**Application Form**

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*Executive Summary*

We are currently in the 6th extinction wave, loosing approximately about 1000 times more species per year than at the end of the era of the dinosaurs. At the same time, mankind still grows unabatedly in numbers and due to advances in economic development consumes more and more resources.

Still, the management and counter measures to these truly global problems are anchored at the national level, while many countries, specifically many emerging countries do not command the structures or information to implement and monitor effective resource management programs. Among other needs, a monitoring framework producing a set of indicators making possible the regular assessment of modern resource management practices is urgently needed to track national commitments to global efforts, such as the Paris Agreement and the United Nations Sustainable Development Goals. For example in Mexico, the National Commission for the Knowledge and Use of Biodiversity (CONABIO) and the National Institute of Statistics and Geography (INEGI) have committed to further the technologies needed and to implement them in an official government approved scheme in order to provide much more accurate, hi-resolution and relevant information to law makers and decision makers. One urgent need is to develop an indicator which effectively assesses the condition of the ecosystems in order to be able to prioritize land use in the country. In GEO, the Earth Observations for Ecosystem Accounting (EO4EA) initiative seeks to understand and enhance the use of Earth Observations for the development of Ecosystem Accounts based upon and consistent with the UN System of Environmental Accounts – Experimental Ecosystem Accounts. The Initiative also responds to the Mandate of the GEO Mexico City Declaration of 2015. Additionally, the Earth Observations in Service of the 2030 Agenda for Sustainable Development (EO4SDG) initiative enables contributions to the 2030 Agenda by GEO and the Earth observations community. The primary purpose of this Initiative is to organize and realize the potential of Earth observations and geospatial information to advance the 2030 Agenda and enable societal benefits through achievement of the SDGs. This Initiative supports efforts to integrate Earth observations and geospatial information into national development and monitoring frameworks for the SDGs. (2017-2019 GEO Work Programme)

Colombia and Mexico, two megadiverse countries in America, have a long history of systematically advancing biodiversity data acquisition, management and analysis using cutting edge technology. They share recent advances in the monitoring of species by means of the deployment of in-situ sensors, like camera traps and autonomous recording units (ARUs). For example, NAIRA (Castelblanco et al. 2016) is a software tool developed in Colombia for the management and analysis of camera trap images. CONABIO recently funded a project aimed at producing the largest insectivorous neotropical bat call library in the world. At CONABIO, additional sound reference libraries are currently being amassed, among others also amphibian and anthropogenic sounds. Since 2014, the Mexican National Biodiversity and Ecosystem Degradation Monitoring System (SNMB, García-Alaniz et al. 2017) has been operational. It is an interinstitutional program for large scale in-situ biodiversity related data sampling of México. In collaboration with institutions from Mexico and abroad, CONABIO has been developing since 2011 the MAD-Mex (monitoring activity data for the Mexican REDD+ program, Gebhardt et al. 2014) system to provide standardized annual wall-to-wall land cover and land cover change information by automated optical satellite image classification (https://github.com/CONABIO/antares3/tree/develop). MADMEX uses INEGI's official standard land cover classes and INEGI produced training data for model fitting and validation (INEGI, National Institute of Statistics and Geographics, https://www.inegi.org.mx/programas/ce/2019/). Land cover change is one of the most immediate consequences of humanity's transformation the Earth's ecosystems and landscapes. To understand the impact and extent of global land cover change, we need data from EO satellites, the only source that provides a continuous and consistent set of information of the Earth (Câmara, G. et al, 2016).

The funding through Amazon and GEO we seek will be used in various ways. Machine learning models have made important advances in fields such as object recognition in sounds and images (Mac Aodha et al. 2018 and Yousif et al. 2019). This will allow the processing of huge biodiversity data streams coming from the field in Mexico and Colombia alike. AWS will also be used for land cover and land cover change mapping (https://conabio.github.io/antares3/, https://conabio.github.io/antares3/deployment/aws_cloud.html). We will produce cartography including new classes of land use (agricultural) and land cover with the MAD-Mex system. Specifically, the consistent production of high-resolution land cover change information will help increase the sensitivity of our indicator (EI) to the changes occurring on the ground.

All this new information will be used to enhance EI models in order to build a truly integral biodiversity indicator. Information based on these indicators will be made accessible to governmental and local stakeholders by means of reports and dashboards. As a final note, EI modelling is a much computationally less-intensive task as the resulting cartography is of a coarse resolution (currently 1000m and 250m). AWS processing is not necessarily needed for this. The EI index has been calculated on premise at both Conabio and Humboldt institute.

**Expected impact & regional strategy**

Institutionally, Mexico benefits from the integration of statistics and geography in a single institution (INEGI); this allows to have a leading role in matters that involve linking both areas. For example, INEGI's experience in the production of the Geostatistical Framework, as a basis for georeferencing of Censuses and Surveys, has led it to continuously advise and train various national and international entities.

Regionally, the closeness and sense of identity shared with Latin America and the Caribbean breeds greater interaction, which translates into concrete collaborative actions. In addition, INEGI holds the Presidency of UN-GGIM: Americas, which seeks to determine relevant regional issues for the management of GI, and to maximize the benefits derived from its use; favoring so, the establishment of SDI and other initiatives in the region.

Besides the afore-mentioned institutional settings, and integrative tools designed to fulfil national priorities, Mexico has undertaken a State-wide effort for the monitoring and fulfilment of the SDG, through a National Council for the 2030 Agenda. Take, for example, the collaboration of Mexico on the implementation of the SEEA-EEA; in this regard, Mexico fosters the integration of Ecosystem Accounting and EO as relevant inputs for the monitoring and implementation of the SDGs.

Finally, since GEO acts as a broad communication and engagement platform with a well stablished global coverage (100+ countries); and thanks to the regional influence from Mexico in GI, the local impact of this project is easily translatable to the wider community.

**Project plan**

We are currently in the 6th extinction wave, loosing approximately about 1000 times more species per year than at the end of the era of the dinosaurs. At the same time, mankind still grows unabatedly in numbers and due to advances in economic development consumes more and more resources.

This crisis needs to be urgently addressed by reducing drastically the rate of biodiversity loss (Convention on Biological Diversity, 2010). A monitoring framework producing a set of indicators making possible the regular assessment of modern resource management practices is urgently needed to track national commitments to global efforts, such as the Paris Agreement and the United Nations Sustainable Development Goals. Yet, still the management and counter measures to these truly global problems are anchored at the national level, while many countries, specifically many emerging countries do not command the structures or information to implement and monitor effective resource management programs.

International agreements and treaties are looking to address this over consumption and many countries have signed these agreements and committed to a much more efficient use of their resources. One example of resource waste is meat production and the vast amount of resources we do dedicate to its production. Specifically, tropical countries such as Brazil but also Mexico cling to meat production methods which are neither competitive nor adapted to the tropical ecosystems they are embedded in.

Mexico has been trying to address the wasteful practices in its agricultural system in a ground breaking agreement, molded into law at the end of 2018. The new law for sustainable forest management demands that agricultural subsidies must not incentive land cover change. Thus, the law aims to address the problem of ever more forest clearing for cattle ranching specifically in the tropical parts of the country. Mexico has also participated in the Bonn challenge and committed to restore about 8.5 million hectares of its degraded agriculture land. And the new administration has launched a massive poverty reduction program which aims to help small scale farmers boost their income by switching to modern and more adapted food production systems (program “sembrando vida”). Thus, Mexico sports quite modern legislation, in theory able to address the massive resource waste which occurs in the country, yet it does not feature monitoring programs based on remote sensing and in situ data to monitor the effects of its legislation and enforce resource management techniques.

GEOGLAM, the GEO Global Agricultural Monitoring initiative, was initially launched by the Group of Twenty (G20) Agriculture Ministers in June 2011, in Paris. The initiative forms part of the G20 Action Plan on Food Price Volatility, which also includes the Agricultural Market Information System (AMIS, http://www.amis-outlook.org), another inter-institutional initiative with a Secretariat hosted by the UN Food and Agriculture Organization (FAO). The G20 Ministerial Declaration states that GEOGLAM “will strengthen global agricultural monitoring by improving the use of remote sensing tools for crop production projections and weather forecasting”. The main objective of GEOGLAM is to reinforce the international community’s capacity to produce and disseminate relevant, timely and accurate projections of agricultural production at national, regional and global scales by using Earth Observation data. This will be achieved by: (1) establishing a sustained international network of agricultural monitoring and research organizations and practitioners; (2) harmonizing the operational global agricultural monitoring systems based on both satellite and in-situ observations, including through improved coordination of satellite observations. (3) enhancing national agricultural reporting systems.

The Global Forest Observation Initiative (GFOI) seeks to promote forest monitoring and assessment techniques which are robust, consistent, and cost effective to support planning for national development priorities including, climate change mitigation and adaptation. The GFOI aims to: 1. Foster the sustained availability of observations for national forest monitoring systems; 2. Support governments that are establishing national systems by providing a platform for coordinating observations, providing assistance and guidance on utilizing observations, developing accepted methods and protocols, and promoting ongoing research and development; 3. Work with national governments that report into international forest assessments such as the national greenhouse gas inventories reported to the UN Framework Convention on Climate Change (UNFCCC) using methods of the Intergovernmental Panel on Climate Change (IPCC).

The fundamental objective of GFOI is to assist REDD+ (Reducing Emissions from Deforestation and forest Degradation, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks) as well as to enable developing countries to develop sovereign technical, human and institutional capacity to monitor their own forests and account for their own GHG emissions. The intention is that countries will then use this capacity to generate their own robust information to inform more reliable decision making and policy development on the appropriate management of their forests and potentially provide confidence for REDD+ activities. The work of GFOI is undertaken by five components: Methods & Guidance, Space Data Acquisition, Capacity Building, Research and Development (R&D) Coordination, and Administration and Coordination (GFOI Office) (2017-2019 GEO Work Programme).

Since 2011, CONABIO and INEGI have been building systems to modernize the regular, high resolution land cover and land cover change monitoring programs existing in the country at the behest of the ministries of agriculture and the environment (SADAR and SEMARNAT). Mexico features the new MADMEX remote sensing processing framework (Gebhardt et al. 2015) which enables the rapid production of hi-resolution maps. These maps constitute the basis for monitoring tools which aim at subsidy control to avoid land cover change and to suppress effectively deforestation in the country. The new SINACICC platform (Sistema Nacional para la consulta de incentivos concurrentes), boasts spatially explicit information on land cover, Ecosystem Integrity (EI), protected areas, ecosystem services payment schemes and agricultural information which enables the ministries to handle the programs for production incentives efficiently by approving applications based on up-to-date information or, in case programs would incentive land cover change, to propose alternative incentive schemes for land tenants and local populations.

Yet, much more advances are needed to finally come to an efficient resource use in Mexico. CONABIO and INEGI have committed to drive further the technologies needed and to implement them in an official government approved scheme in order to provide much more accurate, hi-resolution and relevant information to law makers and decision makers. One urgent need is to develop an indicator which effectively assesses the condition of the ecosystems in order to be able to prioritize land use in the country. The Earth Observations for Ecosystem Accounting (EO4EA) initiative seeks to understand and enhance the use of Earth Observations for the development of Ecosystem Accounts based upon and consistent with the UN System of Environmental Accounts – Experimental Ecosystem Accounts.  The Initiative also responds to the Mandate of the GEO Mexico City Declaration of 2015.

We propose as an indicator Ecosystem Integrity (EI), currently conceptualized and measured in a variety of ways. Most of the EI measurements at landscape scales are based on land cover change, narrowing its interpretability to characterize ecological species interactions, which is a key role on ecosystem functions (de Bello et al. 2010). This can be a disadvantage because deforestation rates and land use change driven by human activities and not by natural variability are increasing with a “great acceleration” from mid 20 century (Steffen et al 2015). Habitat degradation and habitat loss are the main threats for animals not only because they find their food and protection in preserved vegetation, but also the accessibility by roads let access to poaching and human impact practices (Galetti & Dirzo, 2013). Such animal declines will cascade onto ecosystem functioning and human well-being, *Defaunation* is a major driver of global ecological change (Dirzo et al 2014) particularly in tropical ecosystems where a great mount of species on the Earth live. In particular, key species loss will have long-term consequences in the prevalence of the ecosystems (Hooper et al., 2012).

Biodiversity conservation strategies require a reasonable amount of knowledge about the current environmental changes and trends where high-resolution and temporally updatable based on direct observations has limited our understanding of this connection and its effective use. Recently a great amount of satellite information is available, which can help not only to describe the current environmental information where the species have been recorded in the field but also using time series help to associate management decisions over the positive or negative changes. Therefore, it is necessary to develop data acquisition programs and data management and analysis systems that incorporate both land cover and fauna monitoring.

Colombia and Mexico, two megadiverse countries in America, have a long history of systematic approaches to biodiversity data acquisition, management and analysis. They share recent advances in the monitoring of species by means of the deployment of in-situ sensors, like camera traps and autonomous recording units (ARUs). For example, NAIRA (Castelblanco et al. 2016) is a software tool developed in Colombia for the management and analysis of camera trap images. CONABIO (Mexican National Commission for knowledge and use of biodiversity) recently funded a project aimed at producing the largest insectivorous neotropical bat call library in the world. Presented at the National Society for Bat Research Conference (NASBR), the library currently 2,302 echolocation calls from 1,604 individuals belonging to 7 families and 67 species, representing 63.3% of the insectivorous bat species of Mexico (MacSwiney et al. 2018). At CONABIO, additional sound reference libraries are currently being put together: amphibians and anthropogenic sounds (gun shots, vehicles, chainsaws, human interaction, domestic animals and so on). All designed and prepared for immediate supervised learning experiments for automated detection and classification of biodiversity related signals in sound recordings. One such experiment is already operational at CONABIO in which deep learning is used to detect and classify bat calls at species, family and guild levels (Robredo et al. 2018 and Martínez-Balvanera et al. 2018). In Colombia at Humboldt institute, a web platform has been developed to integrate expert knowledge in species distribution mapping http://biomodelos.humboldt.org.co/ and workflows for taxonomic and geographic verification of species records and species distribution models (BioModelos, https://github.com/LBAB-Humboldt). Since 2014, the Mexican National Biodiversity and Ecosystem Degradation Monitoring System (SNMB, García-Alaniz et al. 2017) has been operational. It is an interinstitutional program for large scale in-situ biodiversity related data sampling of México. It aims to complement existing programs and biodiversity data bases. Most of these, although valuable, are plagued by deep spatial and temporary biases which make it difficult to perform the necessary data analysis to track ecosystem dynamics. CONABIO, intertwined with two other institutions, the National Forestry and National Protected Areas Commissions, devised an interinstitutional effort in which a standardized sampling scheme is applied to more than 2800 localities around the country representing all major ecosystems. This sampling includes manual efforts (like taking pictures of tracks, feces and animals) as well as the deployment camera traps and ARUs.

In collaboration within institutions from Mexico and abroad, CONABIO has been developing the MAD-Mex (monitoring activity data for the Mexican REDD+ program, Gebhardt et al. 2014) system since 2011 to provide standardized annual wall-to-wall land cover and land cover change information by automatic satellite image classification of the Mexican territory, reaching a resolution of up to 5 meters (https://github.com/CONABIO/antares3/tree/develop) with training data for model fitting and validation from INEGI (National Institute of Statistics and Geographics, https://www.inegi.org.mx/programas/ce/2019/) .

Monitoring the vegetation and fauna of countries the size of Mexico and Colombia represents a challenge for both machine learning and computing infrastructure. As mentioned, EI assessment is currently measured at landscape scales based on land cover change, in (García-Alaniz et al. 2017, supplementary material) a framework based on Bayesian Networks to fuse land cover information with in situ forest structure data to assess ecosystem health was proposed. We are now aiming to incorporate georeferenced animal data from diverse biodiversity databases to have integral snapshots of ecosystem condition through time for both countries.

Funding for AWS will be used in these ways:

AWS will be used for land cover and land cover change mapping (https://conabio.github.io/antares3/, https://conabio.github.io/antares3/deployment/aws_cloud.html). We will produce cartography including new classes of land use (agricultural) and land cover with MAD-Mex system. In the area of INEGI that focuses on agriculture statistics, research has been done for identifying the coverage of specific crops in satellite images. Results of these practices are: (1) a field verified database, (2) its application for classifying larger areas, and (3) the starting development of an area sampling frame based on satellite images and field data. Further work and planning of research initiatives met the conclusions that the Open Data Cube and the use of Sentinel-2 data offer a variety of advantages in agriculture related products, which are summarized in the annex table -1-.

Machine learning models have made important advances in fields such as object recognition in sounds and images (Mac Aodha et al. 2018 and Yousif et al. 2019) which will allow the processing of huge biodiversity data streams coming from the field in Mexico and Colombia alike. Currently, in Mexico, over one million ultrasonic recordings are produced every year. We aim to train and deploy deep learning models on cloud computing infrastructure to detect and classify bat species in ultrasonic recordings captured by ARUs from the SNMB and other large-scale monitoring programs. This will feed existing animal occurrence data bases which are prone to heavy spatial and temporary biases. We will also detect and classify anthropogenic sounds in audible recordings as it has been shown to be a better approach to quantifying anthropogenic activity in soundscapes (Fairbrass et al. 2018) than acoustic indices proposed before (Pijanowski et al. 2011).

All this new information will be used to enhance EI models in order to build a truly integral biodiversity indicator (not necessarily run on AWS). Information based on these indicators will be made accessible to governmental and local stakeholders by means of reports and dashboards, for example this site holds information of interest to personnel at the CONANP (Mexico): https://monitoreo.conabio.gob.mx/ sections "Mapas/Geoportal Áreas

Protegidas” and “Indicadores/Áreas Naturales Protegidas”. We propose the development of a novel mobile-ready web app (React-2-EO) which will be housed on AWS. The main feature is a national visualizer that allows the user to explore the surface of Mexico; its content consists of time-series of periodic cloud-free mosaics, and vegetation classifications, both generated using EO satellite data and Open Data Cube (ODC). User interaction will be based on an API with methods for extracting spatial and temporal slices, as well as generating animations, and tracking feedbacks.

| | 1.- MAD-Mex system | 2.- Deep learning for bioacoustics data processing | 3.- React-2-EO Web App |
|---|---|---|---|
| **Objective** | Produce land cover and land cover change maps | Train accurate deep neural networks for detection and classification of bat calls and anthropogenic signals in sound recordings | To make delivering a message based on EO time-series products easy, by providing an approachable tool that generates animations |
| **Description** | MAD-Mex system will use Landsat and Sentinel 2 data between 1996 and 2018 for producing land cover and land cover change for Mexico and Colombia. 31 and 17 classes for the case of Mexico and 17 classes for the case of Colombia have been agreed. There will be new classes of land use (agricultural) for Mexico. | Between Mexico and Colombia, over a million ultrasonic and tens of thousands of audible bioacoustics recordings (soundscapes) are produced every year. It’s intractable to convert this data into biodiversity information without automated processing. Lack of modern hardware has stunted efforts to produce accurate classifiers for bioacoustics processing. On AWS top tier GPUS are always readily available. Pipelines for automated sound processing developed and executed in-house at Conabio will be deployed on AWS. | Software platform that allows (1) to explore the territorial surface of Mexico and see how it has changed in the last 3 decades, (2) to then, generate animations of the change of the surface of a region of the country for a certain time, (3) to provide an emotional reaction towards the animation and, finally, (4) to also observe geolocated statistics of others’ reactions |
| **Deliverables** | -Next generation cartographic products for Mexico and Colombia (land cover maps and land cover change maps)<br>-Technical documentation | -State of the art bat call classifiers (with an unprecedented number of target classes-neotropical bat species)<br>-State of the art anthropogenic signal detectors and classifiers<br>-Technical documentation and trained models available on github | -Backend: servers responding to requests<br>-Frontend: UIX<br>-API<br>(designs and implementation)<br>-Technical documentation |

Note that in order to reach these set goals we also wish to use Sentinel-Hub services for the areas to be analyzed (the whole Sentinel-2 historic archive over national mexican and colombian territory).

**1.- MAD-Mex system**

Since 2018, MAD-Mex system has successfully been deployed in a scalable way in the AWS cloud using kubernetes (https://kubernetes.io/) and the Australian Open Data Cube (ODC) (https://datacube-core.readthedocs.io/en/latest/ ) among other python packages to process geospatial imagery and machine learning algorithms (https://conabio.github.io/antares3/deployment/aws_cloud.html).

To scale the kubernetes cluster we are using kops in combination with tools in AWS like:

- Amazon Route 53 for hosting domain: conabio-route53.net
- Amazon Relational Database System: engine: Aurora database. Specifically, we are using postgreSQL functionality with postGIS extension.
- Amazon Elastic File System: for sharing files between instances of docker containers and store some results of processes of the system
- Amazon S3: to store different levels of satellite data products and processing results

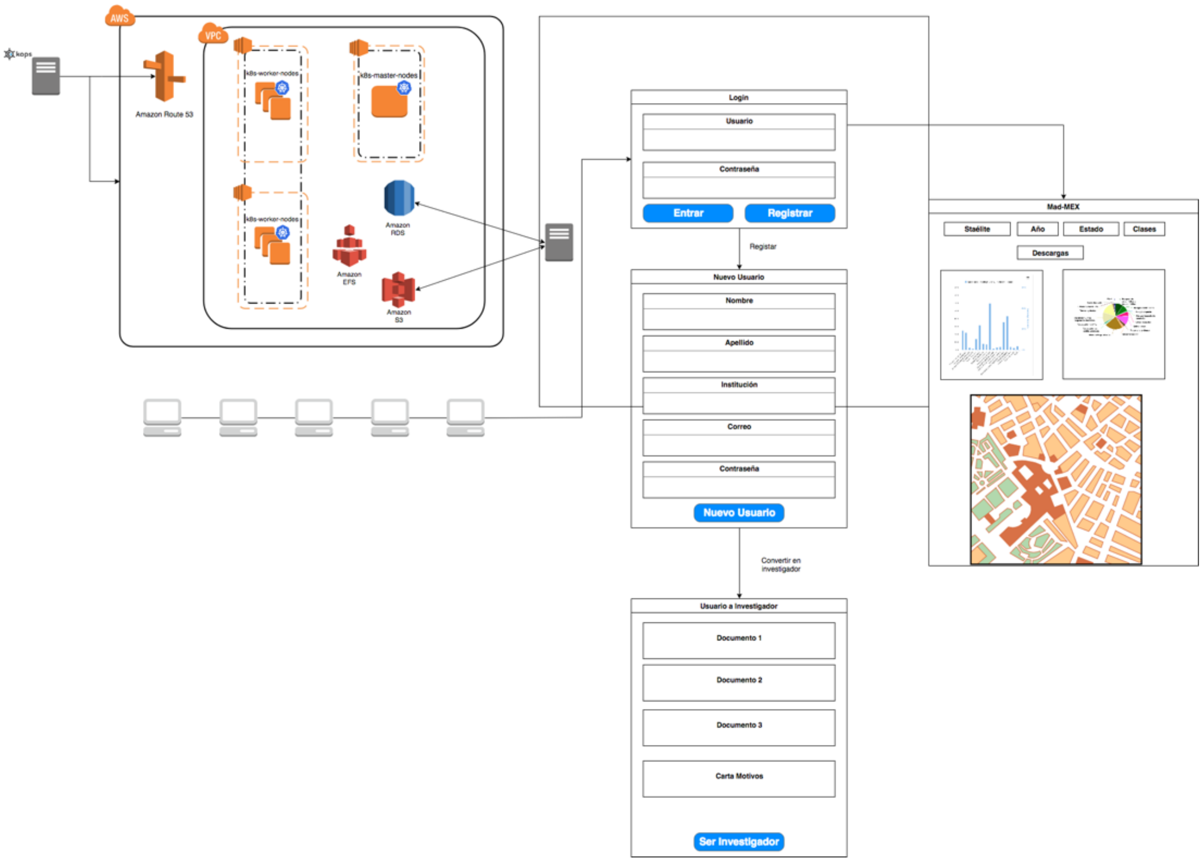



Figure 1. A diagram of the infrastructure/Web API

With this grant we will be capable to produce next generation cartographic products for both countries: Mexico and Colombia using MAD-Mex and also test the functionality of the system using Amazon FSx for Lustre to store data and share files beween EC-2 instances instead of Amazon Elastic File System.

Cartographic products:

**Land cover maps**

Tab 1: List of land cover maps for Landsat data (30 m resolution).

**Mexico**

| Year | Input years |
|---|---|
| 2018 | 2017-2018 |
| 2015 | 2014-2015 |
| 2011 | 2010-2011 |
| 2008 | 2007-2008 |
| 2005 | 2004-2005 |
| 2002 | 2001-2002 |
| 1999 | 1998-1999 |

| | |
|---|---|
| 1996 | 1995-1996 |

**Colombia**

| Year | Input years |
|---|---|
| 2018 | 2015-2018 |
| 2013 | 2010-2013 |
| 2008 | 2005-2008 |
| 2004 | 2001-2004 |
| 2000 | 1997-2000 |

Tab 2: List of land cover maps for Sentinel-2 data (10 m resolution) both for Mexico and Colombia

| Year |
|---|
| 2019 |
| 2018 |
| 2017 |
| 2016 |

**Land cover change maps**

Tab 1: List of land cover change maps for Landsat data

**Mexico**

| Change interval |
|---|
| 2014-2017 |
| 2011-2014 |
| 2008-2011 |
| 2005-2008 |
| 2002-2005 |
| 1999-2002 |
| 1996-1999 |

**Colombia**

| Change interval |
|---|
| 2013-2018 |
| 2008-2013 |
| 2008-2011 |
| 2004-2008 |
| 2000-2004 |

Tab 2: List of land cover change maps for Sentinel-2 data both for Mexico and Colombia

| Change interval |
|---|
| 2017-2019 |
| 2016-2018 |

We will perform tests of our workflows of classification and change detection already developed for processing satellite images using AWS EMR service to deploy a scalable cluster with Spark and test functionality in AWS Athena and AWS lambda.

**Implementation of MAD-Mex system**

Technical documentation of MAD-Mex system can be found at: https://conabio.github.io/antares3/

**AWS credits for MAD-Mex system**

In order to generate the land cover maps and land cover change maps for Mexico and Colombia we estimate $44,000 AWS credits approximately:

| Product | Cost (AWS credits) |
|---|---|
| Land cover annual product | $2000 |
| Land cover change product | $1000 |
| TOTAL | $3000 |

| Land cover annual product (both Mexico & Colombia) | Cost (AWS credits) |
|---|---|
| Landsat: 2002, 2005, 2008, 2011, 2015, 2018 (Mexico) | $12,000 = ($2000 per annual land cover product) |
| Landsat: 2004, 2008, 2013, 2018 (Colombia) | $8,000 = ($2000 per annual land cover product) |
| Sentinel2: 2016, 2019 (Mexico) | $4,000 = ($2000 per annual land cover product) |
| Sentinel2: 2016, 2019(Colombia) | $4,000 = ($2000 per annual land cover product) |
| TOTAL | $28, 000 |

| Land cover change bi-annual product (both Mexico & Colombia) | Cost (AWS credits) |
|---|---|

| | |
|---|---|
| Landsat: 1996-1999, 1999-2002, 2002-2005, 2005-2008, 2008-2011, 2011-2014, 2014-2017(Mexico) | $7000 = ($1000 per land cover change bi-annual product) |
| Landsat: 2000-2004, 2004-2008, 2008-2011, 2008-2013, 2013-2018 (Colombia) | $5000 = ($1000 per land cover change bi-annual product) |
| Sentinel2: 2016-2018, 2017-2019 | $2000 = ($1000 per land cover change bi-annual product) |
| Sentinel2: 2016-2018, 2017-2019 | $2000 = ($1000 per land cover change bi-annual product |
| TOTAL | $16,000 |

| Products | Cost(AWS credits) |
|---|---|
| Land cover maps for both Mexico & Colombia | $28,000 |
| Land cover change for both Mexico & Colombia | $16,000 |
| TOTAL | $44,000 |

| Products | Delivery date |
|---|---|
| Land cover years for both Mexico & Colombia | First year of AWS grant |
| Land cover change for both Mexico & Colombia | Second year of AWS grant |

**2.- Deep learning for bioacoustics data processing**

General pipelines for deep learning base detection and classification of signals have already being developed at CONABIO since 2015. The general workflow for machine learning based object recognition tasks is shown in Figure 2.

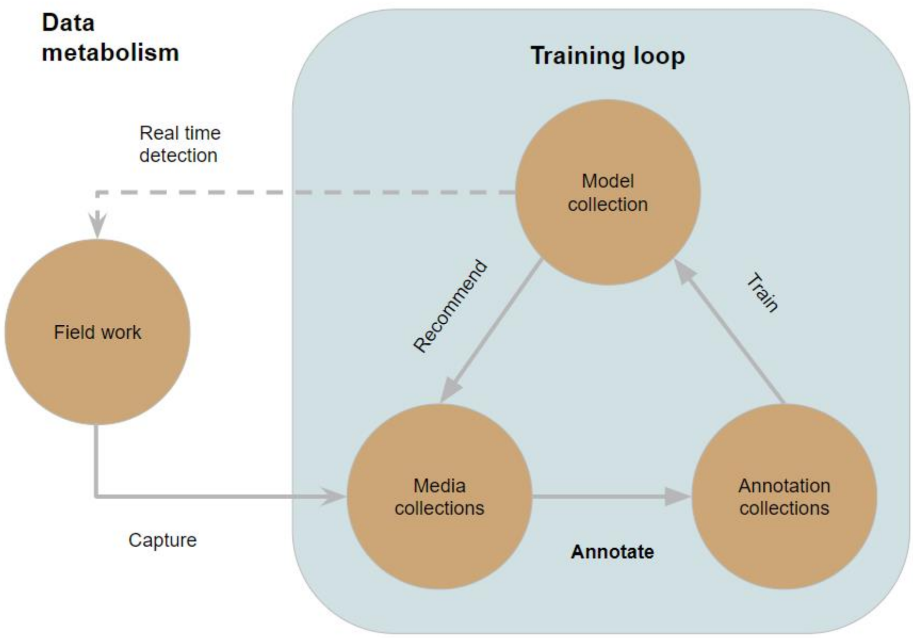



Figure 2. Data metabolism: general workflow for object recognition tasks.

The architecture behind this workflow has only been implemented locally at CONABIO on its High-Performance Computing (HPC) cluster. Its characteristics can be seen in Figure 3.

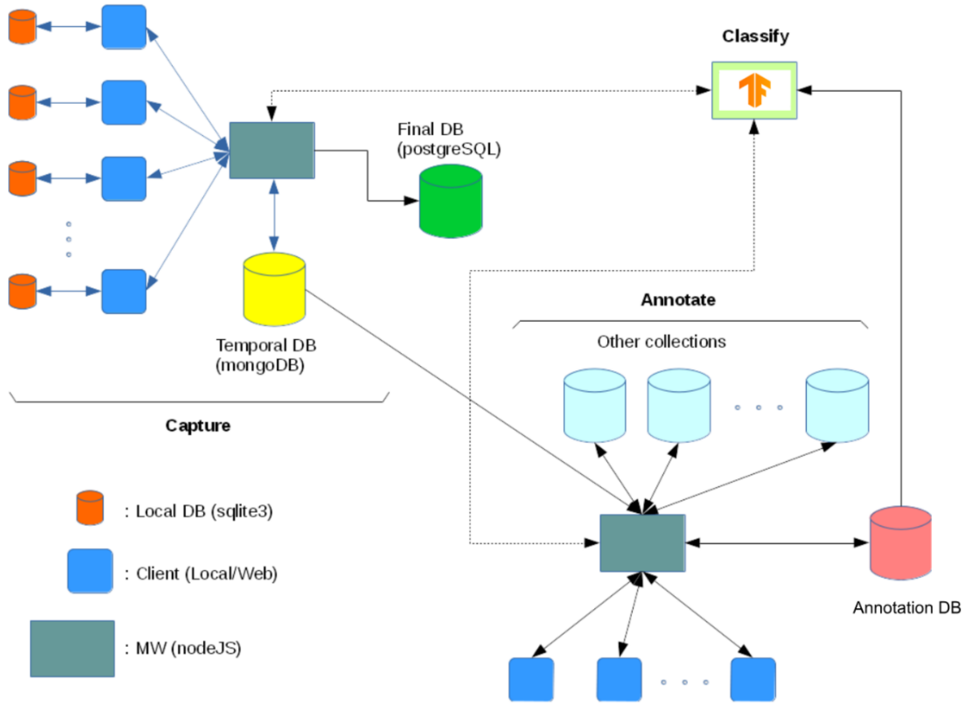



Figure 3. Architecture of data pipelines for object recognition tasks.

The previous architecture involves data acquisition, management and data annotation pipelines. These are based on several data bases and web apps which are not to be developed further in this project. They will, however, be deployed on AWS. This is of great interest to us specifically because CONABIO's HPC cluster is equipped with outdated GPUs (6*Tesla K20Xm) which have stunted deep learning model training for quite some time now. As a main task, the previous pipelines will be deployed on AWS, model training on TensorFlow ready AWS machines. Specific deliverables will be not only the previous system deployed in AWS but finally deep neural network models for the detection and classification of:

- Neotropical Bat Species
- Anthropogenic Sounds

Using all available training data. Efficient experimentation with these models has not been possible with the current infrastructure at CONABIO. Furthermore, the resulting models will be used on all available recordings from Mexico and Colombia (Colombia and Mexico share some bat species) for a first full exercise of bioacoustics data processing in both countries.

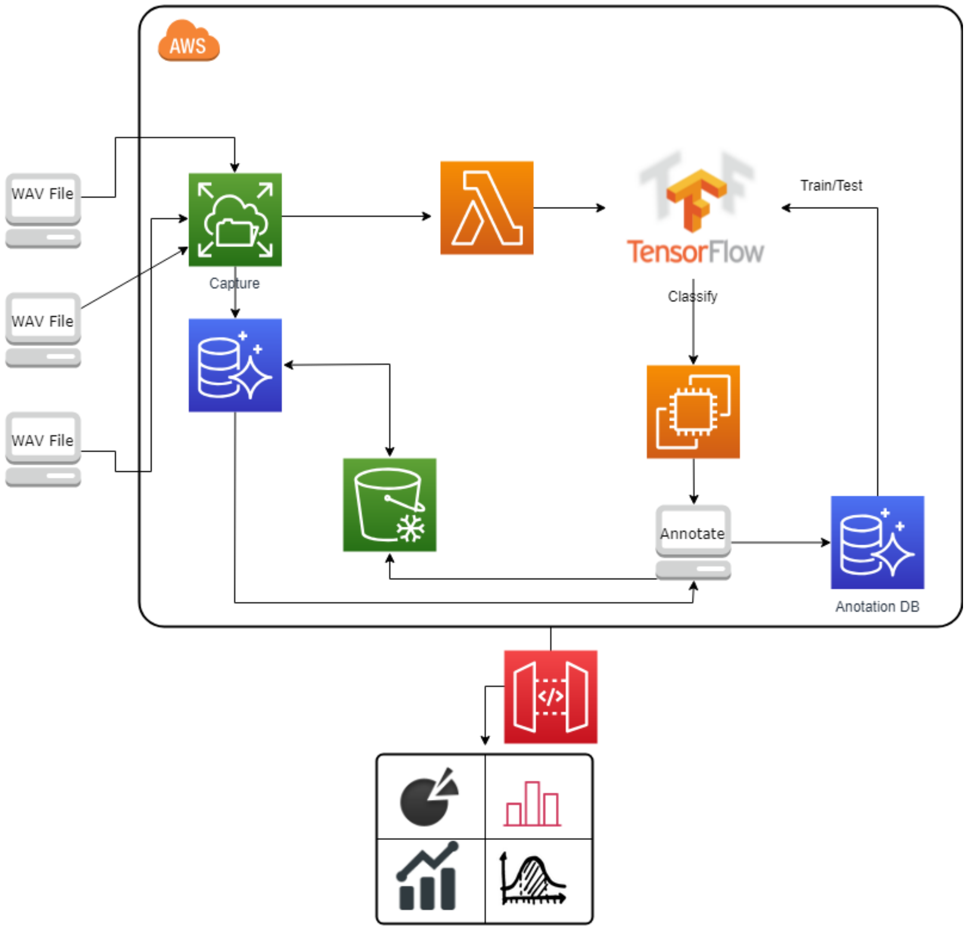



Figure 4. Mockup of deployment on AWS of deep learning for bioacoustics data processing pipelines.

## Deep learning for bioacoustics data processing

In order to train the bat-call and anthropogenic sounds classifiers we estimate a total of 17480 AWS credits

The deep neural networks which will serve as the previously mentioned classifiers will be prototyped in house at Conabio. Final model training and prediction on the full collection of field recordings. From there that for this part of the proposal a single deep learning instance is required. An p3.2xlarge and 10 TB of storage (EBS) is needed for a total of 4 months (~100% usage).

| Products | Cost(AWS credits) |
|---|---|
| Bat-call classifier (final model training-testing-validation) | $4,370 (1-month total computing time, spread out unevenly over 9 months) |
| Anthropogenic sounds classifier (final model training-testing-validation) | $4,370 (1-month total computing time, spread out unevenly over 9 months) |
| Prediction on complete collection of ultrasonic field recordings for detection and classification of bat species | $4,370 (1-month total computing time, spread out unevenly over 9 months) |
| Prediction on complete collection of soundscape field recordings for detection and classification of anthropogenic sounds | $4,370 (1-month total computing time, spread out unevenly over 9 months) |
| TOTAL | $17,480 |

| Products | Delivery date |
|---|---|
| Bat-call and anthropogenic sounds classifiers | First three semesters of AWS grant |
| Labeled collection (bat species and anthropogenic signals) of field sound recordings | Last three semesters of AWS grant |

**Integration between EO products and bioacoustics data**

Since most biodiversity is invisible to Earth observation, indicators based on Earth observation could be misleading and reduce the effectiveness of nature conservation and even unintentionally decrease conservation effort (Bush et al. 2017). Methods to unite Earth observation and field data is urgently needed, Figure 7. We propose a framework based on Bayesian Networks to fuse the data from these two data acquisition paradigms. The resulting models serve not only as a framework to produce inference on the relations of the input variables but also to estimate an ecosystem integrity index. As a proof of concept, the proposal contemplates the fusion of Earth observation products (MAD-Mex) and bioacoustics derived data (Bat species and anthropogenic signal in situ observations).

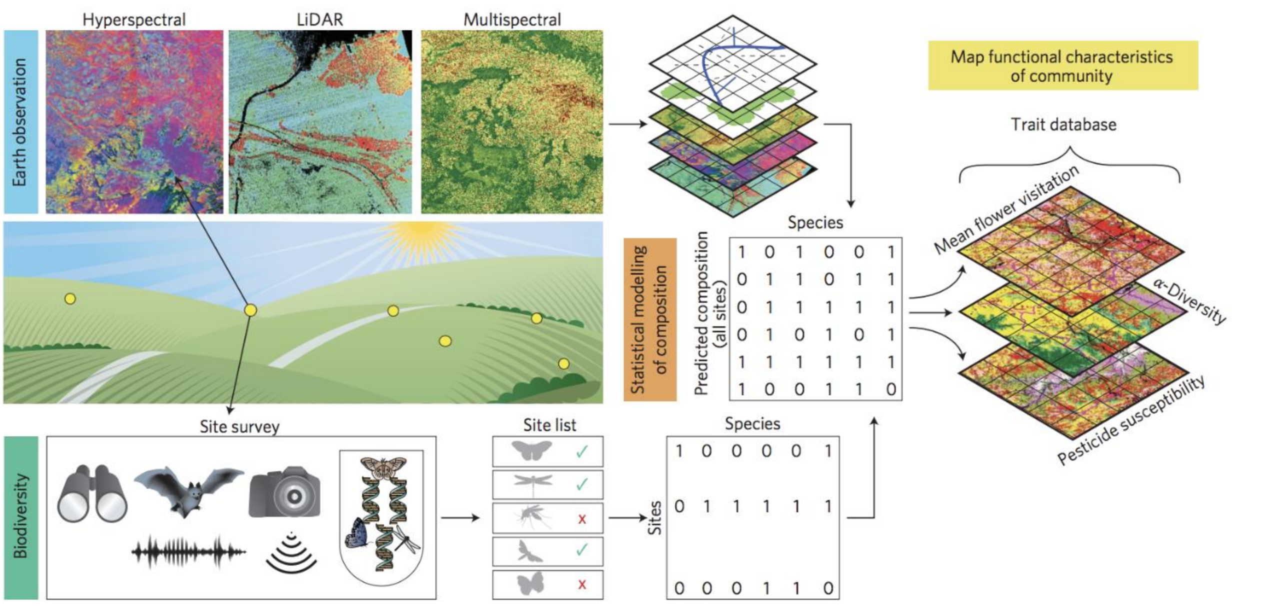



Figure 7. Connecting Earth observation to biodiversiy and ecosystems (Bush et al. 2017)

Finally, INEGI, Conabio and the Humboldt Institute are not solely academic organizations. A main objective is the development of information products that are descriptive, predictive and prescriptive regarding decision making and the dissemination of environmental information to the general public. The React-2-EO app will allow the dissemination of the results from the previous analytical processes in a user-friendly and informative manner: deforestation processes, city growth (land cover and land use change) and trends in ecosystem integrity.

### 3.- React-2-EO Web App

Building up on progress made, INEGI and CONABIO have resolved to implement a specific application of the OpenDataCube (ODC) of Mexico; which aims to make delivering a message based on EO time-series products easy, by providing an approachable tool that generates animations; and consists on a software platform that allows (1) to explore the territorial surface of Mexico and see how it has changed in the last 3 decades, (2) to then, generate animations of the change of the surface of a region of the country for a certain time, (3) to provide an emotional reaction towards the animation and, finally, (4) to also observe geolocated statistics of others' reactions.

This tool is meant to work on any current mobile phone and with the least number of clicks possible, which makes the knowledge and exploration of changes in territorial surface over time much more approachable. It will allow users to interactively explore any region of the country at specific time intervals and generate animated GIFs; and to then provide a reaction (like/dislike) towards the resulting GIF. The mosaics (geomedians) that will be displayed, are a spatial median composed of satellite data that can be used to observe the statistically "average" behavior of an area that summarizes the selected time interval (Roberts, D., et al, High-Dimensional Pixel Composites From Earth Observation Time Series, 2017) (for the mosaics in this app, the time interval used will be chosen considering the source sensor).

Featured geolocated statistics of users' reactions ("like/dislike"), as a sort of collaborative mapping, are expected to provide an indicator for the perception that people have on their surroundings. Once the pipeline is validated for one simple scenario, the project may be translated to other contexts: the platform could expand to host different thematic products (like water or agriculture). Then, statistics of users' reactions might become tangible evidence for the perceived national capacity to fulfill specific purposes of interest that are somehow linked to the product reacted to.

For simplicity, the implementation activities for this platform are divided into 3 stages: Set-up, Landsat, and a final stage for Sentinel-2. During the Set-up stage, we aim (1) to generate a testing dataset, which would ease the proper workflow design and tests; and (2) to establish the necessary backend services, implement graphic user interfaces and implement communication services between both. The result is the infrastructure for the national viewer described previously, which will be used in the next stages.

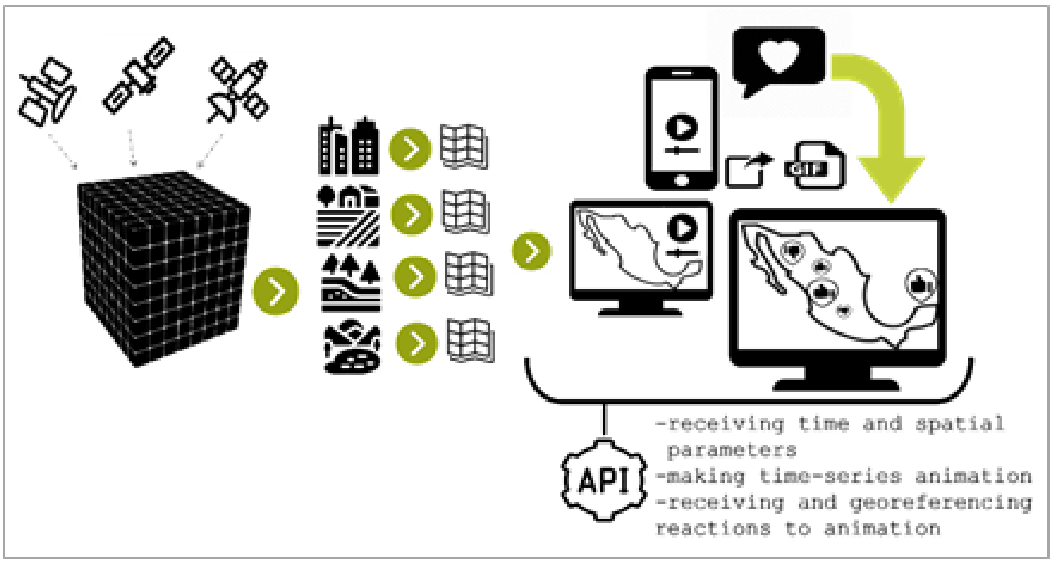
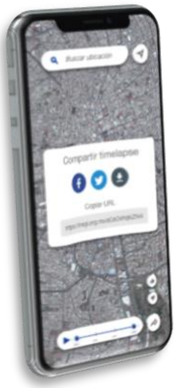
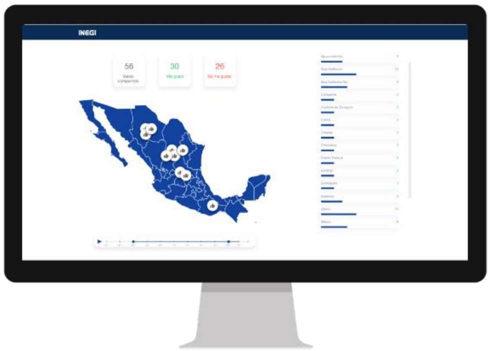



Figure 5. React-2-EO is targeted to EO/GI enthusiasts familiar with mobile devices and web map viewers, and *anyone willing to complement an idea regarding changes over time of the territorial surface of Mexico.*

**Implementation**
Clear description of applications can be found below.

| | | Geospatial Data Cube of Mexico: APP | Geospatial Data Cube of Mexico: Dashboard |
|---|---|---|---|
| General | Summary | Mobile App that allows the user to view/generate animations of the change of the surface of a region of the country for a certain time; this app will capture the reactions of users towards the animations generated | Web app that allows user to display resulting products in a time-series viewer, as well as generate geolocated statistics of the sentiment towards the animations generated (with the mobile app) |
| | Functionality and Reach | The main feature in both apps is a national visualizer that allows the user to explore and see how the territorial surface of Mexico has changed in the last 3 decades | |
| | | This app allows the user to interactively explore any region of the country at specific time intervals and generate animated GIFs; and to provide a reaction (like/dislike) towards the resulting GIF | This dashboard allows the user to interactively explore any region of the country at specific time intervals and geolocated statistics of the reactions towards the animations generated |
| | Description | • These national viewers consist of:<br>(1) approximately 20 or more (number depends on available data) annual cloud-free mosaics, generated using the Open Data Cube algorithms: Geomedian and CWBG, NDVI, NDWI, WOfS, NDBI, BU<br><br>•They will be based on an API with the implemented methods of extraction of spatial and temporal slices, as well as the generation of animations<br><br>• Web service for generating GIFs, API microservices, wms and Database Engine required | |
| | Target user | Frequent users of mobile devices and web map viewers | Geospatial information enthusiasts that are familiar with mobile devices and web map viewers web |
| | Graphics (Preliminary Visual Design) |  |  |
| Data requiremen | Types of content | (1) Annual mosaics | |

<table>
<tr><td rowspan="5"></td><td></td><td></td><td>(3) Geolocated statistics of the reactions towards the animations generated</td></tr>
<tr><td rowspan="2">Description of content data</td><td colspan="2">(1) National annual mosaics<br>• The mosaics (geomedians) that will be displayed, are a spatial median composed of satellite data that can be used to observe the statistically "average" behavior of an area that summarizes the selected time interval (for the mosaics in this app, the time interval used will be one year)<br><br>• The “geomedian,” or geometric median, preserves the relationships between the spectral bands, so instead of obtaining an "average" behavior for each band, we obtain a general measure of the central tendency that works spatially, temporally and spectrally<br><br>• Depending on the resources, other type of mosaics can be included in this stage, such as: CWBG, NDVI, NDWI, WOfS, NDBI, BU; There are up to 7 types of mosaics considered.</td></tr>
<tr><td></td><td>(3) Geolocated statistics of the reactions towards the animations generated<br>• Geolocated statistics of the reactions towards the animations generated</td></tr>
<tr><td rowspan="2">Data sources</td><td colspan="2">Landsat<br>• More than 109,000 Landsat satellite images will be used for the last three decades<br>• Landsat is a joint program of Earth Observations USGS / NASA that has observed Earth since the 1970s<br>• The satellite images of the Landsat program are open<br><br>Sentinel-2<br>• Around 9,000 Sentinel-2 satellite images will be used for the last three years<br>• Sentinel-2 is a program of Earth Observations mission from EU Copernicus Programme (ESA) that has observed Earth since the June, 2015.<br>• The satellite images of the Sentinel-2 program are open<br><br>ARD images are requested by GEO Secretariat as in line with the GEO-AWS EO Cloud Credits Programme.</td></tr>
<tr><td>To generate the GIFs<br>Spatial and temporal ranges provided by the user</td><td>To generate geolocated statistics of reactions<br>Geolocation data from moment of GIFs generation, and corresponding reaction towards the animation</td></tr>
<tr><td rowspan="2">Pipeline</td><td>Start</td><td>- After a presentation screen (splash screen), a national viewer is displayed.</td><td>- When opened, a national viewer is displayed.</td></tr>
<tr><td>Default settings</td><td colspan="2">- The main screen will show a preset region of the country (i.e. it could be the user's real location)<br><br>- The main screen will show one type of content (i.e. it could be Geomedians: Landsat annual cloud-free mosaics)<br><br>- An animation will be displayed on the screen with the change of this region during a pre-set time interval (i.e. it could be the total range of available time)</td></tr>
</table>

<table>
<tr><td rowspan="2">Custom settings (user inputs)</td><td colspan="2">- The user selects the desired type of content using tabs (which will be visible on the screen)<br><br>- The user finds the area of interest, so that only this area will be displayed (using touch screen on the phone, or mouse input for the dashboard)<br><br>- The user selects the desired time range using a rangeslider (which will be visible on the screen)</td></tr>
<tr><td>- Once the user is satisfied with the result, the time-series animation of the selected region/type of content, during the chosen time interval, can be exported as an animated GIF by pressing a button (which will be visible on the screen, on top of the map view)<br><br>- After deciding to export the animation, the user may provide an emotional reaction to their custom animation (i.e. it could be "like/dislike")<br><br>• Note: In case of not modifying the default settings, pressing this button will export an animated time-series GIF of the default region and time interval</td><td>- The user may also observe a cumulative map with geolocated statistics of the reactions towards the animations that have been generated</td></tr>
<tr><td rowspan="2">Other details</td><td colspan="2">App and Dashboard will:<br><br>✓ not require any type of registration to the user to use it<br>✓ not have user profiles<br>✓ not charge its users<br>✓ be integrated with other web services and / or internal systems<br>✓ have great visual design (modern look & feel)<br>✓ have an icon</td></tr>
<tr><td>App will:<br><br>✓ work on iOS and Android platforms</td><td>Dashboard will:<br><br>✓ be suited for any web browser</td></tr>
</table>

**Amazon Web Services and Sentinel-Hub credits request for React-2-EO**

<table>
<tr><th>Time frame</th><th>AWS Credits</th><th>Purpose #1</th><th>Purpose #2</th><th>Sentinel-Hub Credits</th><th>Purpose</th></tr>
<tr><td>Working Year 1</td><td>$20,000</td><td rowspan="2">Generate 1 set of 4 (or more) of each product the 7 mosaics, one per each year using ARD Sentinel-2 images<br><br>Generate 1 set of 20 (or more) of each product the 7 mosaics, one per each year using ARD Landsat images</td><td rowspan="3">Support for the mobile application and Dashboard that (1)allow users to view and navigates (in spatial and time dimensions) the products; (2)allow users to generate custom time-series animationss; as well as (3) collect and monitor emotional users' reactions towards their animations</td><td>€ 40,000</td><td rowspan="3">Support for the mobile application and Dashboard that (1)allow users to view and navigates (in spatial and time dimensions) the products; (2)allow users to generate custom time-series animationss; as well as (3) collect and monitor emotional users' reactions towards their animations</td></tr>
<tr><td>Working Year 2</td><td>$9,260</td><td>€ 40,000</td></tr>
<tr><td>Working Year 3</td><td>$9,260</td><td>Generate subsequent sets of annual products the 7 mosaics, one per each year using ARD Landsat and Sentinel-2 images</td><td>€ 40,000</td></tr>
</table>

## Implementation timeline

For simplicity, the implementation activities for this platform are divided into 3 stages, which will be referred to as Set-up, Landsat, and a final stage for Sentinel-2. Further description of these stages and their deliverables can be found below.

| SETUP STAGE | | | | | | |
|---|---|---|---|---|---|---|
| | Production of Geomedian tiles for one selected PathRow | | | Development of APP & Dashboard | | |
| | | | | | | |
| | Data acquisition | Data Processing | Backend | | API | Frontend |
| **Objective** | To obtain Landsat images fit for the generation of the testing dataset | To ease the proper workflow design and tests | To establish the necessary backend services for the operation of the mobile Application and Statistical Dashboard. | | To implement communication services between graphical interfaces and backend services | To implement graphics interfaces for interaction with the User. |
| **Description** | Obtain one path-row of Landsat ARD images | Generate an annual product derived from a time series of satellite images, for a selected path row. | Implement the methods of extraction of spatial and temporal slices, as well as the generation of animations. Set up web map services. Implement reaction storage database and animations log. | | Implement RESTFUL services that capture the reactions of users, accept requests to generate animations and generate geolocated statistics of the sentiment towards the animations generated. | Implement the mobile application that facilitates the user navigation, obtaining emotional reactions and generation of animations. In addition to a control panel to monitor the feeling from the animations generated. |
| **Input Resources** | | Historical series of 20 years of satellite images of a path row of Mexico. | Machine for the processing of geospatial animations. Machine for the Web Map Service. Machine for the Database Engine. | | Machine for the Microservices. | Machine for the Web Server. |
| **Tasks** | Select path-row. Obtain (download) dataset. If needed, process to ARD | Install Local Data Cube<br>Index Images<br>Ingest Images<br>Generate Geomedians for each year | Installation and Configuration of Servers<br>Implementation of the animations generator in python. | | API Design<br>API Implementation | UIX design of the APP<br>UIX design of the Dashboard<br>UI Development of the APP<br>UI Development of the Dashboard<br>APP Integration with API Services<br>Dashboard Integration with API Services. APP published on offitial store |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Deliverables** | One dataset of ARD Landsat images corresponding for a selected path-row | 20 Geomedians, a Geomedian for each year for the selected path row. | Servers running and responding to requests in shell. | | Restful services up and running | App (beta-published) and Dashboard working without errors |
| **Remarks** | | It is only a set of test data, so that software development is done with realistic data. | | | Tests with geomedian products are needed | |
| **Disciplines** | | Data Engineer, Geomatics Engineer, Data Scientist | SysAdmin / Dev Sec Ops / Data Scientist | | API Developer | Mobile / Web Developer |
| **Institutions** | INEGI | INEGI | INEGI | | INEGI | INEGI |
| **Schedule** | 1 Week | 2 Weeks | 15 weeks | | 10 Weeks | 15 weeks |

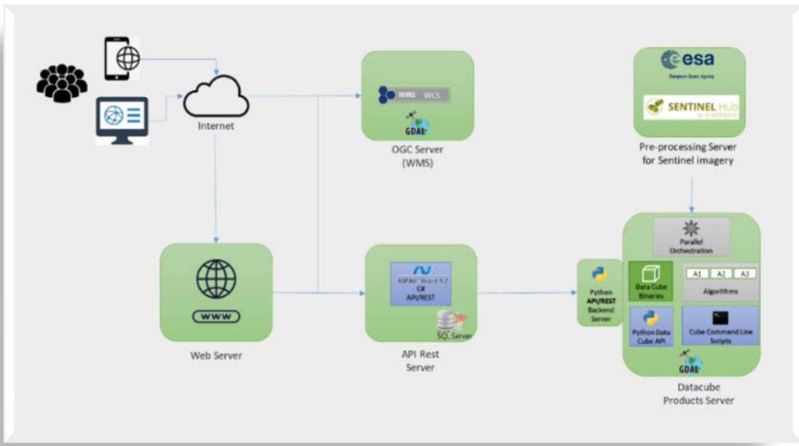
| LANDSAT STAGE | | | | |
|---|---|---|---|---|
| | Production of new Geomedians, ODC Products | | | APP & Dashboard workflow |
| | | | | |
| | Data acquisition | Data Processing | Results Validation | |
| Objective | To ensure availability of needed data inputs for processing stage. | To obtain the annual products by processing the data with AWS | To obtain the expert's validation for the computational process results | To display resulting products in a time-series viewer and animation-creator, allowing user reactions and the publishing of this feedback. |
| Description | Obtain and load the Landsat images and other training datasets, such as INEGI's geospatial information products (DEM, land cover... ) to the AWS storage. Ensure that the Landsat images are ARD. | Use time-series analysis and Machine Learning algorithms applied to the datasets to obtain the annual product images; that will be displayed on the APP and Dashboard | Validate the results from the processes using the knowledge from thematic experts from INEGI | Implementation and support for the mobile application and Dashboard that (1)allow users to view and navigates (in spatial and time dimensions) the products; (2)allow users to generate custom time-series animationss; as well as (3) collect and monitor emotional users' reactions towards their animations |
| Input Resources | AWS credits | Landsat ARD images (historical series of 20 years) and other training datasets, such as INEGI's geospatial information products . AWS credits | 1 set of 20 of each product (geomedian), one per each year. 1 set of aprox. 20 of each product. AWS credits | App (beta-published) and Dashboard working without errors, 1 validated set of 20 of each product (geomedian), one per each year. 1 validated set of aprox. 20 of each product. AWS Credits |
| Tasks | Obtain (download from or directly request to agencies) needed datasets (from Landsat and from INEGI). Load datasets to AWS. If | Define and prepare processing pipeline for every product. Apply the corresponding process. If after validation stage, it is considered | Define and prepare validation pipeline for every product. Apply the validation process. If needed, send data back to processing stage. | Set up web map services with new sets of products. Publish App and Dashboard. Run tests for each use case defined. Control service quality (query responses). |

| | | | | |
|---|---|---|---|---|
| | needed, process images to ARD. | necessary: re-process specific data. | | |
| Deliverables | One dataset of ARD Landsat images and one dataset of INEGI's geospatial information products | 1 set of 20 of each product (geomedian), one per each year. 1 set of aprox. 20 of each product | 1 set of 20 of each product (geomedian), one per each year, validated by themmatic experts from INEGI according to the validation specifiations defined. 1 set of aprox. 20 of each product, validated by themmatic experts from INEGI according to the validation specifiations defined. Documentation of validation process applied. | App and Dashboard published. |
| Remarks | | | | |
| Disciplines | | Data Engineer, Geomatics Engineer, Data Scientist | Data Engineer, Geomatics Engineer, Data Scientist, Thematic experts | SysAdmin / Dev Sec Ops / Data Scientist / API Dev / Mobile Dev / Web Dev |
| Institutions | INEGI | INEGI | INEGI | INEGI |
| **AWS or Sentinel-Hub credits needed** | | | | (mostly depending on user requests) |
| **AWS or Sentinel-Hub credits** | | $ 20, 000 AWS | | € 60,000 Sentinel-hub credits |
| Schedule | 4 weeks | 10 weeks | 20 weeks | 6 weeks on implementaion, continuos process/service afterwards |

| **SENTINEL-2 STAGE** | | | | |
|---|---|---|---|---|
| | Production of new Geomedians, ODC Products | | | APP & Dashboard workflow |
| | | | | |
| | Data acquisition | Data Processing | Results Validation | |
| **Objective** | To ensure availability of needed data inputs for processing stage. | To obtain the annual products by processing the data with AWS | To obtain the expert's validation for the computational process results | To display resulting products in a time-series viewer and animation-creator, allowing user reactions and the publishing of this feedback. |
| **Description** | Obtain and load the Sentinel-2 images and other training datasets, such as INEGI's geospatial information products (DEM, land cover… ) to the AWS storage. Ensure that the Sentinel-2 images are ARD. | Use time-series analysis and Machine Learning algorithms applied to the datasets to obtain the annual product images; that will be displayed on the APP and Dashboard | Validate the results from the processes using the knowledge from thematic experts from INEGI | Incorporation of Sentinel-2 products to existing mobile application and Dashboard |

| | | | | |
|---|---|---|---|---|
| **Input Resources** | AWS credits | Sentinel-2 ARD images (historical series of 20 years) and other training datasets, such as INEGI's geospatial information products . AWS credits | 1 set of a defined number of examples for each product. AWS credits | App and Dashboard published. 1 set of a defined number of examples for each product. AWS credits |
| **Tasks** | Obtain (download from or directly request to agencies) needed datasets (from Sentinel-2 and from INEGI). Load datasets to AWS. If needed, process images to ARD. | Define and prepare processing pipeline for every product. Apply the corresponding process. If after validation stage, it is considered necessary: re-process specific data. | Define and prepare validation pipeline for every product. Apply the validation process. If needed, send data back to processing stage. | Set up web map services with new sets of products. Publish App and Dashboard. Run tests for each use case defined. Control service quality (query responses). |
| **Deliverables** | One dataset of ARD Sentinel-2 images and one dataset of INEGI's geospatial information products | 1 set of a defined number of examples for each product. | 1 set of a defined number of examples for each product, validated by themmatic experts from INEGI according to the validation specifications defined. Documentation of validation process applied. | App and Dashboard published. |
| **Remarks** | | | | |
| **Disciplines** | | Data Engineer, Geomatics Engineer, Data Scientist | Data Engineer, Geomatics Engineer, Data Scientist, Thematic experts | SysAdmin / Dev Sec Ops / Data Scientist / API Dev / Mobile Dev / Web Dev |
| **AWS or Sentinel-Hub credits needed** | | | | (mostly depending on user requests) |
| **AWS or Sentinel-Hub credits** | | $ 18, 520 AWS | | € 60,000 Sentinel-hub credits |
| **Schedule?** | 4 weeks | 4 weeks | 10 weeks | 6 weeks on implementaion, continuos process/service afterwards |

**Proposed architecture**



**Annexes**

Annex table -1-.

| Activities | Without ODC | With ODC |
|---|---|---|
| Crop surface estimation | -Download and preprocess images<br>-Very likely presence of clouds during the Spring-Summer period (rain season)<br>-Likely presence of clouds during the Autumn-Winter period<br>-Only one image is used for the estimation<br>-Software for processing the image | -ARD images<br>-Cloud-free images<br>-Several images used (time-series) for the estimation<br>-Processing algorithms<br>-Possibility to develop or customize algorithms |
| Crop monitoring | -Download and preprocess images<br>-Very likely presence of clouds during the Spring-Summer period (rain season)<br>-Likely presence of clouds during the Autumn-Winter period<br>-Only one image is used for the estimation<br>-Software for calculating NDVI | -ARD images<br>-Cloud-free images<br>-Change monitoring (time-series)<br>-NDVI is featured product, and includes other statistical values (min., max., mean) |
| Identification of infrastructure for protected agriculture<br><br>&<br>Verification and update of terrains (parcels) | -Download and preprocess images<br>-Very likely presence of clouds during the Spring-Summer period (rain season)<br>-Likely presence of clouds during the Autumn-Winter period | -ARD images<br>-Cloud-free images<br>-Several images used (time-series)<br>-National cover (and nation-wide processing) |

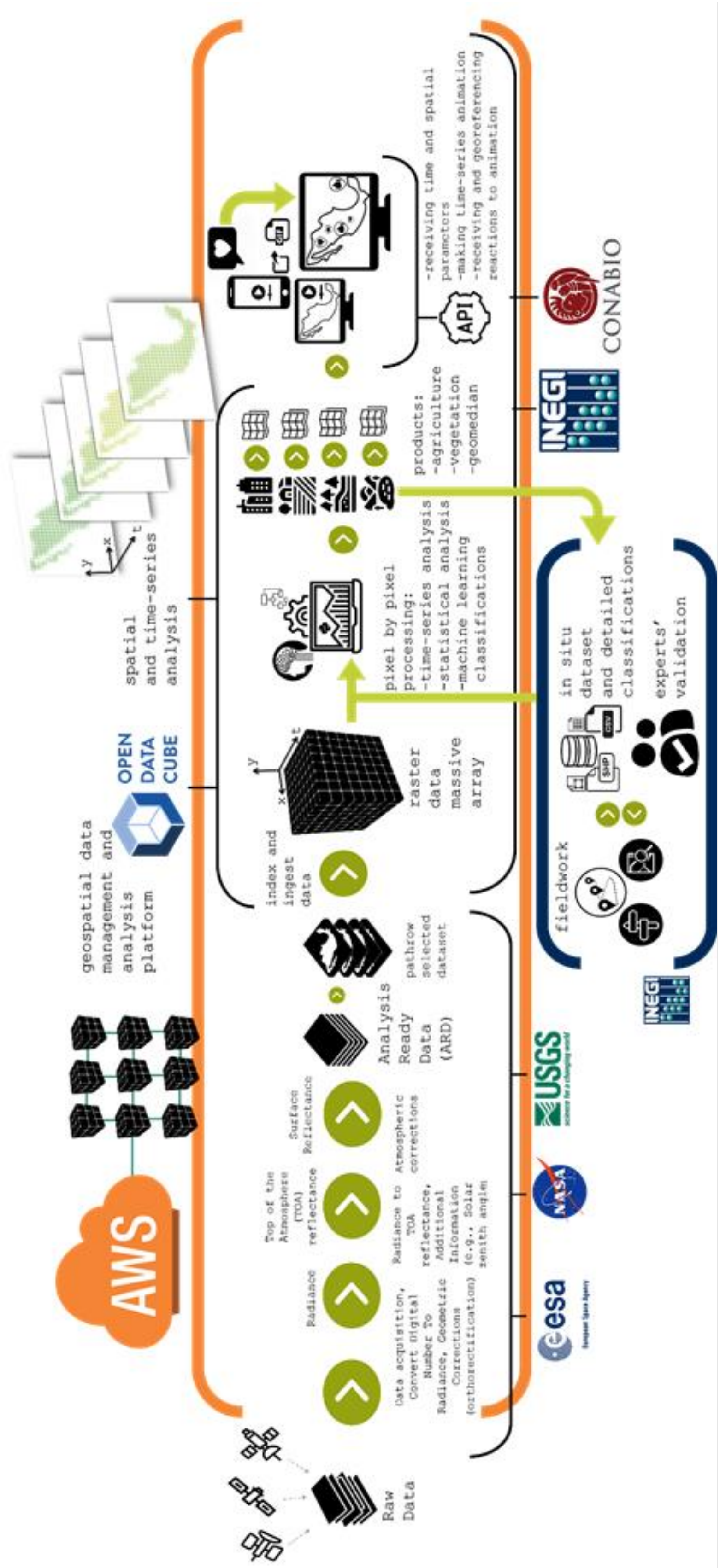



Figure 6. MEXICAN GEOSPATIAL DATA CUBE REACT-2-EO (DETAILED)

The pipeline that permits the execution of this project can be found on the diagram.

**Diagram Description**

There are 2 main sets of brackets.

- The orange brackets contain those processes that ought to be run on AWS
- The blue brackets represent additional work/data from INEGI, such as experts' validation
- These 2 sets of brackets are connected with 2 green arrows that mark the stage at which they intervene each other

The main row, which is almost completely contained in the orange brackets, is divided in 3 main process blocks.

Fist block (from left to right) englobes the process to obtain Analysis Ready Data from Raw Data:

- ARD is the input for the Open Data Cube: spatial agencies control the spatial programs for these satellites
- USGS-NASA may provide Landsat ARD. ESA guides through the acquisition/processing of Sentinel ARD
- This process is considered within the orange brackets (AWS)
- Note we wish to use Sentinel Hub services of the area to be analyzed (the whole Sentinel-2 archive over national Mexican and Colombian territory)

| | | | |
|---|---|---|---|
| **Input** | Raw data | Radiance | Top of the Atmosphere (TOA) reflectance |
| **Process** | Data acquisition, Convert Digital Number to Radiance, Geometric Corrections (orthorectification) | Radiance to TOA reflectance, Additional Information (e.g., Solar zenith angle) | Atmospheric corrections |
| **Output** | Radiance | Top of the Atmosphere (TOA) reflectance | Surface Reflectance |

Second block represents the Open Data Cube stage, where spatial and time-series analysis is carried on:

- ARD is ingested into a Data Cube, which creates a massive array of raster data
- This array can then be accessed, processed and analyzed at pixel-level or object level; according to the desired final products (geomedian, classifications)
- Note that the input to these processes is not exclusively ARD, other INEGI's products may be used as well: results will also be validated and approved by experts
- This is expressed with 2 in-and-out green arrows that connect to the blue brackets
- Blue brackets represent INEGI's experts' validation, fieldwork, in situ datasets and detailed classifications

The third block represents the stage where the tool that generates animations; and allows to explore the territorial surface of Mexico and see how it has changed in the last 3 decades

- The main feature is a national visualizer that allows the user to explore the surface of Mexico
- Its content is the output of the previous block: time-series of periodic cloud-free mosaics, and vegetation classifications
- This is represented with a "play" icon on the screens
- The tool that allows to generate animations is represented with the icon for GIF
- User interaction will be based on an API with methods for extracting spatial and temporal slices, as well as generating animations, and tracking feedbacks.
- This is expressed with a green arrow that connects a dialogue globe (with a heart in it) to a PC monitor with a map of "Likes and Dislikes"

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