at the municipal and federal levels. The information is displayed in interactive maps and shapefiles, and available for download.

Meanwhile, Colombia's forest and carbon monitoring initiative (SMByC) also features an Early Warning for Deforestation (AT-D) system that processes low-resolution satellite images to identify loss of natural forest cover. The national environment institute, IDEAM, also tracks "hotspots" and issues nationwide deforestation alerts on a weekly basis. Detailed maps and reports are provided by IDEAM, albeit currently only through March 2021.[8]

In Peru, MINAM developed an early warning service operating in near real-time and generates weekly reports that are available to download. This system leverages LANDSAT technology and can detect up to 10% forest cover loss within a pixel. Detected loss includes deforestation due to agricultural expansion, illegal mining, road opening, selective logging, and natural forest loss caused by hurricane-force winds and landslides in steep mountainous areas.

8 By the writing of this report (September 2022) the page of early alerts of deforestation of IDEAM is offline, not allowing the identification of the most updated AT-D to date. After a direct request, we were informed that AT-D for 2021-22 are in current consolidation and would be published "shortly".

1.3 Land-Use Change and Rural Land Registries

Understanding land-use change and the key data provided by environmental information systems is critical to untangling the dynamics of agricultural land use and urbanization. Many of the available databases on land cover also provide insights on how land is used. For decades, remote sensing technologies have helped track changes in land use due to human activity. More recently, satellite imagery has enhanced our ability to monitor land degradation, deforestation, pollution, and agricultural land abandonment, as well as the development and transformation of urban areas (Liang, S. et al, 2012). Analyzing this information alongside data on the expansion of economic activities such as cattle ranching and agriculture can provide important insights into the environmental damage these industries wreak on the Amazon rainforest.

While official information on land cover is often outdated, sometimes by as much as ten years, other important technological tools can be leveraged to reveal land use changes. For example, by overlapping geospatial data on land cover changes with satellite images on land use patterns, observers can identify risk factors and precursors to deforestation. More recently, countries have made significant progress in the development and updating of rural land registries with detailed, farm-level information on property, boundaries, and actual land use. This includes baseline information on conservation areas and indigenous reserves. Crucially, rural registries have also shown how property size can be an indicator of land concentration and how extensive cattle ranching and agriculture can serve as precursors to land change.

In Brazil, IBGE and MapBiomas introduced land cover in their annual reporting. The IBGE database (up to 2018) on land use examines use of the land across a variety of classifications, from “urban”, “agricultural”, “managed pasture”, to “forest”, among others. MapBiomas analyzes through 2020 forested land, natural non forested areas, farmland, land without vegetation and covered by water. The TerraClass project, developed and carried out by the Amazon Regional Center (*Centro Regional da Amazônia* – CRA) in partnership with the Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária* – Embrapa), uses remote sensing and geoprocessing techniques in conjunction with PRODES data to monitor Amazon deforestation and map changes in forest cover and land use in the region. The project keeps track of perennial and temporary agricultural production, bodies of water, mining, cultivated pasture, forestry, urbanized area, natural and non-forest vegetation.

In Colombia, IDEAM measures land-use change by calculating the share of national territory by varying land types, such as settlements, agriculture, forests, semi-natural areas, wetlands, and bodies of water. However, the Institute’s registry is chronically outdated and includes official information only to 2012. Encouragingly, a multipurpose land cadastral survey (2021), described later in this section, helps keep land use information current. Additionally, the National Aeronautics and Space Administration (NASA) Carbon Monitoring System (CMS) tracked changes in land cover in the Colombian Amazon from 2001 to 2016. Land cover types accounted for in its records include forests, natural grasslands, urban areas, pastures, secondary forests, water, and highly reflective surfaces. For the Amazonian region in Colombia, SINCHI provides maps of ‘agricultural landscapes’ with the area transformed by human activities of agriculture and livestock in the region updated by 2020.

In Peru, MINAM also tracks land by specific type of coverage, including forests, agriculture, prairies, wetlands, and settlements. However, the latest official information on file dates only to 2016. Encouragingly, regional and international groups, such as MAAP, have increasingly stepped up to provide an alternative to measuring land-use change using satellite-based technologies, including in Peru. These tools allow observers to track land cover and identify land used employing advanced algorithms.

Many of these mechanisms point to the drivers of deforestation by identifying activities such as gold mining, oil palm and cacao farming, land grabbing and infrastructure development. Despite the fact that data is often out of date, these three countries have recently made progress in the development of an important source of information: cadastral information with details of rural information at the rural property level with detailed information on property, boundaries and the actual use of the land, and also including conservation areas and indigenous reserves.

In Brazil, the National System of Environmental Information (*Sistema Nacional de Informação sobre Meio Ambiente* – SINIMA) is the entity tasked with managing official information on this sector by integrating various datasets and information systems. The Rural Environmental Registry (*Cadastro Ambiental Rural* – CAR) is the centerpiece of these systems. CAR displays electronic registries for rural properties nationwide, and allows policymakers and the general public to track the properties for land use, including the integrity of Permanent Preservation Areas, restricted-use land, legal reserves, forests and other forms of native vegetation and consolidated rural areas.[9] This data can be used to enhance regulation, monitoring, environmental and economic planning, and efforts to prevent deforestation. By crossing CAR data with information from the agricultural census, organizations such as Embrapa could map evolving land use and analyze the implications for environmental degradation.

The Colombian government relies on the Agustín Codazzi Geographic Institute (IGAC) Multipurpose Land Cadastral Survey (*Catastro Multipropósito*) to monitor land use for agricultural, cattle ranching, urban development, urban parks, among other economic activities. The survey contains information on national parks, protected areas, and delineation of rural properties. Georeferenced data at the rural property level is available for download. *Catastro Multiproposito,* released in 2021 (with updates planned every 5 years), is one of the most important sources of land-use, rural property, and many socio-environmental variables in the country. IGAC has developed projects to provide maps of the classification of land for their vocation for use and use conflicts, where a detail is available the discrepancy between the use that populations currently makes of the natural environment and the use that he should have according to their environmental, ecological, cultural, social and economic potentials and restrictions.

In Peru, the General Director of Sanitation of Agricultural Property and Rural Registry *(Dirección General de Saneamiento de la Propiedad Agraria y Catastro Rural)* of Ministerio de Desarrollo Agrario y Riego (MIDAGRI) centralized the Rural Registry with information on agricultural land titles and properties of countryside populations and native groups. A powerful, user-friendly visualization tool is available, facilitating public access to WMS sevice to download shapefies.

9 The 2012 Brazil Forest Code defines these areas as having been settled and occupied by humans prior to July 22, 2008. Within a given Permanent Preservation Area, agroforestry, ecotourism and rural tourism are permitted only on consolidated areas. (Presidência da República - Casa Civil, 2012).

Most countries provide official measures of land use on a yearly basis. Fortunately, all three countries under review have complemented their official data with non official, civil society initiatives to keep rural land registry and general cadastral information up to date. Maintaining current land use information is essential for keeping track of different economic sectors and managing their potential impacts across nations. Land registries are the most important sources of data on property, vocation of the land, delimitation of protected areas.

1.4 Land Degradation

One of the most important reasons to track changes in land cover and land use is to gauge their impact on land degradation. Degradation can result from natural causes, such as erosion, but also can be provoked by human activity, such as pollution. In all three countries under review, livestock grazing causes considerable negative environmental impacts, including erosion and soil compaction. This is especially the case regarding commercial agriculture which requires intensive use of fertilizers and pesticides and erodes the soil, leading to falling productivity and reduced groundwater-retention over time. Such activities are particularly concerning for the fragile soils of the Amazon Basin. Even where datasets do not track livestock presence or loss of soil cover, overlapping grids of soil degradation and cattle population could shed light on the impacts of the livestock sector.

All three countries maintain records of soil type and quality. While these records are not always timely, they can nevertheless include important indicators such as the natural structure of the soil components and how it alters its function. Brazil, for example, taps Embrapa's GeoInfo database. In Colombia, IDEAM relies on its Soil Degradation Monitoring and Tracking Program, while Peru looks to data from MINAM, which draws on Modi and LANDSAT images. Colombia's SIAT-AC provides a layered view of forest degradation from 2000-2020.

The challenge is to identify metrics reported over time and agreed upon across all three countries. Such shared indicators are not yet in place. However, they have the potential to flag trends in the agricultural frontier and provide a more granular look at how expanding agricultural production encroaches on the rainforest. As land becomes degraded, farmers and cattle ranchers typically move on, hence expanding the frontier. Tracking this trend requires a data source that can be monitored remotely rather than in-the-field measurements. For now, these efforts are still a work in progress.

2. GHG Emissions

GHG emissions inventories have become an integral piece of the 2015 Paris Agreement, obliging companies, cities, states and nations to measure progress towards emission-reduction targets. A national inventory of GHG provides a snapshot of human activities that cause emissions and those that contribute to their removal. Following international standards, national inventories often estimate emissions for five sectors: energy, industry, livestock, treatment of resources, and changes in the land use. In accordance with the Paris Agreement's protocols for global greenhouse gas standards, Brazil, Colombia and Peru have all created national inventories

In Brazil, Law No. 12187/2009 established the National Policy on Climate Change *(Política Nacional sobre a Mudança do Clima* – PNMC), which includes an annual report of estimated GHG emissions from the Ministry of Science, Technology and Innovation (MCTI). Brazil has five annual estimates of GHG, the latest published in 2022, with emissions projected for 2020. Also, it has presented four United Nations Framework Convention on Climate Change (UNFCCC) Biennial Update Reports (BUR), updated through 2020. Online visualizations and Excel files on GHG emissions are available by sector,

gas type, and states. Additionally, the Climate Observatory (*Observatório do Clima*) manages the Greenhouse Gas Emission and Removal Estimating System (SEEG), which follows the Intergovernmental Panel on Climate Change (IPCC) and MCTI methodology and guidelines to calculate location- and sector-specific emissions for Brazil based on government, private sector, and civil society data reporting (IPCC, 2006). The system stores information dating back to 1970, though the GHG emission inventories span from 1990-2020.

In Colombia, the latest update of National Inventory of GHGs is available in the UNFCCC BUR version 3, released in 2021 (IDEAM, Fundación Natura, PNUD, MADS, DNP, CANCILLERÍA; 2021). In accordance with international standards and methodologies, the national inventory reported the amount of GHG (CO_2 equivalent) emitted through 1990-2018, as well as the share of total by sector (%), available only in a PDF report, with no databases available to download.

In Peru, the National Inventory of Greenhouse Gas (INFOCARBONO) was established in 2014 by the Ministry of the Environment, in order to comply with the commitments assumed by the country upon signing of the UNFCCC and the Kyoto Protocol. However, due to significant reporting delays, the most recent INFOCARBONO inventory was published in 2016. The report and Excel files of national level emissions by sector are available for download. So far, Peru has released two editions of the UNFCCC Biennial Update Report, the latest in 2019 with data for 2014.

National greenhouse gas balances and other similar inventories are typically reported on a two year cycle (for some economic sectors this frequency could be considered inadequate) International initiatives now play key roles in tracking current trends in GHG emissions. For instance, the Global Carbon Project provides researchers, policymakers, and the general public with a reliable and standardized database of national- and city-level GHG emissions from 1960 to 2020. Similarly, the World Resource Institute's Climate Watch platform compiles data from a number of reputable sources (including the Global Carbon Project) for nationwide and sector-specific GHG emissions inventories.

3. Economic Activities

There are several indicators available to effecitively measure the evolution of cattle ranching and agriculture in the Amazon basin. By measuring the growth of livestock and the movement of cattle over time, as well as the expansion of agricultural land, it is possible to obtain a clearer picture of the overall impact these sectors have on the Amazon forest. Other proxy indicators include production for domestic consumption and export of meat, dairy products, and key agricultural goods, each of which are mass market drivers of changes in land use. Additionally, by superimposing maps of designated forests, natural and protected areas on those harboring expansive cattle and agriculture activities, policymakers could have a more precise tool to identify irregular use of the land.

3.1 Cattle ranching

3.1.1 Livestock inventories and subproducts

An inventory of cattle herds in Brazil is available by the Municipal Livestock Survey (*PPM - Pesquisa da Pecuária Municipal*) of the IBGE, with information broken down by the number and type of animals, the production of the main primary livestock products and the average annual unit price. The information, available for download in Excel and ODS formats, is produced annually (up to 2020) at the municipal level.

In the case of Colombia, the Colombian Federation of Cattle Ranchers (Federación Colombiana de Ganaderos – FEDEGAN) maintains its own annual livestock inventory at the municipal level, available for download in Excel files. Likewise, the Colombian Agricultural Institute (Instituto Colombiano Agropecuario – ICA) also maintains an annual livestock census that tracks animals by species, municipality, and vaccination status among other factors. We failed to identify a specific livestock inventory in Peru (some information is available in the census and survey section below) for small scale cattle raising, although more thorough data is available for other priority animals, such as the alpaca.

In addition to bovine herd size, keeping track of the number of slaughtered animals could help to capture the scope and evolution of the livestock industry. Colombia's Livestock Slaughter Survey (Encuesta de Sacrificio de Ganado), carried out by the National Statistical Office (DANE), and Brazil's quarterly report by IBGE (Pesquisa Trimestral do Abate de Animais), provide relevant data on respective national production and prices in the sector. All sources are updated and available to download in microdata format. The Igarape Institute was unable to identify an equivalent survey in Peru, although the Integrated Agricultural Statistics System (Sistema Integrado de Estadística Agraria – SIEA) provides information on principle livestock species and subproducts. Even there, a complete dashboard is available only up to 2020, and PDF reports and basic Excel tables are updated with a three month delay.

Other variables related to livestock traceability are key to identifying the presence and spread of cattle raising in protected areas, which may be used as a proxy indicator for land grabbing and deforestation. Unfortunately, this data is not commonly available for public use. For example, the Ministry of Agriculture, Livestock and Food Supply of Brazil (MALFS) operates the Brazilian System of Individual Identification of Cattle and Buffalo (SISBOV), designed to register and monitor livestock production to allow individual traceability. The system tracks livestock sales from rural properties to meatpackers to markets abroad. In 2021, a complete list of registered users by manufacturers and importers was available in PDF file, currently offline.

The potential value of this information for tracking environment crime has been highlighted by a number of organizations, including the Brazil Coalition Climate and Forests and Agriculture. The Coalition notes that cross-referencing data could bring more transparency to the supply chain, potentially guaranteeing beef production free from illegal deforestation. The mechanism would work through data integration between Animal Transport Guide (GTA) permits, the CAR, and the respective legal mechanisms that allow their joint validation. These requirements are not new; they make up protocols of established "agreements signed within the scope of the SISBOV and by the TACs (Terms of Adjustment of Conduct) between the MPF (Federal Public Ministry) and the meat processors operating in the Legal Amazon, Brazil" (Coalizão Brasil, 2020).

Colombia and Peru keep similar databases but do not make them readily available to the wider public. Nonetheless, these information banks are key to disentangling the dynamics of the beef chain and identifying potential drivers of deforestation. And in Peru, the National Agricultural Health Service of Peru (SENASA) has recently implemented traceability for slaughterhouses (MINAGRI, 2020). While Colombia's National System of Identification and Information of Cattle (SINIGAN) of ICA is not available for public consultation. However, other sources could be tapped to help shed light on the beef chain, including hard-to-access cattle vaccination registries.

The Igarape Institute identified another innovative source of information to help track cattle movements from protected areas. This measure was used by EIA (2021) for Colombia,

and, in Brazil, by Bloomberg and Reporter Brasil (2021), as a way to unpack the dynamics of "cattle laundering" by tracing beef originating from illegally deforested areas to supermarket chains. Information on Colombian cattle movements is not publically available but may be requisitioned by petitioning by the country's ICA-SIGMA system. Equivalent systems are available in Peru (SENASA's Cattle Internal Transit Sanitary Certificate) and Brazil (MALFS's Animal Traffic Guide GTA), albeit with no public information access.

3.2 Census and Surveys

The most comprehensive source of information on livestock activity is the National Livestock Census, which each country may consult to identify the potential and effective use of the land. For the countries under review, censuses are the most important sources of data on agricultural and livestock as well as on national producers. Nevertheless, censuses typically are not up to date; Brazil's latest was released in 2017, Peru's in 2012 and Colombia's dates to 2014. Hence, the available censuses fail to account for the most recent evolution of cattle stocks and flows of herds and production.

In Brazil, the IBGE Agricultural Census, last conducted in 2017, assesses livestock and herd size at the municipal level about every five years. It also keeps a record of agricultural establishments and the latest information on the land titles and the financial standing of property holders. Preparations for the next survey are due to begin in 2022. Information is posted on an interactive platform, with the full microdata available for download.

In Colombia, the National Administrative Department of Statistics (*Departamento Administrativo Nacional de Estadística* – DANE) conducts its Livestock Census (*Censo Pecuario*) intermittently. The government's last census was carried out in 2014, and before that only in 1970. The last version reported on the number of livestock in each state, as well as the number of rural properties and types of animal found on each. The government has yet to announce a date for its next census. The National Institute of Statistics and Informatics of Peru (Instituto Nacional de Estadística e Informática – INEI) last conducted the National Livestock Census (Censo Nacional Agropecuario – CENAGRO) in 2012, reporting on the amount of livestock at both the property and municipal levels. The next survey is expected to be carried out in 2022.

Yet another, more flexible statistical operation common to the region is the National Agricultural Survey (ENA)[10], which analyzes the total property area, use of soil, production and yield of the main crops (seasonal and permanent) and fruit trees. It also measures each property's share of pastures and forests, as well as milk production and the livestock inventory. While Colombia and Peru claim to canvas farmland annually, both countries last released complete versions of the national agricultural surveys, replete with microdata, in 2019. In Colombia an online visualization is available.

In summary, all three countries provide abundant information on livestock inventories, slaughter and farm production. The challenge is for each nation to keep current permanent records of the evolution and distribution of the multiple facets of cattle raising, including regular national inventories and quarterly surveys. Nevertheless, Peru lags Colombia and Brazil in processing and divulging current data, which may explain the relatively modest

10 In Brazil, equivalent products are the Municipal Livestock Survey PPM and the Systematic Survey of Agricultural Production LSPA, included in other sections of this report

contribution that agriculture and livestock kicks in to Peruvian GDP. Given the vital role national statistics play in generating baseline economic information, all countries should make efforts to compensate for their chronically outdated national agricultural censuses with complementary sectoral surveys.

This section identified a number of databases and approaches that can potentially be accessed in order to develop robust tracking methods, such as on certifications of origin, vaccinations and movement of livestock. While information is not routinely available, it can be requisitioned through official channels and transparency mechanisms (e.g. freedom of information requests) across all three countries.

3.3 Agriculture

Distribution and evolution of livestock and related products show the extent and impact of agricultural production and activity on the Amazon. These activities may also generate knock-on effects such as land grabbing and deforestation. Given the differentiated impact of crops across the region, country-specific databases should be considered, such as soy in Brazil, and oil palm in Colombia and Peru. All these products have been associated to differing degrees with deforestation and forest degradation.

In addition to regular monitoring systems of agriculture, maps of agricultural frontiers provide the official area of expansion of agricultural activities over the natural environment. Both Colombia and Peru recently released relevant monitoring projects with updated rural information; by contrast, Brazil's assessments rely on a 2003 database, an important lacuna for this emerging global breadbasket.

3.3.1 Agricultural Production

For the three countries under review, databases such as agricultural censuses and surveys quoted in the aforementioned section on cattle raising include robust information on agriculture, and should be considered a starting point. At the same time, the censuses are best seen as updated baselines which should be complemented with regular surveys. All three countries have specific systems designed to oversee the evolution of agriculture, stocks and prices.

In Brazil, the Systematic Survey of Agricultural Production (*Levantamento Sistemático da Produção Agrícola* – LSPA) keeps track of agricultural land use, harvested areas, crop yields and production since the early 1970s on a monthly basis, with municipal level data available for download. The National Supply Company (*Companhia Nacional de Abastecimento* – CONAB) also maintains an online database with agricultural information and specific data for maize, soy, rice, beans and coffee. A full online visualization platform provides information on production and other variables such as supplies, prices and markers with a tool to download files at the state level.

Colombia's AGRONET system is a Colombian agricultural sector information and communication network overseen by the Ministry of Agriculture and Development. Information available online was last updated in 2020. In Colombia, producers have developed their own information systems. Some products relevant for the Amazonan area are palm oil and cereals. More specifically, the National Palm Oil Growers Federation (*Federación Nacional de Cultivadores de Palma de Aceite* – FEDEPALMA) tracks palm oil production, while the National Federation of Cereal and Legume Producers (*Federación Nacional de Cultivadores de Cereales, Leguminosas y Soya* – FENALCE) tracks cereal and legume production. In both cases information is available on a yearly basis with information presented in online tools. FENALCE's data can be accessed only via a Power BI for visualization.

Peru's Integrated Agricultural Statistics System (*Sistema Integrado de Estadística Agraria* – SIEA) referenced in the previous section also has a specific visualization platform for agricultural products with an update of 2 months of delay.

3.3.2 Agricultural Frontier

Another key source of information are the maps defining the so-called agricultural frontier, defined as the area of expansion of agricultural activities over the natural environment. Colombia describes the agricultural frontier as the uncharted line "that separates the areas where agricultural activities are carried out" from protected areas and "those of special ecological importance and the other areas in which the agricultural activities are excluded by mandate of the law" (UPRA, 2018). The agricultural frontier is the baseline for planning agricultural land use and the efficient use of productive rural land, thus limiting the loss of ecosystems of environmental importance.

The current map of the Brazilian Amazon agricultural frontier, while badly outdated (the latest data is from 2006), created an important precedent by analyzing the human impact on the region. Providing details on the distribution of grain cropping, especially soybean, corn and rice, as well as cotton, the map displays not only the "spatial dynamics" of new crops scientifically adapted to grow in the savanna, but also "the intensive use of machinery, equipment and inputs." Although a key and detailed reference, the map of the agriculture frontier is outdated by more than 15 years in Brazil.

By contrast, Peru and Colombia only recently produced maps of their agricultural frontiers. The latest map by the Colombian Unit of Rural Agricultural Planning (*Unidad de Planificación Rural Agropecuaria* – UPRA) is based on data of 2019. Mapping the national agricultural frontier was one of the mandates of Colombia's Comprehensive Rural Reform, as stipulated in the 2016 peace agreement between the government and the Revolutionary Armed Forces of Colombia (FARC). The Rural Reform sought to address the root causes of the country's prolonged rural conflict and farmers' longstanding reliance on illicit crops. Mapping the agriculture frontier was described as a key precondition for formalizing property ownership and the safeguarding of protected zones and forest preserves. The map, drawn on a 1:100.000 scale, is available for download and for public visualization online.

Peru's Ministry of Agricultural Development and Irrigation MIDAGRI has mapped agricultural lands, tapping images from the Sentinel-2 satellite and Google Earth (from 2018) to demarcate areas with and without crops. The map is not as detailed as the Colombian version, but represents an important advance, given the outdated land use data from Peru's official Agricultural Census (CENAGRO) census.

Conclusion

This technical note provides an inventory of available land-use databases that capture economic activities cross-cutting three countries in the Amazon Basin. The document unpacks data availability, economic activities, and possible links to land-use change and land cover. This review also lays a foundation for future studies on the impact of economic activities such as cattle ranching and agriculture over deforestation and GHG emissions on the Amazonian Basin.

Precision analysis of the geographical expansion of economic activities requires regular monitoring over time rather than a collection of cross-sectional snap-shots. This is now possible thanks to new technologies capable of monitoring land degradation, deforestation, agriculture, land abandonment, and transformation of urban areas due to development. Cattle ranching, agriculture, and intensive crop rotation are important examples of dynamic activities that, may begin innocuously enough, but can intime provoke negative environmental impacts. Monitoring and managing these risks could be an important step toward containing and preventing wider damage.

Pervading this inventory is the finding that official government land use and land cover databases (IBGE for Brazil, IDEAM for Colombia, and MINAM for Peru) typically rely on outdated information, often available only with a two to four-year delay. The chronic data gap on annual deforestation rates means that alternative databases are indispensable. Encouragingly, private companies and civil society organizations are playing an essential role in generating faster, cheaper, and regularly updated information. This growing roster of independent groups includes MapBiomas in Brazil, Terra-i in Peru, and regional projects such as MAAP, RAISG, Mapbiomas Amazonas. Global entities like the University of Maryland's GLAD Initiative and World Resource Institute's Global Forest Watch also provide valuable information. Compared with Colombia and Peru, Brazil boasts the most advanced and complete information system to track deforestation and its driving factors (even if outdated at times). Here again, official data must be complemented by civil society groups, which in turn provide important alternative information systems.

In creating this inventory, the Igarape Institute identified multiple methodologies for different types of organizations involved in monitoring systems across the three countries analyzed. Government agencies, universities, and other civil society organizations obtain forest and vegetation cover data via remote sensing technologies, mainly from LANDSAT, while regional and global projects use space imagery. Yet, given the paucity of up-to-date data, several private sector companies, such as DigitalGlobe (Maxar), Planet and Sentinel have emerged to fill information gaps. They help provide critical information necessary to measure land cover, land-use change, while also generating timely reports and early warning systems of deforestation.

Agricultural activities vary widely across the region. In Brazil, soy production expanded as a response to the growing demand for feed in the cattle-raising industry and created pressure for deforestation of lands. In Colombia, forest conversion to agricultural land increased after 2016, especially in areas dedicated to palm oil. Debate in Peru has focused on the impact of small-scale cultivation by migrant farmers and subsistence producers versus that of large-scale mechanized agriculture. While a comprehensive tracing system of cattle and agricultural production is still not in place, detailed inventories of livestock are available in all three countries. Nevertheless, such information is routinely released after a considerable backlog, delaying timely analysis and impeding cross referencing with early warnings of deforestation and changes in land cover.

This paper offers a preliminary inventory of the databases available across the three countries and a rapid appraisal of their ability to measure the key economic activities driving changes in land cover and GHG emissions. Going forward, it would be helpful to understand the relationship between datasets and other phenomena including biodiversity loss and the carbon footprint associated with economic activity. Publicly available information could become an important back up in the absence of a comprehensive official tracing system for products that are bought and sold in supermarkets across the globe. The eventual goal is to ramp up traceability: the ability to track goods across the supply chain and monitor economic actors, their interconnections, and the wider footprint they leave on the environment.

Crucially, traceability can help elucidate the often murky relationship between beef exports and deforestation risks. The same methods used to track the delivery of packages to one's doorstep could be adapted to follow beef, dairy, and other goods from farm to market. The science and technology are sufficiently advanced to make this happen. What is missing are political will and a system of accountability. In the future, supply chain monitoring will become a priority, especially for consumers, international markets, and the financial sectors, all of whom are starting to recognize the importance of sustainable sourcing of food and beef exports from the Amazon region. Powerful tools for monitoring and tracing exist, including hyper-spectral imaging, which will soon become crucial in these areas. They can ensure more transparent supply chains and generate tangible and consequential improvements on the ground.

Annexes: Databases Information

Land cover by forest and forest change

Country	Database (original name)	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Monitoramento da Cobertura e Uso da Terra*	National statistical office: Brazilian Institute for Geography and Statistics (IBGE)	Scale of 1:1,000,000	2000, 2010, 2012, 2014, 2016, 2018. Outdated: 4 years delay	Shapefiles
Brazil	*Máscara de Floresta na Amazônia Legal*	Official agency: National Institute for Space Research (INPE)	Scale of 1:250,000	2016-2021. Updated annually	Shapefiles. Online platform
Brazil	MapBiomas	Collaborative network formed by NGOs, universities, and technology startups	Scale of 1:1,000,000	1985-2020. Updated annually	Shapefiles. Online platform
Colombia	*Sistema de Monitoreo de bosque y Carbono* (SMByC)	Official agency: Hydrology, Meteorology and Environmental Studies (IDEAM)	Scale of 1:1,000,000, 30 m resolution	1990, 2000, 2005, 2010, 2012, then annually. Latest update 2020. Outdated: 2 years delay	Shapefiles. Online platform
Colombia	SIAT-AC (Territorial Environmental Information System of the Colombian Amazon): land cover and forest loss	Official agency (regional): Amazonian Scientific Research Institute SINCHI	Colombian Amazon. Scale of 1:1,000,000	2002-2020. Outdated: 2 years delay	API and shapefiles. Online platform
Peru	*Programa Nacional de Conservación de Bosques para la Mitigación del Cambio Climático*	Official agency: Ministry of Environment (MINAM)	Resolution 30 m	2000-2020. Outdated: 2 years delay	Files in Excel, raster and vector (geographic information)
Peru	i-Terra Peru	Government and private consortium: Ministry of environment (MINAM) and International Center for Tropical Agriculture (CIAT)	Maps with resolution at 250 m	jan 2004-6 months of delay (updated)	Shapefiles

continuation

Country	Database (original name)	Organization	Geographical Availability	Time Coverage	Data Link
Global/ Regional	The Monitoring of the Andean Amazon Project (MAAP)	NGO: Amazon Conservation Association (ACA)	Uses GLAD database (3 mt resolution)	Near real time	Reports (no database available to download)
Global/ Regional	MapBiomas Amazonia - *Red Amazónica de Información Socioambiental Georreferenciada* (RAISG)	Consortium of civil society organizations from the Amazon countries	Amazon region. Maps with resolution 1:250,000	2018-2020. Updated annually	Shapefiles and API to download. Online platform
Global/ Regional	The Global Land Analysis and Discovery (GLAD)	Department of Geographical Sciences at the University of Maryland	Global. Maps with 30 meter resolution	2000-2019. Outdated: 2 years delay	Maps to download, Excel with stats. Online platform
Global/ Regional	Global Forest Watch	The Sustainability Consortium and the World Resources Institute (WRI)	Global. Maps with 30 meter resolution	near real time	Visualization dashboard, no database to download

Early Warning Systems for Deforestation databases

Country	Database (original name)	Organization	Geographical availability	Time coverage	Link information to download
Brazil	*Sistema de Detecção do Desmatamento na Amazônia Legal em Tempo Real* (DETER)	Official agency: National Institute for Space Research (INPE)	Brazilian Amazon. For the general public, the polygons are made available with a minimum size of 6.25 ha	2004-present. Publication periodicity: each 2 months	Shapefiles
Colombia	*Alertas tempranas de Deforestación* (AT-D)	Official agency: Hydrology, Meteorology and Environmental Studies (IDEAM)	Hotspots of deforestation. Scale of 1:1,000,000, 30 m resolution	2016-latest april 2021. Publication periodicity: Weekly. currently the page is offline (march 2022)	Shapefiles (offline by September 2022)
Peru	*Alertas tempranas de Deforestación* (AT-D)	Official agency: Ministry of Environment (MINAM)	Pixel level. Resolution 30 m	2016-present. Publication periodicity: each 2 weeks	Shapefiles. Online platform

Land use and land registry databases

Country	Source	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Monitoramento da Cobertura e Uso da Terra*	National statistical office: Brazilian Institute for Geography and Statistics (IBGE)	Scale of 1:1,000,000	2000, 2010, 2012, 2014, 2016, 2018. Outdated: 4 years delay	Shapefiles
Brazil	MapBiomas	Collaborative network formed by NGOs, universities, and technology startups	Pixel level	1985-2020. Updated annually	Shapefiles
Brazil	TerraClass	Consortium of official agencies: Brazilian Agricultural Research Corporation (EMBRAPA) and the The National Institute for Space Research (INPE)	Municipalities, Natural areas	2004, 2008, 2010, 2012, 2014. Outdated: 8 years delay	Shapefiles. Online platform
Colombia	*Proporción de la superficie cubierta por diferentes tipos de coberturas*	Official agency: IDEAM (Forest and Carbon Monitoring System [SMByC])	National. No availability of disaggregated units	2000-2012. Outdated: 10 years delay	Excel. No availability of georeferenced data
Colombia	Landsat-derived Annual Land Cover Maps for the Colombian Amazon (CMS)	Oak Ridge National Laboratory Distributed Active Archive Center (NASA / ORNL DAAC)	Colombian Amazon - Spatial Resolution: 30 m	2001-2016. Outdated: 6 years delay	Shapefiles
Colombia	SIAT-AC (Territorial Environmental Information System of the Colombian Amazon): agricultural landscape	Official agency (regional): Amazonian Scientific Research Institute SINCHI	Colombian Amazon. Scale of 1:1,000,000	2002-2020. Outdated: 2 years delay	API and shapefiles. Online platform
Peru	*Uso y cambio de uso de la tierra*	Official agency: Programa Nacional de Conservación de Bosques para la Mitigación del Cambio Climático (MINAM)	States, provinces and districts	1995-2016. Outdated: 6 years delay	Shapefiles
Brazil	*Cadastro Ambiental Rural*	Official agency: National System of Environmental Information (SINIMA)	Rural properties	2021. updated (next update in 5 years)	Excel and Shapefiles. Online platform
Colombia	*Catastro Multipropósito*	Official agency: Agustín Codazzi Geographic Institute	Rural properties	2021	Shapefiles

continuation

Country	Source	Organization	Geographical Availability	Time Coverage	Data Link
Colombia	Classification of land for their vocation for use	Official agency: Agustín Codazzi Geographic Institute	Scale 1:100.000	2017	Shapefiles
Colombia	Land conflicts by use	Official agency: Agustín Codazzi Geographic Institute	Scale 1:100.000	2017	Shapefiles
Peru	*Catastro rural*	General Director of Sanitation of Agricultural Property and Rural Register (MINAGRI – DIGESPACR)	Map	N/A	Shapefiles. Online platform

Land use change

Country	Source	Organization	Geographical availability	Time coverage	Datalink
Brazil	*Degradação de pastagens na Amazônia Ocidental Brasileira*	Official agency: Brazilian Agricultural Research Corporation (EMBRAPA)	Municipalities	2012	Shapefile
Colombia	*Proporción del área de suelos degradados por erosión y salinización*	Official agency: Hydrology, Meteorology and Environmental Studies (IDEAM)	States	2020-2011	Excel
Colombia	SIAT-AC (Territorial Environmental Information System of the Colombian Amazon): forest degradation	Official agency (regional): Amazonian Scientific Research Institute SINCHI	Colombian Amazon. Scale of 1:1,000,000	2002-2020. Outdated: 2 years delay	API and shapefiles. Online platform
Peru	*Estudio e identificación de áreas degradadas*	Official agency: Ministry of Environment (MINAM)	States	2015-2020	Excel

Greenhouse Gas (GHG) Emission databases

Country	Database (original name)	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Estimativas Anuais de Emissões de Gases de Efeito Estufa*	Official agency: Ministry of Science, Technology and Innovation (MCTI)	Country and states	1990-2020 (latest released in 2022)	Excel and reports
Brazil	*Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa* (SEEG)	Observatório do Clima	Country, states, municipalities	1990-2020 (released 2021)	Excel
Colombia	*Emisiones Netas Nacionales de Gases de Efecto Invernadero* (GEI) UNFCCC Biennial Update Report 3 (BUR3)	Official agency: Hydrology, Meteorology and Environmental Studies (IDEAM)	Country and states	1990-2018	PDF report with tables
Peru	National Inventory of Greenhouse Gases (INFOCARBONO)	Official agency: Ministry of Environment (MINAM)	National	2016, 2014, 2012, 2010, 2005 Y 2000	Excel and reports
International	Global Carbon Atlas	The Global Carbon Project (GCP)	Global, by countries	1960-2000	Online platform
International	Climate Watch	World Resources Institute (WRI)	Global, by countries	1990-2019	Online platform

Livestock inventories and subproducts databases

Country	Database (original name)	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Pesquisa da Pecuária Municipal* (PPM)	National statistical office: Brazilian Institute for Geography and Statistics (IBGE)	Municipalities	1973-2020. Updated annually	Excel and ODS files
Brazil	*Serviço Brasileiro de Rastreabilidade da Cadeia Produtiva de Bovinos e Bubalinos* (SISBOV)	Official agency: Ministry of Agriculture, Livestock and Food Supply (MALFS)	Rural properties	2021. Official request required	PDF list
Colombia	*Censo Pecuario*	Official agency: Colombian Agricultural Institute (ICA)	Municipalities	2018-2022. Updated annually	Excel
Colombia	*Inventario bovino*	Federation of Cattle Ranchers (FEDEGAN)	Municipalities	2016-2021. Updated annually	Excel
Brazil	*Pesquisa Trimestral do Abate de Animais*	National statistical office: Brazilian Institute for Geography and Statistics (IBGE)	States	2017-updated quarterly	Microdata

Census and surveys

Country	Database (original name)	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Censo Agropecuario*	National statistical office: Brazilian Institute for Geography and Statistics (IBGE)	Rural properties	2017. Every 5 years, next in 2022	Microdata. Online platform
Colombia	II *Censo Nacional Agropecuario* (CNA)	National statistical office: National Administrative Department of Statistics (DANE)	Rural properties and municipalities	2014. No date of future version	Microdata
Peru	IV *Censo Nacional Agropecuario* (CENAGRO)	National statistical office: National Institute of Statistics and Informatics (INEI)	Rural properties and municipalities	2012. Next expected in 2022	Microdata
Colombia	*Encuesta nacional agropecuaria* (ENA)	National statistical office: National Administrative Department of Statistics (DANE)	Rural properties and municipalities	2012-2019. Updated annually	Microdata. Online platform
Peru	*Encuesta nacional agropecuaria* (ENA)	National statistical office: National Institute of Statistics and Informatics (INEI)	Rural properties and municipalities	2014-2019. Updated annually	Microdata

Agriculture databases

Country	Database (original name)	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Levantamento Sistemático da Produção Agrícola* (LSPA)	National statistical office: Brazilian Institute for Geography and Statistics (IBGE)	Municipalities	2006- monthly updated	Microdata
Brazil	*Portal de Informações Agropecuárias*	Official agency: Companhia Nacional de Abastecimento (CONAB)	States	2020-2022	Online tool with data to download
Colombia	AGRONET	Official agency: Ministry of Agriculture and Development	Municipalities	2017-2020	Online tool with data to download
Colombia	*Datos sobre palma de aceite*	Federation of growers: National Palm Oil Growers Federation (FEDEPALMA)	Municipalities	2000-2022	Online tool with data to download
Colombia	*Datos sobre cereales y leguminosas*	Federation of growers: National Federation of Cereal and Legume Producers (FENALSE)	States	2018-2022	Power BI
Peru	*Sistema Integrado de Estadística Agraria* (SIEA)	Official agency: Ministry of Agricultural Development and Irrigation (MIDAGRI)	States	Latest dec 2021	PDF reports and excel tables. Power BI

Agricultural frontier databases

Country	Source	Organization	Geographical Availability	Time Coverage	Data Link
Brazil	*Fronteira Agrícola – Amazônia Legal*	National statistical office: Brazilian Institute for Geography and Statistics – IBGE	Municipalities	Based in 2003 data	Shapefile and maps in PDF
Colombia	*Frontera Agrícola* -	Official agency: Colombian Unit of Rural Agricultural Planning – UPRA	Scale 1:100.000	2019	Shapefile. Online platform
Peru	*Mapa Nacional de Superficie Agrícola del Perú*	Official agency: Ministry of Agricultural Development and Irrigation – MIDAGRI	Scale 1:100.000	2020	Shapefile

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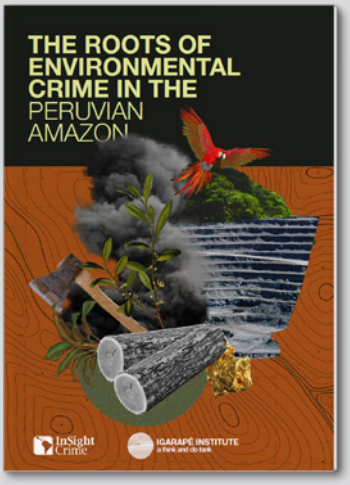

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