NIGERIA NATURAL CAPITAL ACCOUNTING

COMPILATION OF PILOT ECOSYSTEM ACCOUNTS FOR NASARAWA AND KADUNA STATES

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Foreword

Traditional economic indicators like the gross domestic product (GDP) do not fully capture the environmental costs and benefits associated with economic activities and financial transactions or help in understanding how the depletion of natural resources and degradation of the environment affect the economy and human wellbeing. Natural capital accounting fills this gap by quantifying the economic value of natural resources and ecosystems to offer a more holistic view of sustainability and economic health. It can support policymakers in understanding the trade-offs and synergies between economic policies and environmental goals.

The World Bank has supported the development of natural capital accounting in Nigeria through intersectoral cooperation among various government institutions alongside capacity-building activities and policy dialogue, with the objective of building technical capacities to produce the accounts and increase understanding of the policy applications of natural capital accounting. This report presents the first set of Ecosystem Accounts in the two Nigerian states, Kaduna and Nasarawa. Reports on Land Accounts and Greenhouse Gas Accounts are published separately.

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Acronyms and abbreviations

Abbreviation	Expansion of the acronym
ACReSAL	Agro-Climatic Resilience in Semi-Arid Landscapes
AI	Artificial Intelligence
ARIES	Artificial Intelligence for Environment & Sustainability
BC3	Basque Centre for Climate Change
ESA- CCI	European Space Agency Climate Change Initiative
ES	Ecosystem Service
FAO	Food and Agriculture Organisation of the UN
FREL	Forest Reference Emissions Level
GFM	Global Forest Management
LULC	Land Use and Land Cover
NBS	National Bureau of Statistics
NCA	Natural Capital Accounting
SEEA	System of Environmental-Economic Accounting
SEEA-EA	System of Environmental-Economic Accounting-Ecosystem Accounting
TWG	Technical Working Group
UN	United Nations
UNEP	United Nations Environment Programme
UNSD	United Nations Statistical Division
WB	World Bank

Executive summary

The primary objective of this initiative was to develop ecosystem services accounts for two pilot states in Nigeria, according to the System of Environmental-Economic Accounting Ecosystem Accounting (SEEA-EA). The SEEA-EA is the international statistical standard for natural capital accounting and constitutes an integrated and comprehensive statistical framework for organizing data about natural resources, including the services provided by ecosystems. The ecosystem services accounts were compiled using the ARIES (Artificial Intelligence for Environment and Sustainability) for SEEA[1]. This innovative solution, a collaborative creation by BC3 (Basque Centre for Climate Change), UNEP (United Nations Environment Programme), and UNSD (United Nations Statistical Division), facilitates the assembly of data and information based on revised and endorsed scientific knowledge, to compile accounts consistent with the standard, and is accessible via the UN Global Platform[2].

ARIES for SEEA is the open, free and user-friendly modelling platform used to obtain ecosystem accounts. Compared to other approaches to environmental assessment, it has the advantage that the results of analyses can be easily adapted to different geographic, temporal and methodological contexts so that the results of a specific project can be easily scaled and reapplied. This is important to facilitate the compilation of accounts in the future. Whenever new information is made available in ARIES, the accounts can be recompiled for other accounting areas (e.g. other states) or different years, with minimal effort. Moreover, should the underlying data change significantly (e.g. a time series of local data is developed by the country), ARIES can be used to re-assess previous estimates based on the new information made available. This provides an alternative to a consistent compilation and revision of Ecosystem Service (ES) accounts.

In pursuit of enhancing proficiency with the ARIES for SEEA application and the broader process of ecosystem accounts compilation, an in-person workshop was organized in Abuja from November 8th to 10th, 2023. The workshop provided a blend of theoretical and practical presentations covering ecosystem accounting, semantic and environmental modelling, and explained how the artificial intelligence (AI) engine which powers the analyses is based on human inputs. For this reason, the input

[1] https://aries.integratedmodelling.org/aries-for-seea-explorer/

[2] https://unstats.un.org/bigdata/un-global-platform.cshtml

provided by the TWG is essential in the production of the accounts. Practical sessions were dedicated to employing the ARIES for SEEA application in generating accounts.

In response to the attendees' feedback, the training's emphasis was shifted towards incorporating local data into the accounts. This adjustment highlighted the strong desire and necessity among the National Statistical Bureau (NBS), the pilot state offices, and other federal agencies engaged in the project to learn the methodologies required for independent account production.

The final result of this process was the adaptation of the global model to include specific local data available, which allowed the creation of the first comprehensive Ecosystem Accounts for Kaduna and Nasarawa states, with a particular focus on Ecosystem Services. The short time and resources available for the project limited the outputs that could be feasibly produced. Nevertheless, this achievement marks a significant step forward in the practical application of environmental-economic accounting within Nigeria, offering a template for future efforts to integrate environmental considerations into national and regional planning and policy-making processes, and show how significant results can be achieved under limited resources when leveraging on interoperable models and data available from the United Nations Sector Hub[3].

[3] https://unstats.un.org/bigdata/hubs/spain/

1. Introduction

The World Bank (WB) has supported the development of Natural Capital Accounting (NCA) in Nigeria using the SEEA (System of Environmental-Economic Accounting) framework. This work was part of a larger WB technical assistance program on Climate Resilience and Environmental Management, that consisted of advisory, analytical, and capacity-building activities to support dialogue with the Federal Government of Nigeria towards further development and implementation of its climate agenda, consistent with its global commitments and sustainable development vision.

The compilation of SEEA accounts for Kaduna and Nasarawa states was financially supported by the Global Programme for Sustainability (GPS) Trust Fund managed by the WB and aimed at demonstrating how to integrate economic and environmental data into a framework and how to determine the changes in stocks of environmental assets, and the services and benefits they provide to the economy and communities. This work was spearheaded by Nigeria's National Bureau of Statistics (NBS), under the stewardship of the interdisciplinary Technical Working Group (TWG). This group included members from various federal government departments and agencies, as well as representatives from offices at the state level of Kaduna and Nasarawa, the two pilot states. This ensured a comprehensive and inclusive approach to the development process.

The two selected states are benefiting states of Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL) Project (P175237), whose objective is to increase the implementation of sustainable landscape management practices in targeted watersheds in northern Nigeria and strengthen Nigeria's long-term enabling environment for integrated climate-resilient landscape management. The Ecosystem accounts compiled for Kaduna and Nasarawa will help the implementing agency and state administrations to better prioritize the selection of investments in catchment areas and will serve as input to the integrated landscape management planning tools. Data collected from ecosystem accounts and the methodology for the preparation of the ecosystem accounts can be used in other states using local data where available. Local data were not available for this study. The accounts generated estimate the physical supply of ecosystem services in the two pilot states, developed using the ARIES (Artificial Intelligence for Environment and Sustainability) technology, based on previously developed models and public available datasets.

This study does not compile use tables, which identify beneficiaries of the supply. Nevertheless, these results can be used as an important reference to compare future work on physical supply tables, and future work can build upon these outputs as a starting point to develop complete supply and use tables. The project engaged external support from several organizations. The most important contribution came from the Basque Centre for Climate Change (BC3), which supplied its specialized scientific knowledge on environmental analysis and climate change, and besides the lack of data and previous work in environmental accounting made it possible to generate ecosystem services physical supply accounts. The United Nations Statistics Division (UNSD) and GPS reviewed the technical reports. The collaborations underscored the global commitment to sustainable development and the vital role of accurate and comprehensive environmental-economic accounting in achieving it. This work highlights the importance of building capacity in the two pilot States and in the federal agency to support these types of analyses, particularly the collection of local environmental data, and the use in the economy, possibly by sector, of natural resources such as water, timber and crop productions.

This project not only signifies Nigeria's proactive stance towards embedding sustainability into its economic planning and policy-making, but also serves as a model for other countries seeking to integrate natural capital accounting into their development agenda. By leveraging the SEEA framework, Nigeria aims to achieve a more sustainable balance between economic development and environmental stewardship, ensuring that natural resources are managed for the benefit of current and future generations. The involvement of a wide range of stakeholders, both local and international, highlights the importance of collaborative efforts in addressing global environmental challenges and advancing sustainable development worldwide.

2. Rationale and applications of compiling ecosystem services accounts in Nigeria

Creating environmental accounts is crucial for improving policy decisions that influence the development of Nigeria's economy and its environmental sustainability. These accounts measure the value of ecosystem services, or the benefits that nature offers to the Nigerian people, emphasizing the need for their conservation and sustainable utilization to ensure the natural resources of the country remain available for future generations. Accurately pinpointing areas that require intervention, or identifying where efforts yield significant ecological and economic benefits, is essential for making informed choices that will benefit Nigeria in both the medium and long term.

3. State of environmental accounting in Nigeria

This is the first compilation of accounts in the two pilot states consistent with SEEA-EA framework. This endeavour builds upon previous efforts, notably the creation of national landcover maps developed as part of the Forest Reference Emissions Level project[4]. However, it's important to note that such classifications, until now, have not been applied for the compilation of official national or state-level environmental accounts, and turned out to need adjustment to be used for this purpose. The original landcover classifications have been revised and integrated with additional datasets for the period analyzed, namely the years 2015 and 2020. This comprehensive approach has enabled the generation of the first accounts in these states, offering a more detailed and accurate reflection of the states' environmental assets and their interaction with economic activities. This advancement represents a significant step forward in the application of the SEEA-EA framework at the state level, enhancing our understanding of ecosystem services and their crucial role in sustainable development within these regions. Using the current data, accounts computed in this project can be scaled up to other states, as well as extended to future accounting years as data become available.

[4] https://redd.unfccc.int/media/nigeria_national_frel_modified_revised__for_posting.pdf

4. Methodology adopted

To quantify Ecosystem Services (ES) in biophysical terms, and consistent with the SEEA Ecosystem Accounting framework[5], the models and methodologies already integrated in the ARIES for SEEA application were adjusted based on additional state-level information provided by members of the Technical Working Group (TWG).

4.1 Availability of data

The datasets available for the two pilot states of Kaduna and Nasarawa were integrated into the system. This included political boundaries as well as land use and land cover (LULC) maps. Unfortunately, there were not many additional local inputs that were geo-referenced and could be used to fine-tune the state-level results, but all information provided by the participating agencies and bodies was integrated. The official boundaries of Nasarawa state were used, while for Kaduna, the state boundaries were extracted from the GADM repository[6] using the level 3 information.

4.2 Land use and land cover datasets

LULC maps document the physical material at the surface of the earth (land cover) and how humans utilize the landscape (land use). They are critical for a wide range of applications, from biodiversity conservation to urban planning, and from climate change mitigation to water resource management. They are also indispensable tools for environmental accounting, serving as foundational elements for understanding and managing the Earth's resources and ecosystems effectively. Global datasets were used in the majority of cases because there was an absence of national or local data available.

The following LULC datasets were considered for this analysis:

i. *Globeland 30:* Global dataset developed by the National Geomatics Centre of China using Landsat and Chinese HJ-1 imagery, covering the years 2000, 2010, and 2020 at 300m resolution. Includes 10 classes, among them- Cropland, Trees, Grassland, Wetland, Waterbody, Built-up, Bare surface. Good spatial resolution and reasonable accuracy but only a single ‘tree’ category covering many variations of forested land cover. Savanna is not differentiated.

[5] https://seea.un.org/ecosystem-accounting
[6] https://gadm.org/index.html

ii. *European Space Agency Climate Change Initiative (ESA-CCI):* Global dataset developed by the European Space Agency under the Climate Change Initiative, covering each year from 1992-2020, with a 300m resolution distinguishes 22 classes (listed later). Reasonable accuracy, high temporal resolution and consistency of the data over the time series but has a lower spatial resolution than the other datasets and tree crops (cocoa, oil palm, etc) are mixed within the 'tree' category.

iii. *Nigeria Forest Reference Emissions Level (FREL):* Nationally developed dataset commissioned through FAO supported by FCPF grant of the WB. Maps for 2006 and 2016 at a resolution of 30 m. 12 landscape classes: Undisturbed forests, Mangroves, Forested freshwater, Forest plantation, Disturbed forest, Tree crop plantation, Savanna, Grassland, Arable land, Settlements, Bare surface, and Waterbody. Good spatial resolution, and differentiates four types of tree cover plus savanna, but accuracy is questionable. Training data are not available in sufficient detail to extrapolate maps for other years.

iv. *Global Forest Management (GFM) assessment:* Global dataset using Belgian PROBA-V imagery for 2015. Identifies 7 classes: Non-forest, Naturally regenerating forests without any signs of management, Naturally regenerating forests with signs of management, Planted forests, Plantation forests (rotation up to 15 years), Oil palm plantations and Agroforestry. Uses 8,136 training points in Nigeria. High level of accuracy for tree cover. Training dataset and model are available. But only considers tree cover categories in detail and requires substantial extra work to extrapolate to other years.

v. If three epochs were used to conduct the classifications, the 2015 GFM used here cannot be justifiable considering the differences in the period of both two images.

From these four datasets that were evaluated as potential candidates, the TWG initially indicated a preference for the FREL[7] dataset, which was recognized as a product validated at the national level. Created in 2019 in partnership with the Food and Agriculture Organization of the United Nations (FAO), the FREL dataset was provided by the Federal Department of Forestry and offered raster data for the years 2006 and 2016. Subsequently, however, it was revealed that the FREL data contained inaccuracies, as indicated by several unlikely LULC changes from 2006 to 2016.[8] It was therefore decided to switch to the ESA-CCI[9] datasets for generating both land and ecosystem accounts. This

[7] https://www.fao.org/3/cb1327en/cb1327en.pdf
[8] Nigeria Natural Capital Accounting, Land Accounts (January 2024)
[9] https://maps.elie.ucl.ac.be/CCI/viewer/

dataset offers comprehensive coverage since 1992 and high accuracy in non-forest areas, and was considered a better choice for generating consistent results over a time series.

The TWG chose 2015 as the baseline year and aimed to extend the accounts up to 2020, coinciding with the most recent year for which classified ESA-CCI data were available. Only images of the same year can be compared for easy analysis. It is also important to determine the degree to which humans intervene in Nigerian forest areas. For this purpose, the Global Forest Management[10] (GFM) dataset[11] from 2015 was used to identify the following forest management practices:

a) Intact forest
b) Forests with signs of human impact (incl. logging)
c) Planted forest
d) Plantation forests with a rotation period of up to 15 years
e) Oil palm plantations
f) Agroforestry

More information on the content of the GFM dataset can be found in section 10 of their scientific publication.[12]

The generation of the final maps is explained in the next section. It uses geospatial data from ESA-CCI and GFM and then crosswalks categories to the FREL dataset, to allow future comparison with the classification adopted at a national level.

Nasarawa state representatives provided a local land cover map for the year 2015, containing 12 classes. This dataset was not used for this analysis due to the lack of a time series that hindered the main objective of this report of assessing trends of the ecosystem services analyzed.

[10] https://www.nature.com/articles/s41597-022-01332-3
[11] https://zenodo.org/records/5849150
[12] https://www.nature.com/articles/s41597-022-01332-3#Sec10

4.3 Landcover and land-use semantic annotation and reclassification

The FREL, ESA-CCI and GFM datasets were semantically annotated into ARIES[13], providing a consistent description of the content of each class in the datasets. Semantic annotation of data is the process of attaching metadata to various parts of a dataset to add context or meaning that can be understood by both humans and machines. This metadata describes the data, explains its components, and shows how it relates to other data. This is crucial for the data integration in ARIES. Through a decision-tree model, ARIES determined the priority of information available in the different datasets, using the relevant feature represented in a specific dataset to identify more precisely a LULC (e.g. vegetation density is used to distinguish Open and Closed forests). Each land cover class in the resulting map was identified following these set of rules:

1. The land use information from the GFM dataset took priority to identify Agroforestry areas and distinguish Forest Plantations from natural and semi-natural forests;
2. The ESA-CCI land cover classification was used to categorize the landcover classes; the results were then crosswalked to the national classification used in FREL, which is more appropriate to distinguish the relevant landscape characteristics in Nigeria.

Using this approach, the final map could distinguish:

1. intact and human-managed forests,
2. densely vegetated and sparse vegetation areas, and
3. different types of forests (e.g. Evergreen, Deciduous, Broadleaf, Coniferous, Mixed forests and their combinations).

The reclassification aimed to make the data interoperable with the existing information in ARIES. The final product was consistent with the initial inputs but condensed the necessary information from these three spatial data products to derive an improved map. The semantic modelling integrated the information from these three datasets to provide a final mapping that generated more accurate results than by analyzing those datasets independently. The generated maps, re-coded using the reclassification described above, were used as inputs in the existing model in ARIES to estimate ecosystem services more accurately using SEEA EA-consistent models.

[13] https://docs.integratedmodelling.org/technote/index.html#_the_semantic_layer_semantic_modeling

The land cover maps identify, in the period 2015-2020, 25 land cover classes in Nigeria, 19 in Nasarawa and 18 in Kaduna.

Table 1 – Landcover classification used to estimate ES, and its comparison to the FREL classification

Classes (#)	Land Cover semantic	Land Cover label in the FREL classification
1	Agricultural land with natural vegetation	Forest Plantation
2	Artificial surface	Settlement
3	Bare area	Bare surfaces
4	Bare rock	Bare surfaces
5	Closed deciduous broadleaf forest	DenseForest
6	Closed evergreen broadleaf forest	DenseForest
7	Closed savanna	Savanna
8	Complex cultivation patterned land	ArableLand
9	Deciduous broadleaf forest	Woodlands and sparse forest
10	Deciduous shrubland	Woodlands and sparse forest
11	Evergreen broadleaf forest	SparseForest
12	Grassland	Grassland
13	Mangrove	Mangrove
14	Non irrigated arable land	Arable land
15	Non irrigated arable land herbaceous	Arable land
16	Open deciduous broadleaf forest	Woodlands and sparse forest
17	Open evergreen broadleaf forest	Woodlands and sparse forest
18	Open savanna	Savanna
19	Permanently irrigated arable land	Arable land
20	Shrubland	Woodlands and sparse forest
21	Sparse herbaceous cover	Woodlands and sparse forest
22	Sparse shrub cover	Woodlands and sparse forest
23	Sparse vegetation	Woodlands and sparse forest
24	Water body	Waterbody
25	Wetland	Freshwater swamp

4.4 Ecosystem services modelled within the project

Below is the full list of ESs accounts generated, which are part of the SEEA EA reference list of Ess (Table 6.3 SEEA-EA manual). The selection of the accounts was based on the services available in the ARIES modelling platform which are recognized as more relevant to inform environmental policy-making in the two pilot states. The land cover maps described in the previous chapter were a primary input in all models (except for Water supply), and defined the spatial resolution used for these analyses. All maps and tables showed in this chapter are available for download and visualization at this link:
https://data.integratedmodelling.org/dataset/ecosystem-accounts-nigeria-2015-2020

4.4.1 Ecosystem mapping

The SEEA EA framework foresees to identify the individual contribution of Ecosystem Service (ES) supply by Ecosystem Type (ET). Due to the limited time and resources available for the project, it was decided to invest more attention in the compilation of land accounts, since those are a primary input for the compilation of ESs supply accounts themselves. ETs were modelled following the methodology proposed by Sayre's in his World Terrestrial Ecosystems approach[14], using temperature domains, landform, and elevation data, with aridity domains, combined with land cover data. This approach allows to identify the major ecosystem types everywhere on earth, which is very useful in contexts in which no previous analysis was undertaken to identify with a spatial explicit analysis at relatively high resolution the presence of ecosystems according to the IUCN Global Ecosystem Typology. On the other hand, the mapping could be substantially improved if based on inputs from local experts and local data. These are to be considered ancillary output of the ESs analysis, needed to categorize the ES supply accounts. One area of improvement for future generations of accounts, is to fine-tune such models using local data and knowledge, to better identify the rich and heterogenous ecosystem landscape in Nigeria.

4.4.2 Regulation services

These represent the services provided by ecosystem processes that moderate natural phenomena. The category includes carbon storage and climate regulation, erosion control, flood control, pollination, and water purification. Those are defined in the SEEA EA

[14] https://doi.org/10.1016/B978-0-12-409548-9.12474-1

framework[15] as "the ecosystem contributions to reducing concentrations of GHG in the atmosphere through the removal (sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. These services support the regulation of the chemical composition of the atmosphere and oceans". Within this project, the following regulating services were estimated:

4.5 Climate regulation

The terrestrial carbon storage model computes terrestrial carbon stock as the sum of vegetation stocks, composed of above-ground biomass (AGB), below-ground biomass (BGB), and soil organic carbon (SOC) stocks. None of these components are limited to forests, but the model does not take into account woody debris.

4.5.1 Vegetation carbon stock

The Vegetation carbon storage is quantified as the sum of AGB and BGB carbon storage, using a look-up table based on:

a) Land cover type,
b) Ecofloristic region according to FAO classification,
c) Continental region,
d) The presence of frontier forests (a proxy for the degree of forest degradation), and
e) The recent occurrence of fires.

The method and the look-up table used were first published in the IPCC Tier-1 Global Biomass Carbon Map (Ruesch et al. 2008). This original publication contains results only for the year 2000, using the same approach the database was extended to cover the period 2001 to 2020. The dataset is publicly available at this link:
https://data.integratedmodelling.org/dataset/global-vegetation-carbon-soil-2001-2020

AGB and BGB were modelled simultaneously using the vegetation carbon model for the years, 2015 and 2020. To estimate vegetation stocks, it was assumed that each terrestrial land cover class, with the few exceptions of Artificial Surface and Waterbodies (among the land cover classes present in the Nigerian context), contributes to storing carbon to varying extents. The

[15] https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_white_cover_final.pdf

classes with the highest contribution to carbon stock are forests and wetlands, particularly mangroves, but each class contributes proportionally to the total carbon stock of an area.

4.5.2 Soil organic carbon stock

In contrast, the information provided on SOC stocks is based on a static dataset produced in 2020 that maps global soil organic carbon. The dataset used for this purpose is a product from ISRIC—World Soil Information[16], which includes soil carbon information at depths up to 200 cm. We generated results based on SOC at 30 cm depth.

4.5.3 Soil and sediment retention

This group of services includes Soil erosion control services and landslide mitigation services. In this project, the first was estimated. The erosion control services are defined as the ecosystem contributions to reduce the loss of soil and thus support the use of the environment for human activities (e.g., agricultural activity) and other natural services that contribute to the well-being of society (e.g., water supply). In particular, the presence of vegetation has secondary effects of stabilizing the soil and reducing the effects of its erosion. While it could be considered as intermediate output, in this application soil erosion control is considered a final service.

This account reports the level of modelled soil erosion produced by the Revised Universal Soil Loss Equation (RUSLE) model (Renard et al, 1997) and provides biophysical estimates of the prevention of soil loss by vegetation (in tonnes of sediment per hectare per year) by generating results under current condition and estimating the same results on the assumption that the vegetation is removed, to observe the loss prevented from the presence of vegetation (i.e. soil retention). The equation used to estimate this service is the follows:

$Soil\ Loss\ =\ R\ x\ K\ x\ L\ x\ S\ x\ C\ x\ P$ where:

R is the rainfall-runoff erosivity factor,

K is the soil erodibility factor,

L is the slope length factor,

S is the slope steepness factor (gradient),

C is the cover and management factor, and

[16] https://www.isric.org/explore/soilgrids.

P is the erosion control practices factor.

While this model lacks the estimated effects of gully erosion and dispersive soil[17], it is the state-of-the-art approach to computing soil loss based on the information available in this context.

4.6 Provisioning services

Provisioning services are the tangible resources or goods that people obtain from ecosystems, such as agriculture production. They are described as “those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems” by the SEEA EA manual.

4.6.1 Crop production

Crop provisioning services, as defined in the SEEA-EA framework, are “the ecosystem contributions to the growth of cultivated plants that are harvested by economic units for various uses including food and fiber production, fodder and energy.” They are a final ecosystem service.

The model for ecosystem contribution in crop provisioning focused on 12 globally important crops used as staples to supply food, bioenergy, and other key products; these are rice, maize, soybeans, wheat, barley, oil palm, potato, rapeseed, rye, sugar beet, sugar cane, and sunflower. Lacking the subnational time series of agricultural statistical data needed to produce credible spatially disaggregated crop production data (Joglekar et al, 2019), we relied on crop production data from the Spatial Production Allocation Model (SPAM) for 2010, replaced by national data where available (SPAM 2020). To account for changes in crop production over time, we adjusted cell-level production values upwards or downwards based on yearly changes in crop production from FAOSTAT Food and Agriculture Data (FAOSTAT 2020).

Of the 12 crops, seven were found in the studied regions: Wheat, Sugar cane, Rice, Palm oil, Maize, Soybean, and Potato.

[17] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/revised-universal-soil-loss-equation

The methods from Vallecillo et al. (2019) were followed by estimating the ecosystem contribution to crop production (EcoConCrop) as the ratio of natural inputs to natural-plus-human inputs, in energetic terms. Since Nigeria is not an EU nation, instead of using the crop-specific values provided, the EU average was used. As coefficient more specific for the Nigerian context are deemed more appropriate to model provisioning services, those can be used for future estimates (e.g. Energy approach used in Kenya[18]). Nevertheless, the optimal solution would be to estimate those coefficients for Nigeria. The TWG was not aware of existing data to support this work.

These accounts measure the biophysical quantities of services provided by ecosystems and can be used to identify the benefits received by economic units.

4.6.2 Crop-pollinated production

The SEEA EA defines this service as "the ecosystem contributions by wild pollinators to the fertilization of crops that maintains or increases the abundance and/or diversity of other species that economic units use or enjoy". This is recorded as a final service. The nesting probability and flower occurrence were used to compute the landscape-related component of pollinator insect occurrence. These use land cover types to map the probability of such occurring in each point and they were modelled based on the ESTIMAP approach, to assess ecosystem services mapping at European scale[19]. Climatic factors (solar radiation and temperature) were used to compute the weather-related component of pollinator insect occurrence and are called from Copernicus Atmosphere Monitoring Service[20] Components of insect occurrence related to weather factors and landscape structure were then combined to produce the pollinator occurrence map, shown in the results section.

4.7 Water supply (runoff and baseflow)

The SEEA EA describes these services as "the combined ecosystem contributions of water flow regulation, water purification, and other ecosystem services to the supply of water of appropriate quality to users for various uses including household consumption." This is considered a final service. The simple water strategy model was inspired by the InVest

[18] Cohen, M.J., Brown, M.T., Shepherd, K.D., 2006. Estimating the environmental costs of soil erosion at multiple scales in Kenya using emergy synthesis. Agric. Ecosyst. Environ. 114, 249–269

[19] Zulian, G.; Paracchini, M. L.; Maes, J.; Liquete, C. & others (2014). ESTIMAP ecosystem services mapping at European scale. https://data.europa.eu/doi/10.2788/64369

[20] https://atmosphere.copernicus.eu/

Seasonal Water Yield Model developed by the Natural Capital Project (Sharp et al., 2018). To understand the hydrological processes in a catchment, the model computes the relative contribution of land parcels to the generation of both base-flow and quick-flow. The ARIES simple water strategy models currently include: Global land surface runoff (quick-flow) data (occurring during or shortly after rain events) and Global subsurface base-flow data (occurring during dry weather).

The model focuses on the net amount of water generated on a Basic Spatial Unit (BSU). It accounts for the subsidy of water from upslope BSUs to a specific BSU and the actual streamflow generated by that BSU. The estimates are obtained by applying the model replicating the InVEST approach using Copernicus data. Land cover maps are one of the inputs used but play a secondary role here, and Copernicus data has a coarse resolution of 10 km. For this reason, the biophysical models underlying the results in the tables were run at 600 m resolution (not at 300 m, as per the other ES).

All the results from the water supply should be calibrated, and current results can only be used cautiously as indicative values, to assess trends over time.

4.7.1 Run-off or Quick flow

Run-off (Rf), representing the generation of streamflow with watershed residence times of hours to days, is a function of the amount of rain that runs off from the land surface quickly versus infiltrating into the soil. It is determined with a curve number (CN)-based approach, using event-based meteorological data and CN lookup tables based on hydrological soil groups and LULC types. The model (Sharp et al., 2018) computes the monthly runoff by assuming an exponential distribution of daily precipitation depths on days with rain, as follows:

Rf = n * ((a – S) * exp (-0.2 * S / a) + (pow (S) / a) * exp (0.8 * S / a) *enx (S / a)) * 25.4

$$Rf = n(a-S)e^{-0.2\frac{S}{a}} + e^{0.8\frac{S}{a}}$$

Where,

- n is the number of precipitation events in a specific month
- a is the mean precipitation depth on a rainy day in a specific month: $a = \frac{P}{n}$
- P is the event-based monthly precipitation
- S is derived from the curve number (CN): $S = \frac{1000}{CN} - 10$

4.7.2 Base-flow

Base-flow (Bf), defined as the generation of streamflow with watershed residence times of months to years, is a function of the amount of flow leaving the pixel and of the relative contribution to recharge of that pixel. It derives from the proportion of the cumulative base-flow leaving pixels, with respect to the available recharge to the upstream cumulative recharge: (Sharp et al., 2018)

$$Bf = max(\frac{b_{sum} \cdot L}{l_{sum}}, 0)$$

Where,

- b_{sum} is the cumulative base-flow from a pixel to its downslope neighbour pixels.
- L is the local recharge derived from the annual water budget: $L = P - QF - AET$.
- P is the event-based annual precipitation.
- QF is the annual land surface runoff (Quick Flow): $QF_{annual} = \sum QF_{monthly}$
- AET is the annual actual evapotranspiration.
- l_{sum} is the cumulative local recharge from upslope neighbour pixels to a pixel.

5. Core accounting tables and maps

This chapter summarizes the modelling output in tabular format, to summarize the maps, which result from the underlying geospatial explicit analysis that takes place to estimate each ES. Legends for the ES maps follow the standard output of a hot map, in which warmer colours are associated with higher physical values, while colder colours are associated with lower values. The results generated are the biophysical values for the ES services studied. The project aim was to compile supply tables in biophysical terms. The possibility to expand the analysis beyond these accounts, and record the use made of those supply tables, was out of the scope of this project, and prevented by the lack of data or previous analyses in regard to beneficiaries of these services (i.e. sector in the economy), made not possible to estimate complete supply and use tables. In general, it is a good practice to compare results with available statistics. The statistics provided at the regional level were either unavailable or considered unreliable to be used for environmental accounting. Whenever possible, national statistics were used and approximated to the region studied to generate these results. The results are disaggregated by LC, rather than by ET, as recommended by the SEEA EA framework. For the consideration explained in 2.1, the results provide better insight when disaggregated at the level of landcover classes, so this analysis shows these results as primary output. Nevertheless, ES outputs are also categorized by ET, and are available for consultation at this link:https://data.integratedmodelling.org/dataset/ecosystem-accounts-nigeria-2015-2020.

5.1 Extent accounts

5.1.1 Land extent accounts

Table 1 - Land cover extent account in Nigeria in 2015 and 2020

Land cover class	**Opening area 2015**	**Expansions**	**Regressions**	**Net change**	**Closing area at start of 2021**
Agricultural land with natural vegetation	212,470.72	5,828.53	1,887.04	3,941.49	216,412.21
Artificial surface	6,307.23	2,064.71	7.55	2,057.16	8,364.39
Bare area	130.19	35.56	4.24	31.32	161.51
Bare rock	24.17	0	1.52	-1.52	22.64
Closed deciduous broadleaf forest	2,196.82	1,554.8	38.31	1,516.49	3,713.31
Closed evergreen broadleaf forest	32,595.71	57	497.79	-440.79	32,154.92

Land cover class	**Opening area 2015**	**Expansions**	**Regressions**	**Net change**	**Closing area at start of 2021**
Closed savanna	2,413.15	382.64	55.06	327.58	2,740.73
Complex cultivation patterned land	60,998.3	732.63	1714.69	-982.07	60,016.24
Deciduous broadleaf forest	5,041.68	1331.74	419.85	911.89	5,953.57
Deciduous shrubland	5,795.27	23.76	682.72	-658.97	5,136.3
Evergreen broadleaf forest	3,608.95	437.14	121.63	315.52	3,924.47
Grassland	26,828.89	246.94	865.18	-618.24	26,210.64
Mangrove	8,961.51	80.29	109.79	-29.5	8,932.01
Non irrigated arable land	351,347.76	72.79	5,512.89	-5,440.1	345,907.67
Non irrigated arable land herbaceous	62,926.13	1,635.78	346.63	1,289.15	64,215.27
Open deciduous broadleaf forest	67,291.59	1,020.03	896.07	123.97	67,415.56
Open evergreen broadleaf forest	1,107.53	22.93	37.32	-14.39	1,093.14
Open savanna	133.82	16.6	7.94	8.66	142.48
Permanently irrigated arable land	6,894.1	30.08	72.11	-42.03	6,852.07
Shrubland	42,677.37	724.87	3,199.25	-2,474.38	40,202.99
Sparse herbaceous cover	403.57	0	99.47	-99.47	304.1
Sparse shrub cover	0.18	0	0	0	0.18
Sparse vegetation	195.93	159.92	17.2	142.72	338.65
Water body	28,094.57	220.76	20.09	200.67	28,295.24
Wetland	3,928.18	9.05	74.2	-65.15	3,863.03
Unaccounted	0.09	0	0	0	0.09
Totals	**932,373.41**	**16,688.54**	**16,688.54**	**0**	**932,373.41**

Table 1. summarizes the change observed in the landscape by land cover class over the period, 2015-2020. The columns for Expansions and Regressions refer to the extent to which each class has increased or decreased over the period, while the Net Change column gives the difference between the initial and final years.

Non-irrigated arable land is the class that shrank the most over this period, while agricultural land with natural vegetation accounted for the greatest expansion.

Image 1 - Land cover map of Nigeria in 2015

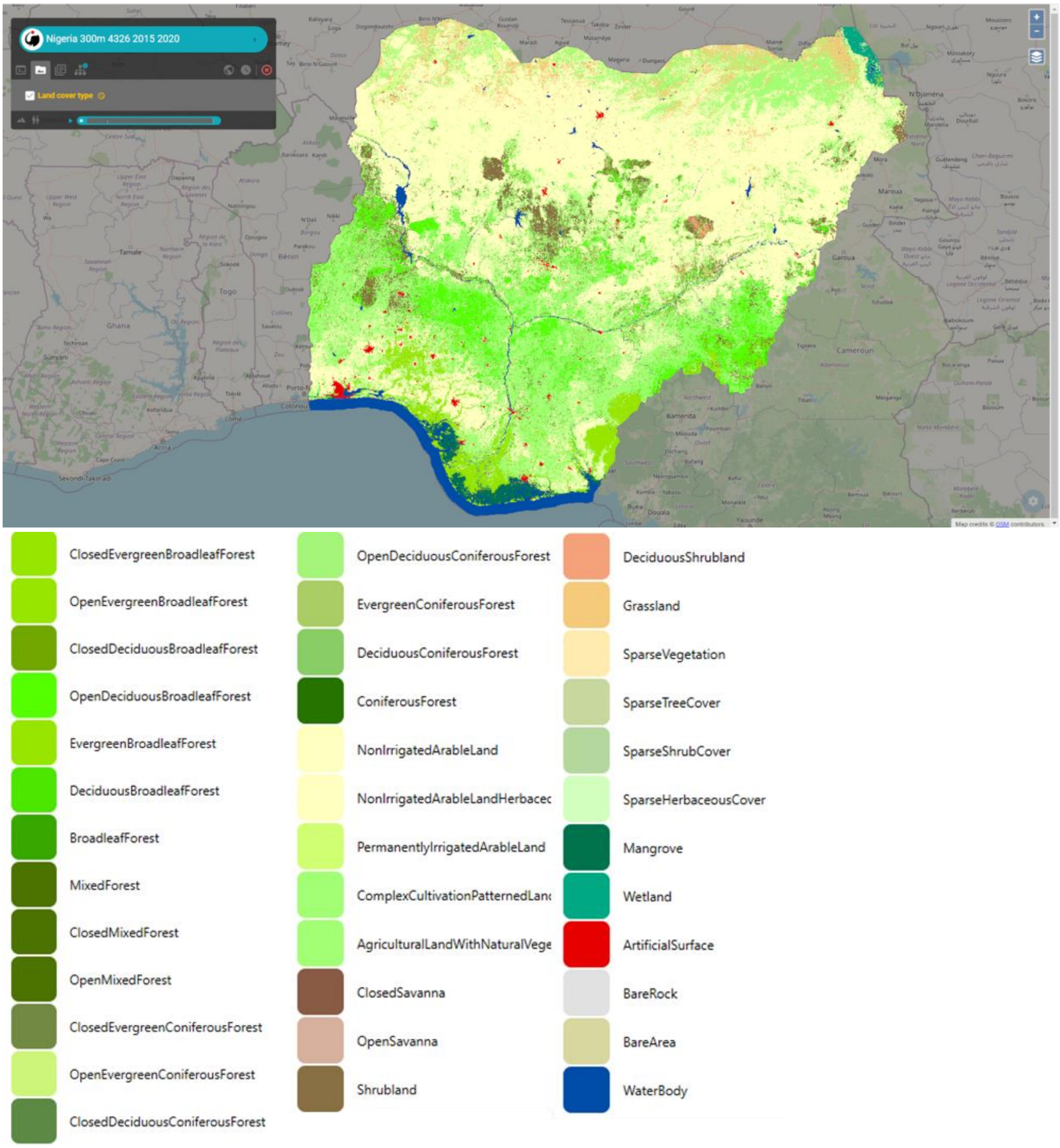


Table 1.2.1. - Land cover area in Nasarawa in 2015 and 2020
Table 1.2.2. - Land cover area in Kaduna in 2015 and 2020

LANDCOVER (in km^2)								
	Nasarawa				Kaduna			
Landcover	**in 2015**	**in 2020**	**net change**	**% change**	**in 2015**	**in 2020**	**net change**	**% change**
Artificial surface	97.80	118.00	20.20	20.65%	227.64	350.95	123.31	54.17%
Water body	187.00	201.00	14.00	7.49%	182.23	186.84	4.61	2.53%
Wetland	2.14	1.43	-0.71	-33.18%	0.00	0.00	0.00	0.0%
Mangrove	7.24	10.60	3.36	46.41%	0.18	0.18	0.00	0.0%
Permanently irrigated arable land	31.10	30.80	-0.30	-0.96%	29.98	29.80	-0.18	-0.6%
Non irrigated arable land	7.600.00	7.270.00	-330.00	-4.34%	18.134.31	17.907.57	-226.74	-1.25%
Non irrigated arable land herbaceous	253.00	331.00	78.00	30.83%	4.557.62	4.755.95	198.33	4.35%
Agricultural land with natural vegetation	12.000.00	12.300.00	300.00	2.5%	9.449.47	9.524.35	74.88	0.79%
Complex cultivation patterned land	1.610.00	1.510.00	-100.00	-6.21%	2.162.83	2.120.84	-41.99	-1.94%
Closed savanna	9.54	11.60	2.06	21.59%	3.21	7.21	4.00	124.61%
Open savanna	0.71	0.27	-0.44	-61.97%	0.89	0.98	0.09	10.11%
Shrubland	1.250.00	1.070.00	-180.00	-14.4%	7.899.18	7.600.06	-299.12	-3.79%
Deciduous shrubland	399.00	324.00	-75.00	-18.8%	449.04	358.82	-90.22	-20.09%
Grassland	1.00	1.00	0.00	0.%	2.04	2.04	0.00	0.0%
Evergreen broadleaf forest	0.09	0.09	0.00	0.%	0.00	0.00	0.00	0.0%
Open evergreen broadleaf forest	5.53	5.71	0.18	3.25%	0.80	0.71	-0.09	-11.25%
Closed evergreen broadleaf forest	6.69	6.69	0.00	0.%	0.45	0.53	0.08	17.78%
Deciduous broadleaf forest	372.00	485.00	113.00	30.38%	75.15	113.07	37.92	50.46%
Open deciduous broadleaf forest	2.960.00	3.000.00	40.00	1.35%	1.454.45	1.500.30	45.85	3.15%
Closed deciduous broadleaf forest	52.00	151.00	99.00	190.38%	55.26	224.70	169.44	306.62%
Bare area	0.98	1.00	0.02	2.04%	0.00	0.00	0.00	0.0%
Bare rock	1.00	1.00	0.00	0%	0.18	0.00	-0.18	-100.%
Total	***26.860.00***	***26.860.00***	***0.00***	***0%***	***44.684.90***	***44.684.90***	***0.00***	***0.0%***

Table 1.2.1, 1.2.2, 1.3.1, and 1.3.2 summarize the changes in the landscape by land cover category from 2015 to 2020 for the two pilot states. It is evident that in both states there was an increase in deciduous broadleaf forests and a loss of shrubland and deciduous shrubland vegetation. However, these changes should be carefully interpreted. One can notice how most of the increase in forest cover came at the expense of the other natural vegetation classes, and it is crucial to consider that these findings may not fully reflect the reality on the ground. The TWG also remarked how deforestation remains a pressing issue in both states, challenging the apparent positive trends in forest cover. Factors such as unsustainable land use practices and agricultural expansion could be contributing to the observed discrepancies between the data

and the ongoing environmental challenges, and this issue should be further explored in future analyses. The possibility of adding further information on land use, an input that was limited by the availability of data in this assessment, would help to shed more light on this issue.

Table 1.3.1 - Pairwise landcover change (in km^2) in Nasarawa between 2015 and 2020

	PAIRWISE LANDCOVER CHANGE (in km^2) Nasarawa																						
Landcover	Agricultural land with natural vegetation	Artificial surface	Bare area	Bare rock	Closed deciduous broadleaf forest	Closed evergreen broadleaf forest	Closed savanna	Complex cultivation patterned land	Deciduous broadleaf forest	Deciduous shrubland	Evergreen broadleaf forest	Grassland	Mangrove	Non irrigated arable land	Non irrigated arable land herbaceous	Open deciduous broadleaf forest	Open evergreen broadleaf forest	Open savanna	Permanently irrigated arable land	Shrubland	Water body	Wetland	Unaccounted
Agricultural land with natural vegetation	11,770.20	1.61	0.00	0.00	3.31	0.00	0.54	9.02	36.98	7.14	0.00	0.00	0.18	5.09	37.52	9.20	0.00	0.00	0.00	14.56	1.43	0.00	0.00
Artificial surface	0.45	108.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bare area	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bare rock	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Closed deciduous broadleaf forest	0.00	0.00	0.00	0.00	56.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
Closed evergreen broadleaf forest	0.00	0.00	0.00	0.00	0.00	6.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Closed savanna	0.18	0.27	0.00	0.00	0.09	0.00	6.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Complex cultivation patterned land	96.88	3.30	0.00	0.00	2.77	0.00	0.27	1,448.21	28.06	0.00	0.00	0.00	0.27	0.00	0.00	6.70	0.00	0.00	0.00	0.71	1.70	0.00	0.00
Deciduous broadleaf forest	39.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	330.12	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00
Deciduous shrubland	19.29	0.00	0.00	0.00	13.49	0.00	0.00	11.51	4.20	288.47	0.00	0.00	0.18	0.00	20.18	8.48	0.00	0.00	0.00	0.00	0.72	0.00	0.00
Evergreen broadleaf forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00
Non irrigated arable land	245.35	18.47	0.00	0.00	2.86	0.00	0.18	0.00	55.14	0.00	0.00	0.00	1.25	7,232.40	0.00	6.79	0.00	0.00	0.00	1.70	1.34	0.00	0.00
Non irrigated arable land herbaceous	11.88	0.00	0.00	0.00	0.18	0.00	0.00	0.00	3.13	0.00	0.00	0.00	0.00	0.00	232.64	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open deciduous broadleaf forest	0.00	0.00	0.00	0.00	19.20	0.00	0.18	0.00	12.33	0.00	0.00	0.00	0.00	0.00	0.09	2,861.04	0.00	0.00	0.00	0.45	1.43	0.00	0.00
Open evergreen broadleaf forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.73	0.00	0.00	0.00	0.00	0.00	0.00
Open savanna	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.45	0.00	0.00
Permanently irrigated arable land	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.82	0.00	0.09	0.00	0.00
Shrubland	34.29	0.09	0.00	0.00	48.58	0.00	1.34	15.09	12.50	0.00	0.00	0.18	1.52	0.00	41.38	32.68	0.18	0.00	0.36	1,027.79	6.98	0.00	0.00
Water body	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	200.72	0.00	0.00
Wetland	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	1.43	0.00
Unaccounted	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09

Table 1.3.2 - Pairwise landcover change (in km^2) in Kaduna between 2015 and 2020

	PAIRWISE LANDCOVER CHANGE (in km^2) Kaduna																			
Landcover	Agricultural land with natural vegetation	Artificial surface	Bare rock	Closed deciduous broadleaf forest	Closed evergreen broadleaf forest	Closed savanna	Complex cultivation patterned land	Deciduous broadleaf forest	Deciduous shrubland	Grassland	Mangrove	Non irrigated arable land	Non irrigated arable land herbaceous	Open deciduous broadleaf forest	Open evergreen broadleaf forest	Open savanna	Permanently irrigated arable land	Shrubland	Water body	Unaccounted
Agricultural land with natural vegetation	9,274.81	14.82	0.00	7.19	0.00	0.09	5.15	18.03	2.14	0.00	0.00	6.93	70.25	12.08	0.00	0.00	0.00	37.71	0.27	0.00
Artificial surface	0.00	227.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bare rock	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Closed deciduous broadleaf forest	0.00	0.00	0.00	55.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Closed evergreen broadleaf forest	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Closed savanna	0.00	0.00	0.00	0.00	0.00	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Complex cultivation patterned land	57.16	7.54	0.00	2.04	0.00	0.00	2,073.27	9.23	0.00	0.00	0.00	0.00	0.00	3.64	0.00	0.00	0.00	9.15	0.80	0.00
Deciduous broadleaf forest	11.28	0.00	0.00	0.00	0.00	0.00	0.00	63.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00
Deciduous shrubland	22.66	0.09	0.00	33.04	0.00	0.18	10.07	3.37	356.69	0.00	0.00	0.00	10.86	12.09	0.00	0.00	0.00	0.00	0.00	0.00
Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangrove	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non irrigated arable land	94.54	95.01	0.00	0.98	0.00	0.00	0.00	7.90	0.00	0.00	0.00	17,900.63	0.00	0.98	0.00	0.00	0.00	31.26	3.01	0.00
Non irrigated arable land herbaceous	2.40	5.41	0.00	0.09	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	4,549.10	0.18	0.00	0.00	0.00	0.18	0.00	0.00
Open deciduous broadleaf forest	0.00	0.00	0.00	21.50	0.00	2.32	0.00	3.56	0.00	0.00	0.00	0.00	1.07	1,425.74	0.00	0.00	0.00	0.00	0.27	0.00
Open evergreen broadleaf forest	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00
Open savanna	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00
Permanently irrigated arable land	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.71	0.00	0.09	0.00
Shrubland	61.40	0.18	0.00	104.60	0.00	1.42	32.35	7.01	0.00	0.00	0.00	0.00	124.68	45.60	0.00	0.09	0.09	7,521.76	0.00	0.00
Water body	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	182.23	0.00
Unaccounted	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09

Image 1.2 - Land cover map of Kaduna state in 2015

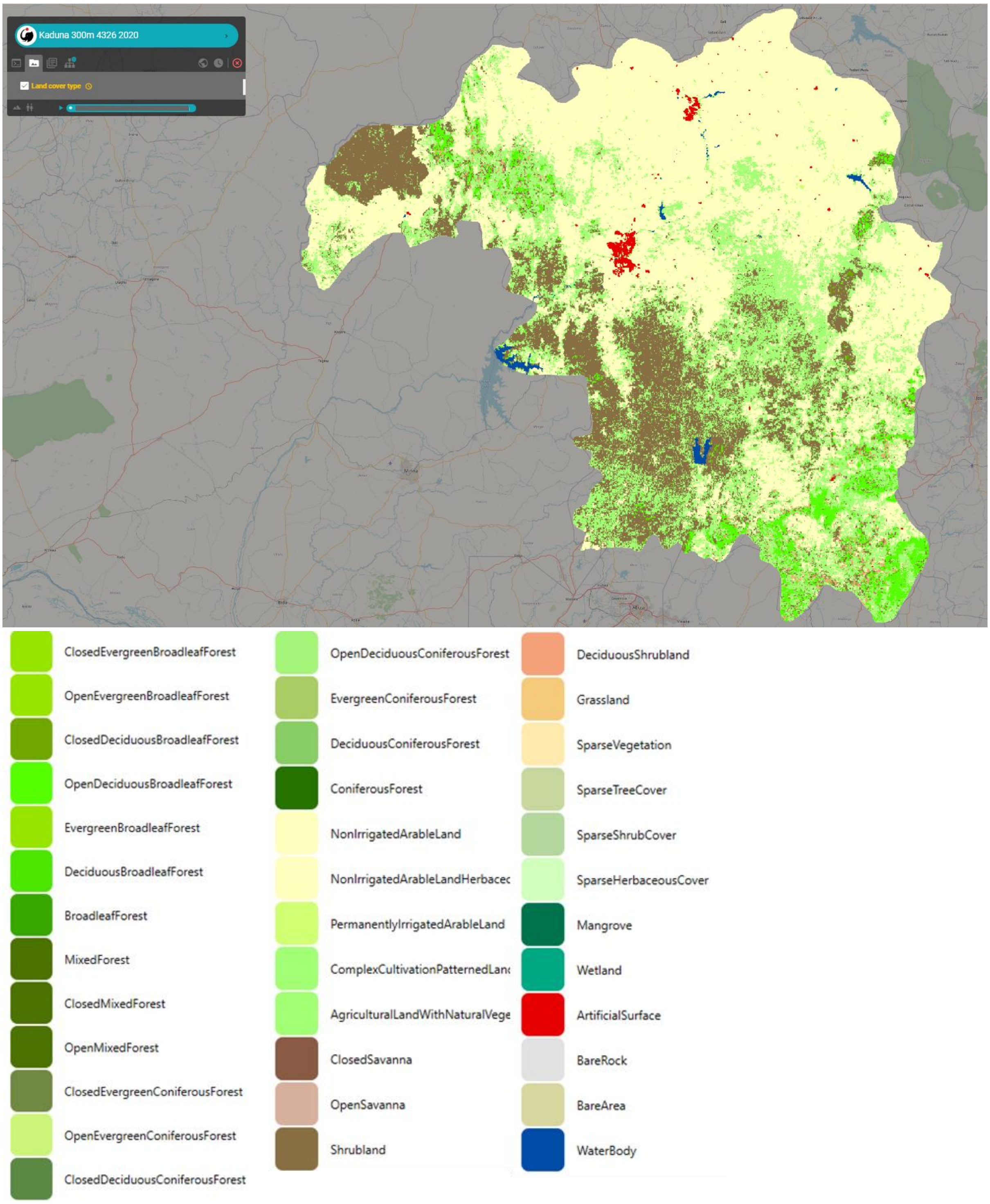
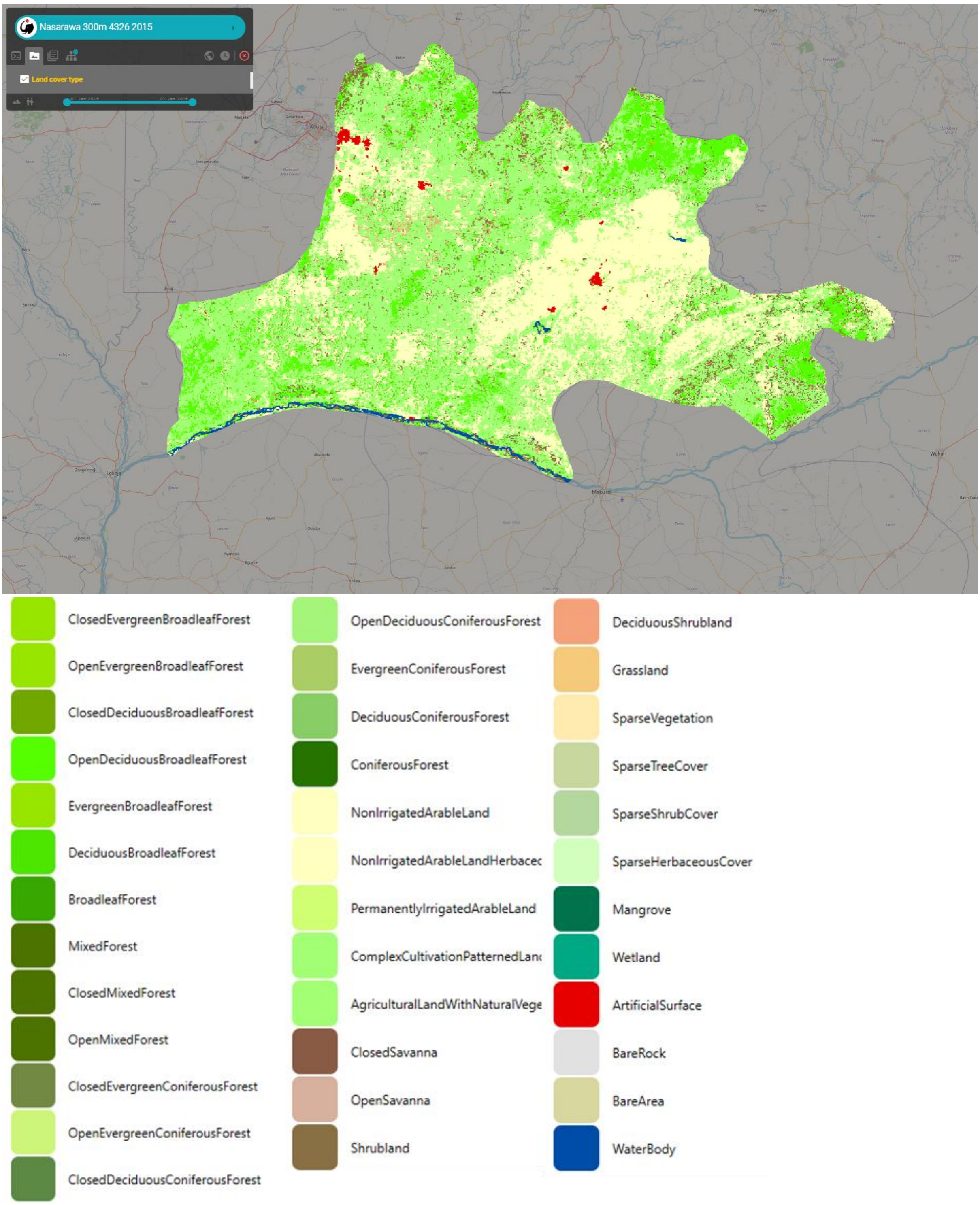


Image 1.3 - Land cover map of Nasarawa state in 2015



3.1.1 Ecosystem extent accounts

Image 1.4.1.1 – Ecosystem Type map in Nasarawa in 2015

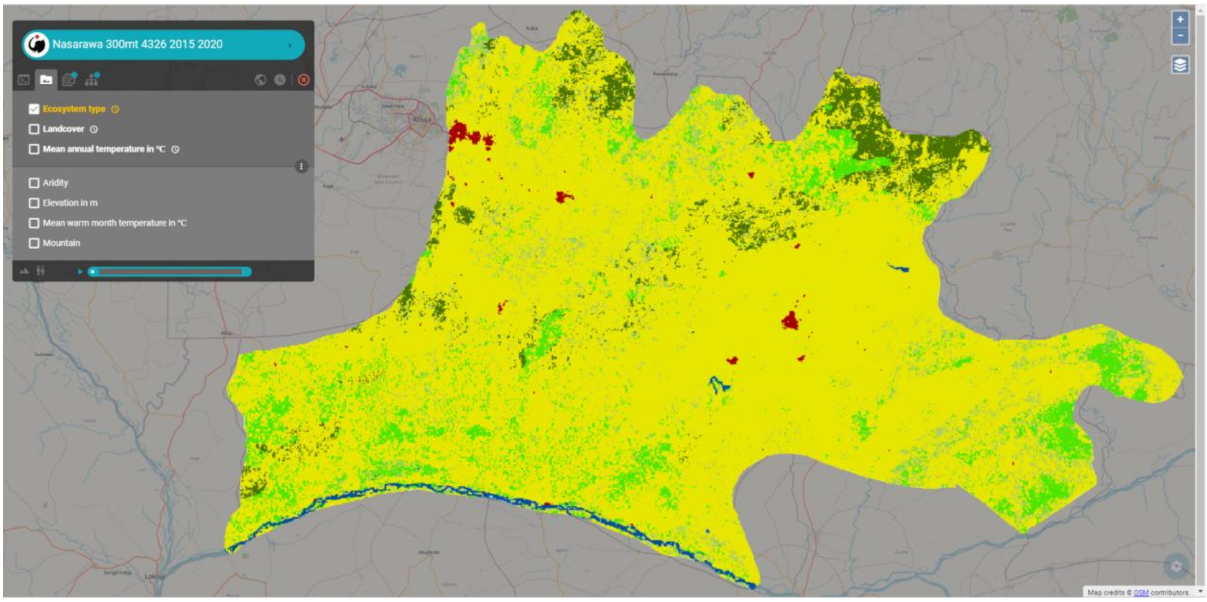


Image 1.4.1.2 – Ecosystem Type map in Nasarawa in 2020

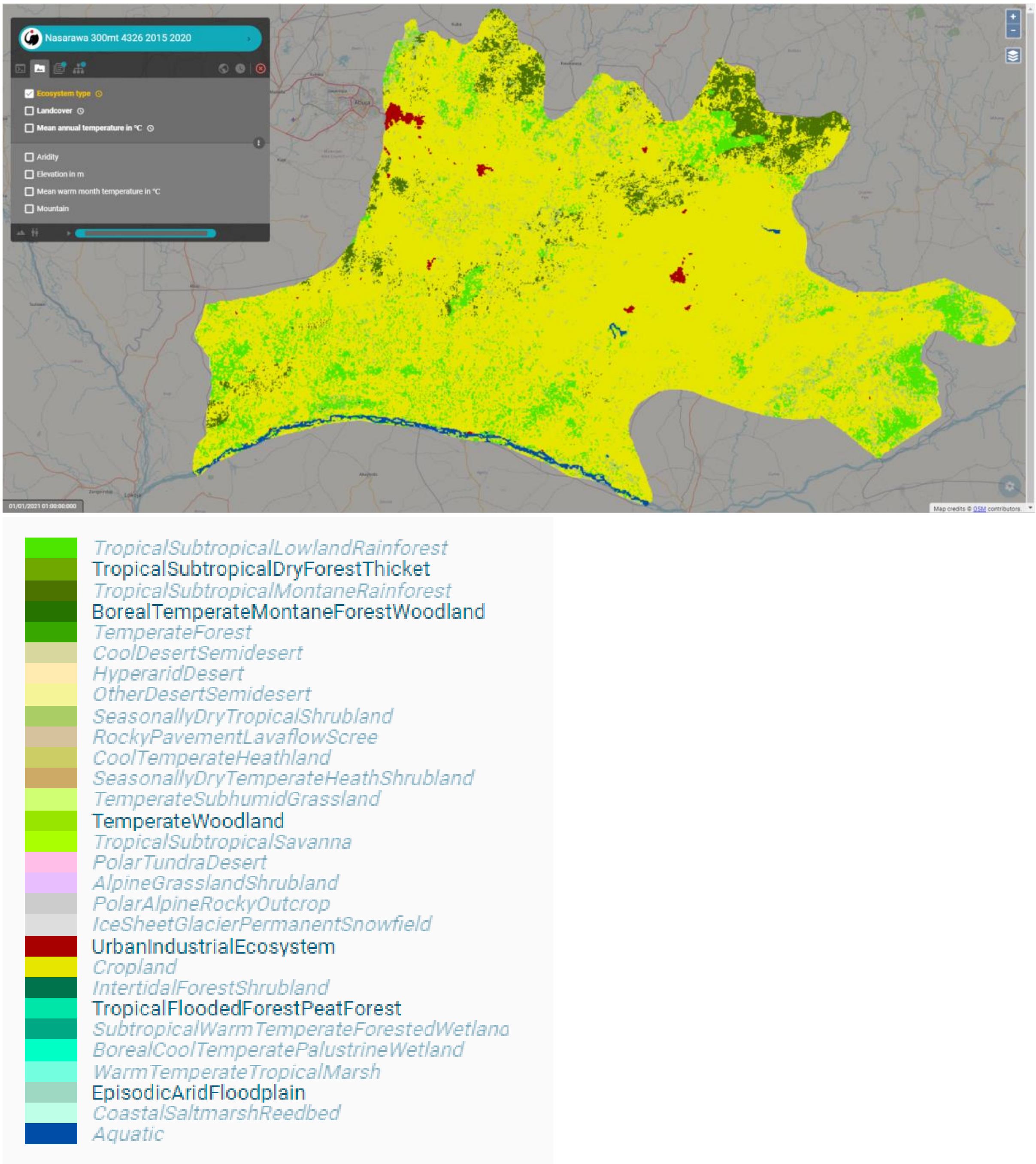


Table 1.5.1 – Ecosystem addition and reduction account in Nasarawa between 2015 and 2020

	Aquatic	Cropland	Intertidal forest shrubland	Rocky pavement lavaflow scree	Seasonally dry temperate heath shrubland	Seasonally dry tropical shrubland	Tropical subtropical lowland rainforest	Tropical subtropical montane rainforest	Tropical subtropi cal savanna	Urban industrial ecosystem	Warm temperate tropical marsh	Totals
Opening area 2015	200.72	21331.03	9.75	2.33	8.83	1580.64	2196.40	1136.61	10.45	108.55	2.24	26587.62
Expansions	15.92	183.11	3.40	0.00	0.00	24.57	209.01	67.21	2.68	24.36	0.00	530.26
Regressions	0.00	211.02	0.45	0.27	0.36	272.85	33.70	9.10	1.25	0.45	0.81	530.26
Net change	15.92	-27.92	2.95	-0.27	-0.36	-248.29	175.31	58.10	1.43	23.92	-0.81	0.00

	Aquatic	Cropland	Intertidal forest shrubland	Rocky pavement lavaflow scree	Seasonally dry temperate heath shrubland	Seasonally dry tropical shrubland	Tropical subtropical lowland rainforest	Tropical subtropical montane rainforest	Tropical subtropi cal savanna	Urban industrial ecosystem	Warm temperate tropical marsh	Totals
Closing area at start of 2021	216.64	21303.11	12.70	2.06	8.47	1332.35	2371.71	1194.71	11.88	132.46	1.43	26587.62

Table 1.6.1 – Ecosystem matrix of changes account in Nasarawa between 2015 and 2020

	Aquatic	Cropland	Intertidal forest shrublan d	Rocky pavement lavaflow scree	Seasonally dry temperate heath shrubland	Seasonally dry tropical shrubland	Tropical subtropical lowland rainforest	Tropical subtropic al montane rainforest	Tropical subtropical savanna	Urban industrial ecosystem	Warm temperate tropical marsh
Aquatic	200.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	4.56	21120.00	1.70	0.00	0.00	24.12	123.07	32.58	0.98	24.01	0.00
Intertidal forest shrubland	0.45	0.00	9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky pavement lavaflow scree	0.27	0.00	0.00	2.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seasonally dry temperate heath shrubland	0.00	0.00	0.00	0.00	8.47	0.00	0.00	0.00	0.36	0.00	0.00
Seasonally dry tropical shrubland	7.69	142.09	1.70	0.00	0.00	1307.79	85.67	34.45	1.16	0.09	0.00
Tropical subtropical lowland rainforest	2.24	31.46	0.00	0.00	0.00	0.00	2162.70	0.00	0.00	0.00	0.00
Tropical subtropical montane rainforest	0.00	8.48	0.00	0.00	0.00	0.45	0.00	1127.50	0.18	0.00	0.00
Tropical subtropical savanna	0.45	0.18	0.00	0.00	0.00	0.00	0.18	0.18	9.20	0.27	0.00
Urban industrial ecosystem	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108.10	0.00
Warm temperate tropical marsh	0.27	0.45	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	1.43

Image 1.4.2.1 – Ecosystem Type map in Kaduna in 2015

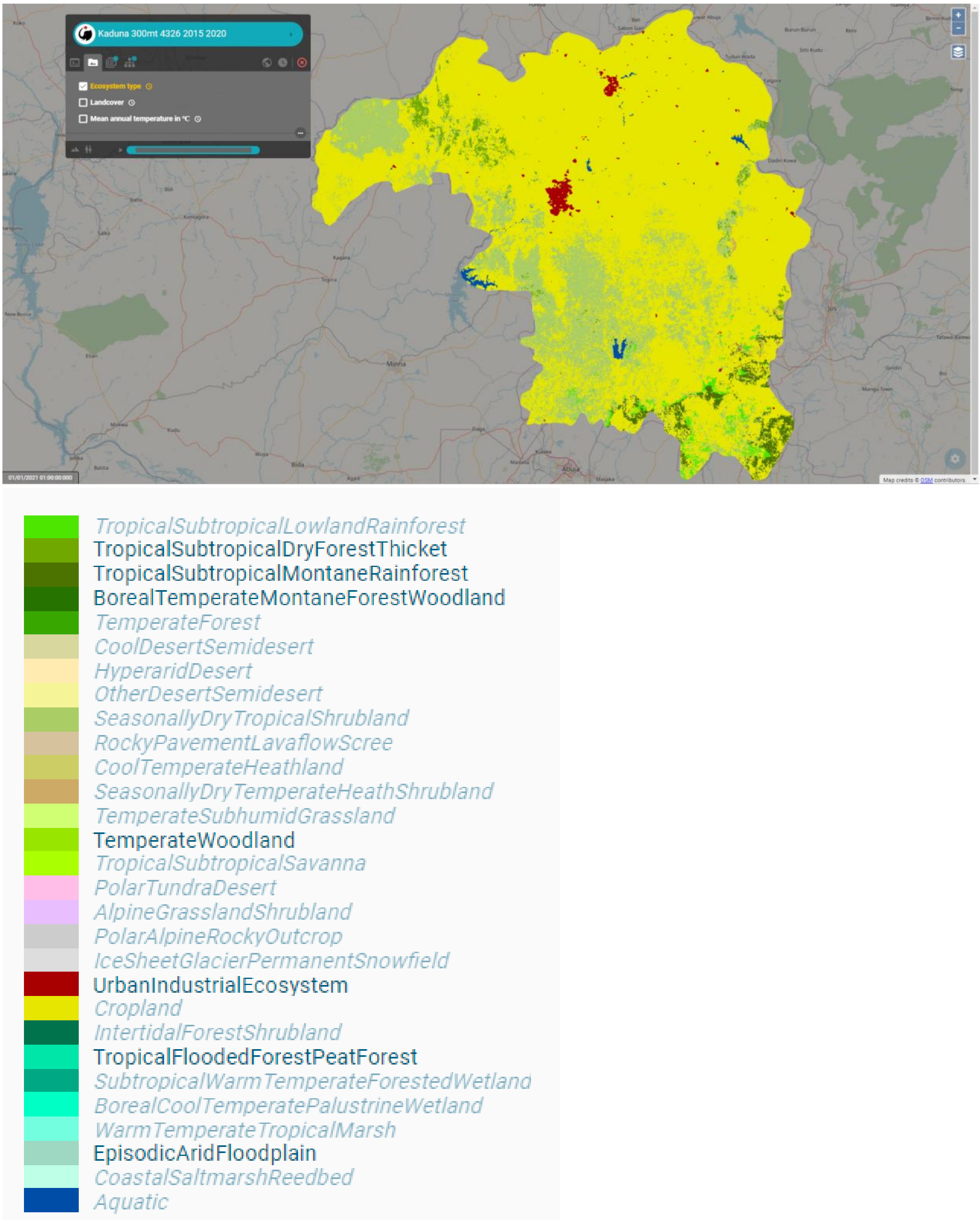


Image 1.4.2.2 – Ecosystem Type map in Kaduna in 2020

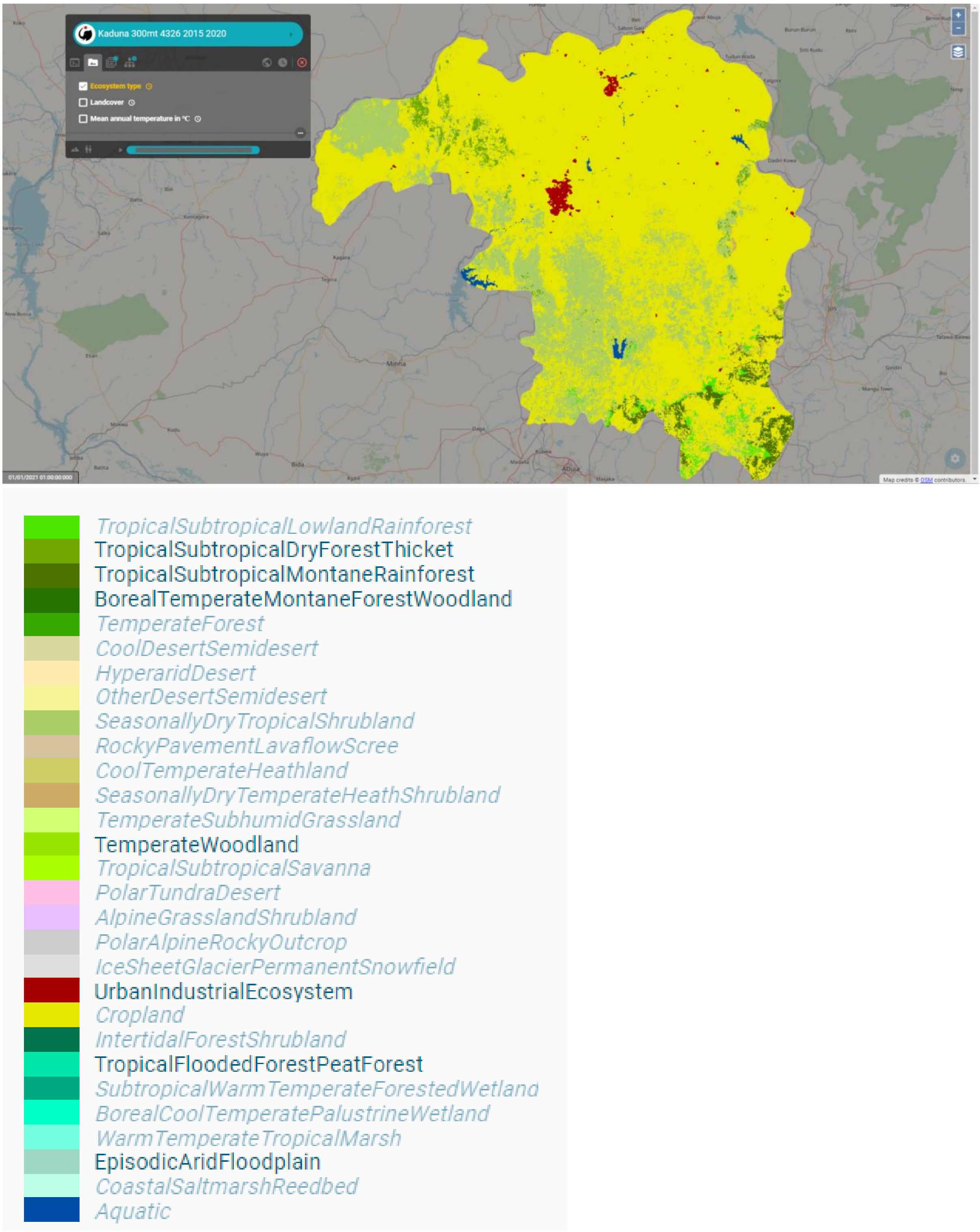


Table 1.5.2 – Ecosystem addition and reduction account in Kaduna between 2015 and 2020

	Aquatic	Cropland	Intertidal forest shrubland	Rocky pavement lavaflow scree	Seasonally dry temperate heath shrubland	Seasonally dry tropical shrubland	Tropical subtropical dry forest thicket	Tropical subtropical lowland rainforest	Tropical subtropical montane rainforest	Tropical subtropical savanna	Urban industrial ecosystem	Totals
Opening area 2015	182.23	34334.21	0.18	0.18	67.79	8280.43	419.83	411.23	755.05	6.14	227.64	44684.99
Expansions	4.61	274.45	0.00	0.00	59.14	79.28	174.98	43.55	49.78	4.10	123.30	813.19
Regressions	0.00	270.16	0.00	0.18	6.67	521.08	7.54	1.25	6.32	0.00	0.00	813.19
Net change	4.61	4.30	0.00	-0.18	52.46	-441.80	167.44	42.30	43.46	4.10	123.30	0.00
Closing area at start of 2021	186.84	34338.50	0.18	0.00	120.25	7838.64	587.27	453.53	798.51	10.23	350.95	44684.99

Table 1.6.2 – Ecosystem matrix of changes account in Kaduna between 2015 and 2020

	Aquatic	Cropland	Intertidal forest shrubland	Rocky pavement lavaflow scree	Seasonally dry temperate heath shrubland	Seasonally dry tropical shrubland	Tropical subtropical dry forest thicket	Tropical subtropical lowland rainforest	Tropical subtropical montane rainforest	Tropical subtropical savanna	Urban industrial ecosystem
Aquatic	182.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cropland	4.17	34064.05	0.00	0.00	1.15	79.28	40.43	8.99	13.18	0.09	122.86
Intertidal forest shrubland	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky pavement lavaflow scree	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Seasonally dry temperate heath shrubland	0.00	1.60	0.00	0.00	61.11	0.00	0.00	1.07	2.76	1.25	0.00
Seasonally dry tropical shrubland	0.00	260.51	0.00	0.00	57.98	7759.35	134.55	33.48	33.85	0.44	0.27
Tropical subtropical dry forest thicket	0.44	7.09	0.00	0.00	0.00	0.00	412.29	0.00	0.00	0.00	0.00
Tropical subtropical lowland rainforest	0.00	1.25	0.00	0.00	0.00	0.00	0.00	409.99	0.00	0.00	0.00
Tropical subtropical montane rainforest	0.00	4.01	0.00	0.00	0.00	0.00	0.00	0.00	748.72	2.32	0.00
Tropical subtropical savanna	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.14	0.00
Urban industrial ecosystem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	227.64

5.2 Regulation services

5.2.1 Climate regulation

Table 2.1.1 - Carbon storage in Nasarawa in 2015 and 2020

Landcover class	Tons of Carbon in 2015	Tons of Carbon in 2020	Net change	% change
Artificial surface	2508719.866	3794998.436	1286278.57	51.27
Mangrove	4895.950757	4895.950757	0	0
Permanently irrigated arable land	351274.9247	348046.8819	-3228.042776	-0.92
Non irrigated arable land	1.97E+08	1.94E+08	-2444490.85	-1.24
Non irrigated arable land herbaceous	4.74E+07	4.98E+07	2350623.007	4.96
Agricultural land with natural vegetation	1.82E+08	1.83E+08	1316047.253	0.72
Complex cultivation patterned land	3.99E+07	3.91E+07	-745420.8884	-1.87
Closed savanna	92462.48758	223419.1651	130956.6775	141.63
Open savanna	18174.74404	19976.87887	1802.134828	9.92
Shrubland	1.32E+08	1.27E+08	-4991362.286	-3.79
Deciduous shrubland	7601692.825	6101509.213	-1500183.612	-19.73
Grassland	30578.09278	30578.09278	0	0
Open evergreen broadleaf forest	26507.47536	23802.0768	-2705.39856	-10.21
Closed evergreen broadleaf forest	14518.96745	17224.36601	2705.39856	18.63
Deciduous broadleaf forest	1970207.457	2879042.642	908835.1852	46.13
Open deciduous broadleaf forest	4.13E+07	4.28E+07	1536601.846	3.72
Closed deciduous broadleaf forest	1645476.437	5829923.114	4184446.677	254.3
Bare rock	1980.406104	0	-1980.406104	-100
Total	6.53E+08	6.55E+08	2028925.265	0.31

Table 2.1.2 - Carbon storage in Kaduna in 2015 and 2020

Landcover class	Tons of Carbon in 2015	Tons of Carbon in 2020	Net change	% change
Artificial surface	2508719.866	3794998.436	1286278.57	51.27
Mangrove	4895.950757	4895.950757	0	0
Permanently irrigated arable land	351274.9247	348046.8819	-3228.042776	-0.92
Non irrigated arable land	1.97E+08	1.94E+08	-2444490.85	-1.24
Non irrigated arable land herbaceous	4.74E+07	4.98E+07	2350623.007	4.96
Agricultural land with natural vegetation	1.82E+08	1.83E+08	1316047.253	0.72
Complex cultivation patterned land	3.99E+07	3.91E+07	-745420.8884	-1.87
Closed savanna	92462.48758	223419.1651	130956.6775	141.63
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Open evergreen broadleaf forest	26507.47536	23802.0768	-2705.39856	-10.21
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Bare rock	1980.406104	0	-1980.406104	-100
Total	6.53E+08	6.55E+08	2028925.265	0.31

While certain land cover classes experienced drastic changes over the period, 2015-2020, the total carbon stock in both states was fairly stable. The changes in carbon stock are aligned with the land cover changes observed in the previous accounts.

Image 2.1 - Carbon organic mass in Kaduna state in 2020

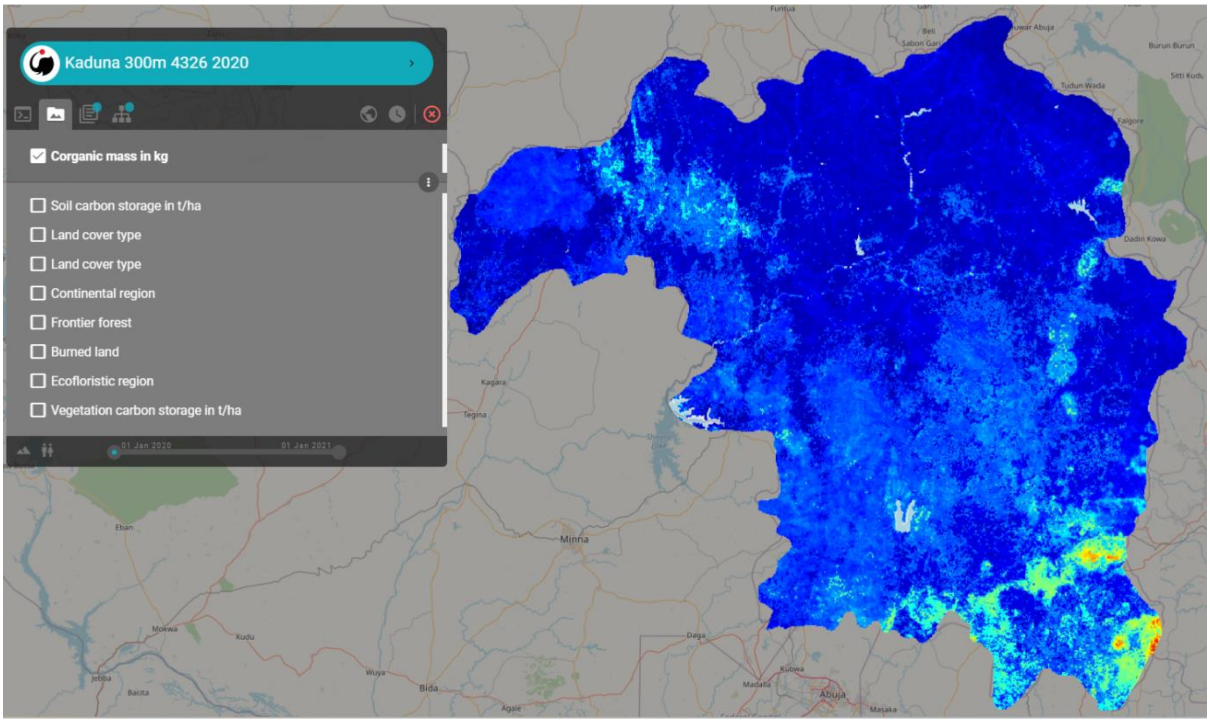


Image 2.2. - Carbon organic mass in Nasarawa state in 2020

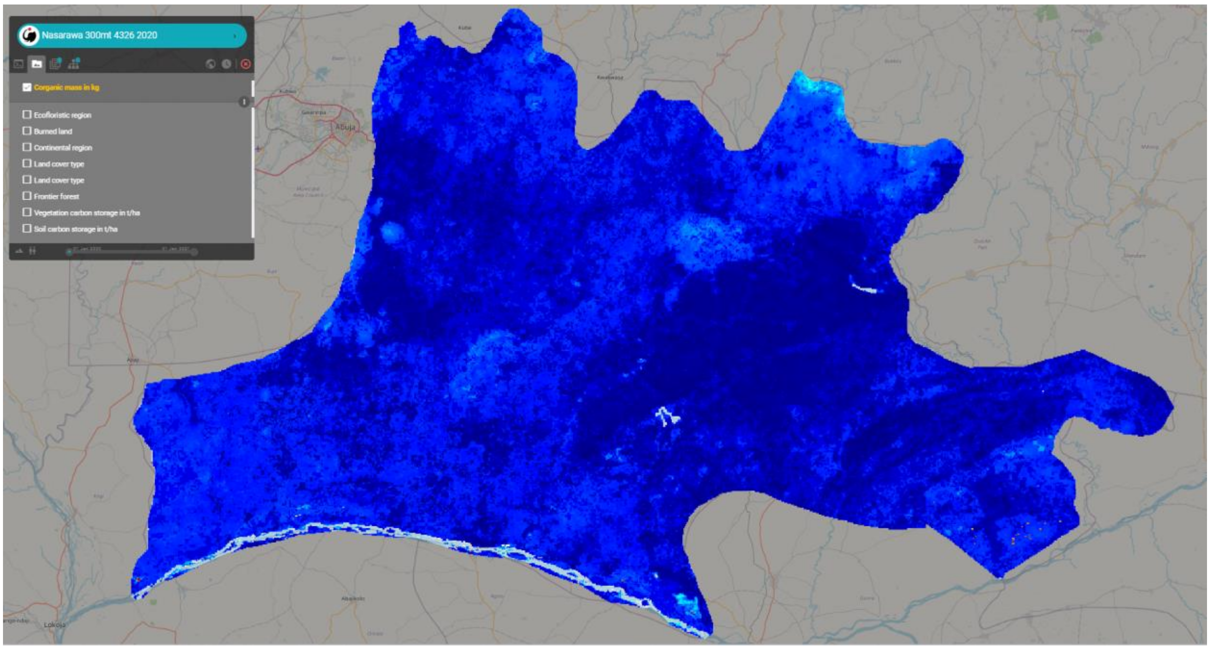


Table 2.2.1 - Vegetation carbon storage in Nasarawa in 2015 and 2020

Landcover class	Tons of Vegetation Carbon in 2015	Tons of Vegetation Carbon in 2020	Net change	% change
Grassland	1000.3894677832457	1071.9362566596908	71.54678888	7.15
Mangrove	110011.72863569463	161620.19976332365	51608.47113	46.91
Open evergreen broadleaf forest	82652.52707505762	86718.19729710903	4065.670222	4.92
Total	1.65279893948763738	1.6927598950984332E8	3996095.561	2.42
Non irrigated arable land herbaceous	126582.49158701584	165266.0144056432	38683.52282	30.56
Open deciduous broadleaf forest	4.35225521416514147	4.3857050082211055E7	334497.9406	0.77
Agricultural land with natural vegetation	9.126674548895642E7	9.3767698084025167	2500952.595	2.74
Deciduous broadleaf forest	5553873.6945291795	7284006.662566391	1730132.968	31.15
Closed savanna	72495.74375953198	88083.8218829193	15588.07812	21.5
Closed deciduous broadleaf forest	759587.8006837748	2254528.517157353	1494940.716	196.81
Bare area	98.24330061336643	98.24330061336643	0	0
Evergreen broadleaf forest	1358.0507827624417	1358.0507827624417	0	0
Shrubland	5751363.659225176	4904355.276625653	-847008.3826	-14.73
Complex cultivation patterned land	1.2242383526895292E7	1.1438868288484452E7	-803515.2384	-6.56
Deciduous shrubland	1834427.4920099452	1489383.4090248756	-345044.083	-18.81
Open savanna	5431.964691616602	2036.4869643389857	-3395.477727	-62.51
Bare rock	89.34666766785178	62.542920349712645	-26.80374732	-30
Non irrigated arable land	3800177.3832511785	3637077.1001642514	-163100.2831	-4.29
Closed evergreen broadleaf forest	100943.15175785181	99586.56497269766	-1356.586785	-1.34
Permanently irrigated arable land	15525.677624866023	15391.780519328962	-133.8971055	-0.86
Wetland	32593.44625110432	21728.250562281093	-10865.19569	-33.34

Table 2.2.2 - Vegetation carbon storage in Kaduna in 2015 and 2020

Landcover class	Tons of Vegetation Carbon in 2015	Tons of Vegetation Carbon in 2020	Net change	% change
Mangrove	2696.3199193836253	2696.3199193836253	0	0
Permanently irrigated arable land	14989.37378169515	14900.660046080407	-88.71373561	-0.59
Non irrigated arable land	9067156.51724844	8953783.64915959	-113372.8681	-1.25
Non irrigated arable land herbaceous	2278807.9443234666	2377975.6339776004	99167.68965	4.35
Agricultural land with natural vegetation	7.044379346431302E7	7.10090981584241E7	565304.6941	0.8
Complex cultivation patterned land	1.5976371858104566E7	1.5652858581483632E7	-323513.2766	-2.02
Closed savanna	22185.44760346157	52644.09874205234	30458.65114	137.29
Open savanna	6747.801283895912	7422.492155387157	674.6908715	10
Shrubland	3.631940141106325E7	3.4944740594394497	-1374660.817	-3.78
Deciduous shrubland	2058074.2866895213	1644047.7661601182	-414026.5205	-20.12
Grassland	1634.6491237192288	1634.6491237192288	0	0
Open evergreen broadleaf forest	12180.478028499667	10827.778748628854	-1352.69928	-11.11
Closed evergreen broadleaf forest	6765.428298606281	8118.127578477093	1352.69928	19.99
Deciduous broadleaf forest	981939.8704806224	1474789.9565674108	492850.0861	50.19
Open deciduous broadleaf forest	1.9725301028802287E7	2.07046824690286147	979381.4402	4.97
Closed deciduous broadleaf forest	793596.8139188598	2938599.5285637276	2145002.715	270.29
Bare rock	17.761489720109793	0	-17.76148972	-100
Total	1.5771166045450264E8	1.59798820464097478	2087160.01	1.32

The vegetation carbon stock (*Table 2.2.1 and 2.2.2*) follows similar patterns to the total carbon stock but shows some more prominent changes. The Artificial surface and waterbody land cover classes do not store vegetation carbon according to this methodology, and for this reason, they do not appear in this table**. The vegetation carbon stock in both states stayed stable.** These results could be improved by comparing them with the Nigerian GHG inventory. These data on carbon stock could be spatialized based on the location of known vegetation provided by other spatial explicit layers containing this information, following the same approach used for crop provisioning services.

Image 2.3 - Vegetation carbon stock in Kaduna state in 2015

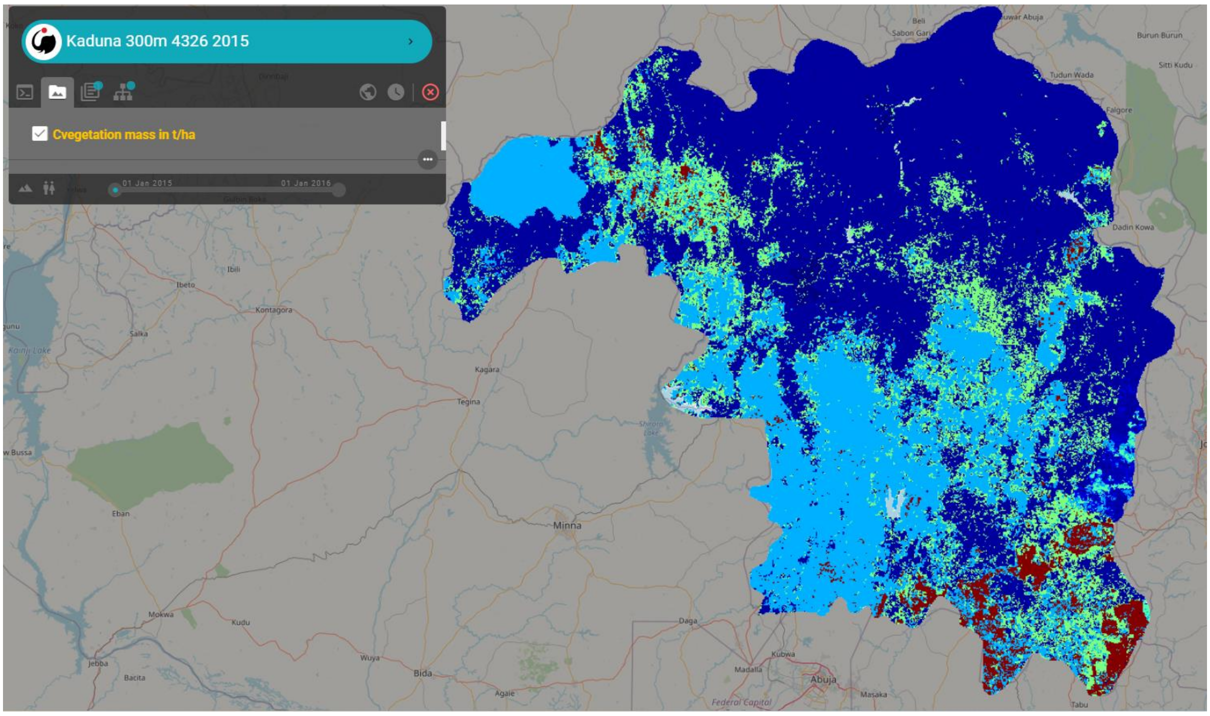


Image 2.4 - Vegetation carbon stock in Nasarawa state in 2015

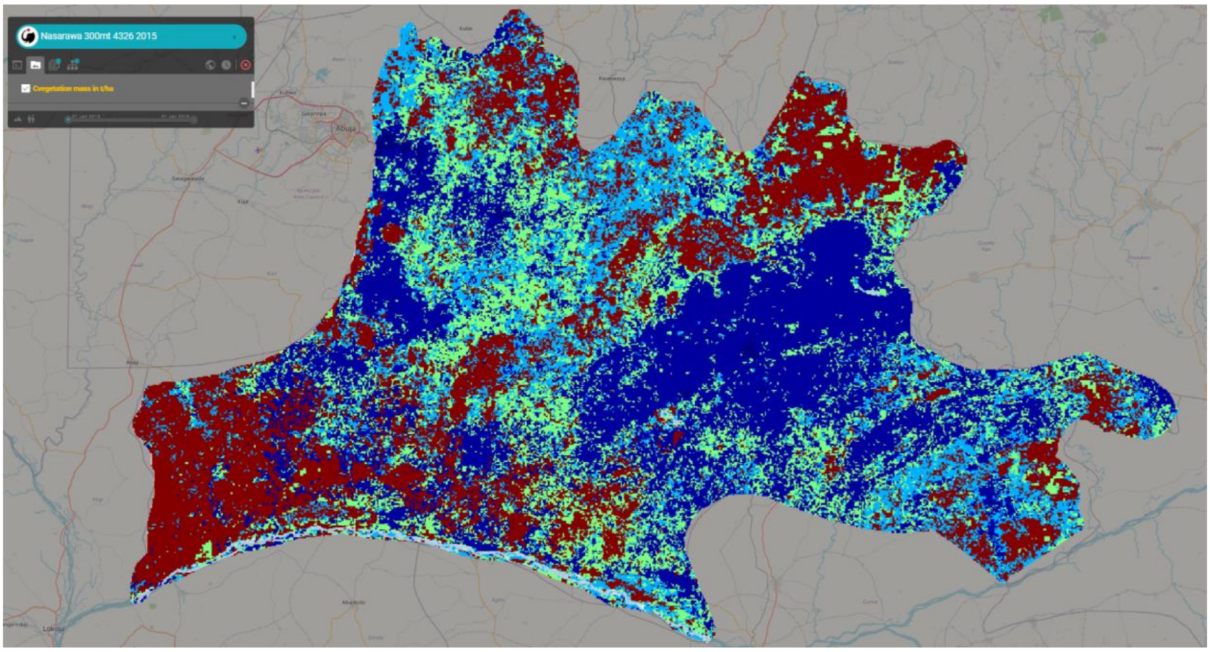


Table 2.3.1 - Soil organic carbon storage in Nasarawa between 2015 and 2020

Landcover class	Tons of Soil Organic Carbon in 2015	Tons of Soil Organic Carbon in 2020	Net change	% change
Artificial surface	978195.9046549929	1170941.7402058027	192745.8356	19.7
Water body	1671968.6348380158	1959419.1368261746	287450.502	17.19
Wetland	38498.48696528567	26820.62756009731	-11677.85941	-30.33
Mangrove	123165.39742598715	171460.56684691654	48295.16942	39.21
Permanently irrigated arable land	289534.4168561159	285499.24310661067	-4035.17375	1-1.39
Non irrigated arable land	7.1967319184926877	6.8712628408401437	-3254690.777	-4.52
Non irrigated arable land herbaceous	2604341.983841043	3410899.0094664604	806557.0256	30.97
Agricultural land with natural vegetation	1.29847487540977878	1.33097413000255158	3249925.459	2.5
Complex cultivation patterned land	1.60574869062399187	1.49509558359491277	-1106531.07	-6.89
Closed savanna	199512.07749091767	236246.38874464977	36734.31125	18.41
Open savanna	24106.49063395253	4939.886249076193	-19166.60438	-79.51
Shrubland	1.50360577221903957	1.2882551542881632E7	-2153506.179	-14.32
Deciduous shrubland	4291328.07878978	3512475.270812777	-778852.808	-18.15
Grassland	24412.644740118423	25575.119939366054	1162.475199	4.76
Evergreen broadleaf forest	1509.9380413608728	1509.9380413608728	0	0
Open evergreen broadleaf forest	97068.97595518682	100510.53108400958	3441.555129	3.55
Closed evergreen broadleaf forest	112140.98024153696	112140.98024153696	0	0
Deciduous broadleaf forest	3963093.594440172	5130161.465348417	1167067.871	29.45
Open deciduous broadleaf forest	3.85935197020075257	3.9001321827257937	407802.1253	1.06
Closed deciduous broadleaf forest	654554.0545055927	1790543.482636725	1135989.428	173.55
Bare area	18603.70519601696	18603.70519601696	0	0
Bare rock	17761.507794360612	9050.221703230713	-8711.286091	-49.05
Total	2.86612803247342058	2.86612803247342058	0	0

Table 2.3.2 - Soil organic carbon storage in Kaduna between 2015 and 2020

Landcover class	Tons of Soil Organic Carbon in 2015	Tons of Soil Organic Carbon in 2020	Net change	% change
Artificial surface	2508719.865625182	3794998.4359697257	1286278.57	51.27
Water body	1004678.7780427363	1062200.104269899	57521.32623	5.73
Mangrove	2199.630837784543	2199.630837784543	0	0
Permanently irrigated arable land	336418.5136813976	333279.1846407547	-3139.329041	-0.93
Non irrigated arable land	1.8758644905197555E8	1.8525524233192058	-2331206.72	-1.24
Non irrigated arable land herbaceous	4.514828833701937E7	4.7399743654122967	2251455.317	4.99
Agricultural land with natural vegetation	1.111663651786328E8	1.11917785674114448	751420.4955	0.68
Complex cultivation patterned land	2.39183892606793237	2.3496481648876727E7	-421907.6118	-1.76
Closed savanna	70277.03997432887	170775.066362504	100498.0264	143
Open savanna	11426.942760662558	12554.386716970297	1127.443956	9.87
Shrubland	9.538228409649858E7	9.1764356085868587	-3617928.011	-3.79
Deciduous shrubland	5543618.538080241	4457461.447026739	-1086157.091	-19.59
Grassland	28943.443656080584	28943.443656080584	0	0
Open evergreen broadleaf forest	14326.997335245984	12974.298055375171	-1352.69928	-9.44
Closed evergreen broadleaf forest	7753.539149154506	9106.238429025318	1352.69928	17.45
Deciduous broadleaf forest	989616.0052700468	1406951.864817265	417335.8595	42.17
Open deciduous broadleaf forest	2.1562460462767627E7	2.2119680868344177E7	557220.4056	2.58
Closed deciduous broadleaf forest	851879.6232188321	2891323.585793807	2039443.963	239.41
Bare rock	1962.644614072139	0	-1962.644614	-100
Total	4.961369049644165E8	4.961369049644165E8	0	0

Table 2.3.1 and 2.3.2 show the disaggregation by land cover class of the Soil Organic Carbon between 2015 and 2020. **Some significant changes can be observed e.g., carbon stores the Kaduna's soil in Open Savanna decreased by almost 80%.** These changes are the results of land cover changes (there was a decrease of around 60% in the area covered by this land cover class). Another example if the decrease of Shrubland and Deciduous Shrubland. There is no change in the overall soil carbon because both 2015 and 2020 are estimated using the same map. The reason for this choice is to provide a result consistent since maps from different years used different methodologies that are not comparable, but this output is useful for assessing the total carbon stock in Table 2.1 of this section.

Image 2.5 - Soil organic carbon stock in Kaduna state in 2020

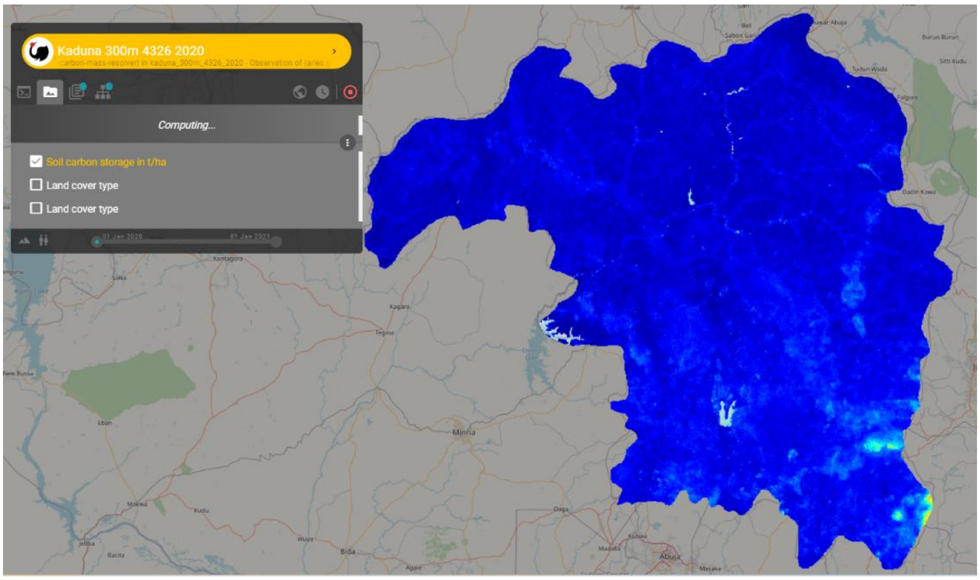
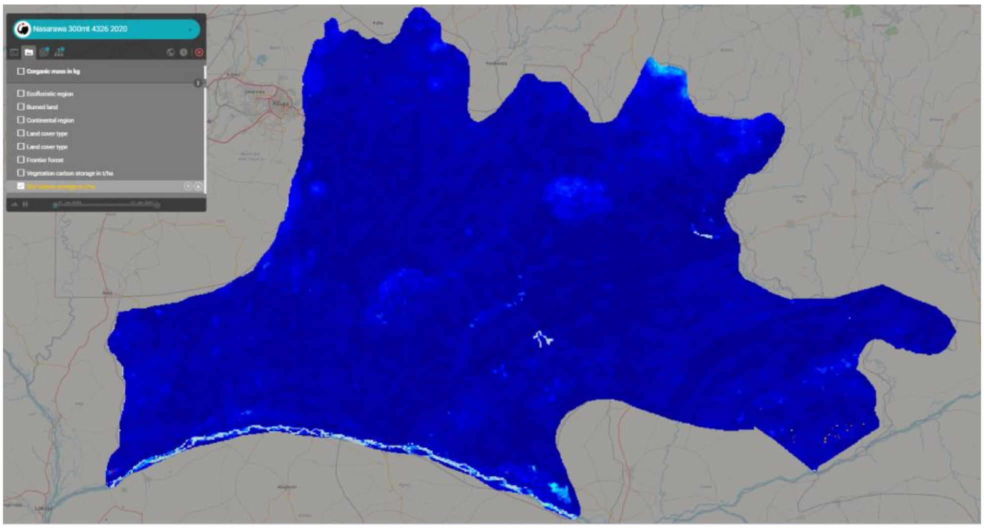


Image 2.6. - Soil organic carbon stock in Nasarawa state in 2020



5.3 Soil and sediment retention

Table 3.1 - Retained soil in Nasarawa in 2015 and 2020

Landcover class	Tons of Retained Soil in 2015	Tons of Retained Soil in 2020	Net change	% change
Agricultural land with natural vegetation	2.33314808249154247	2.3702763573874627	371282.749	1.59
Closed deciduous broadleaf forest	397877.5950300814	912263.6130017437	514386.018	129.28
Closed evergreen broadleaf forest	172491.02729044307	172491.02729044307	0	0
Closed savanna	298107.13271858636	319625.88956425874	21518.75685	7.22
Complex cultivation patterned land	1554221.346903554	1429724.818840191	-124496.5281	-8.01
Deciduous broadleaf forest	1379306.3336615476	1655462.8372264581	276156.5036	20.02
Deciduous shrubland	1098858.522175086	893539.7949155727	-205318.7273	-18.68
Evergreen broadleaf forest	26.837402716731486	26.837402716731486	0	0
Grassland	862.7217238153403	873.4042608802904	10.68253706	1.24
Mangrove	3775.4455721296704	6655.256631694328	2879.81106	76.28
Non irrigated arable land	4905409.59463774	4654581.112861294	-250828.4818	-5.11
Non irrigated arable land herbaceous	145881.33346826382	200937.20297817604	55055.86951	37.74
Open deciduous broadleaf forest	3.19733671972886447	3.22532949456342727	279927.7483	0.88
Open evergreen broadleaf forest	188698.4860789548	202904.15299958744	14205.66692	7.53
Open savanna	459.7885964861036	114.98957588325173	-344.7990206	-74.99
Permanently irrigated arable land	15234.718995608999	14860.690262416292	-374.0287332	-2.46
Shrubland	5025644.153372645	4411270.048204898	-614374.1052	-12.22
Total	7.049463240327557	7.083391966270007E7	339287.2594	0.48
Wetland	2929.343443995388	2529.467175605458	-399.8762684	-13.65

Table 3.2 - Retained soil in Kaduna in 2015 and 2020

Landcover class	Tons of Retained Soil in 2015	Tons of Retained Soil in 2020	Net change	% change
Mangrove	127.08374756203843	127.08374756203843	0	0
Permanently irrigated arable land	9725.503477502081	9491.741191452349	-233.762286	-2.4
Non irrigated arable land	7788491.3995799115	7645926.345153231	-142565.0544	-1.83
Non irrigated arable land herbaceous	1210359.3316844495	1352055.3883992159	141696.0567	11.71
Agricultural land with natural vegetation	1.482155872486301E7	1.49563221583034827	134763.4334	0.91
Complex cultivation patterned land	2111389.5497107417	2035578.303822884	-75811.24589	-3.59
Closed savanna	93933.81226052136	268388.89858916163	174455.0863	185.72
Open savanna	646.2214688973065	760.7261485720471	114.5046797	17.72
Shrubland	2.67578176438889027	2.54724945666624537	-1285323.077	-4.8
Deciduous shrubland	1588562.8452882264	1288097.3895714937	-300465.4557	-18.91
Grassland	18479.366125977158	18479.366125977158	0	
Open evergreen broadleaf forest	19315.652358818854	19016.822597892333	-298.8297609	-1.55
Closed evergreen broadleaf forest	4887.8308288671415	5186.660589793662	298.8297609	6.11
Deciduous broadleaf forest	479345.04378793784	569747.344025003	90402.30024	18.86
Open deciduous broadleaf forest	1.83782799713004647	1.86513303178546957	273050.3466	1.49
Closed deciduous broadleaf forest	746066.5822513526	1907006.0458218271	1160939.464	155.61
Total	7.4028986562626027	7.420000915860814E7	171022.596	0.23

Although some land cover categories underwent significant transformations in the provision of this service, the overall retained soil service across both states remained relatively constant from 2015 to 2020. The fluctuations in the provision of the retained soil service are consistent with the land cover alterations documented in earlier accounts.

Image 3.1 - Soil retention from vegetation in Kaduna state in 2015

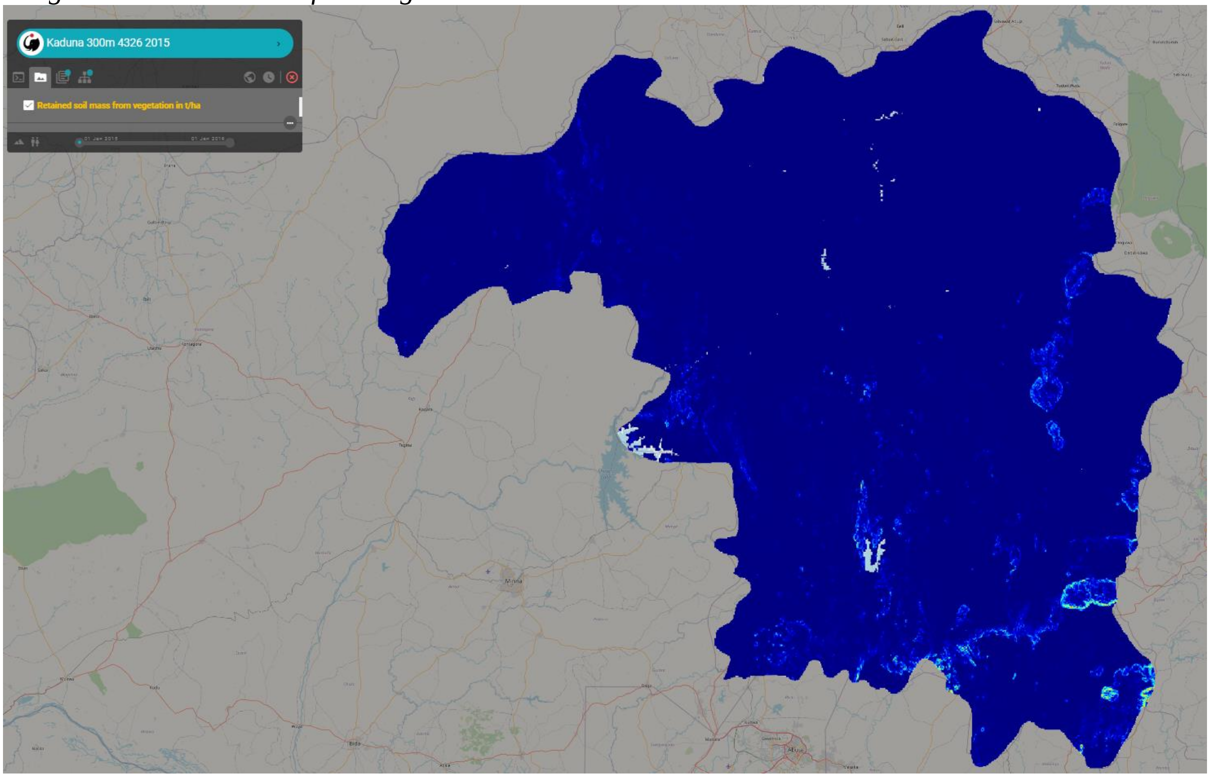
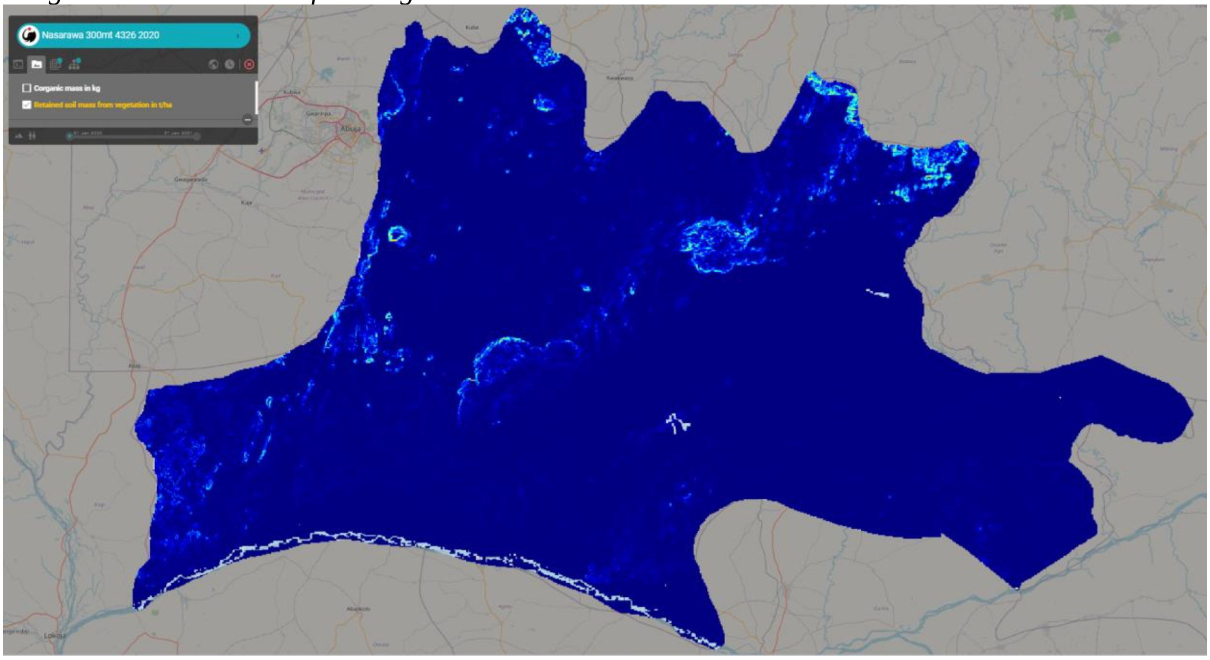


Image 3.2 - Soil retention from vegetation in Nasarawa state in 2020



5.4 Provisioning services

5.4.1 Crop production and crop-pollinators dependent production

The tables of crop provisioning cover the most 12 cultivated crops at the global level. As such, this analysis covers the most important crop production in the two states (Maize and Rice), but does not account for all significant crops production (e.g. Yam, one of the most grown cultivation in Nasarawa, is not considered). The model covers the 11 crops highly dependent on pollinators that are most cultivated at the global level. Among those, only Mango is grown in these two states. The results for Mango are shown in the table above and can be compared with the other productions. The tables summarize the spatial distribution of changes in crop production estimated from aggregated national statistics. For this reason, the relative changes are equal in both states, despite being different in absolute terms. The coarse results of the maps in this section are due to the limitation in data availability on crop production quantities in the national statistics. As explained in the methodology, the crop locations have been identified by using global maps, which have a coarse spatial resolution. The development of datasets to locate the most important crops in the region would be particularly relevant to improving the assessment of crop-related services. Since the contribution by natural resources to crops and pollinators-dependent crops productions have been estimated using coefficients rather than a spatial explicit model, there is no breakdown of the ecosystem service supply by landcover class or by ecosystem type.

This activity was discussed with the participants of the in-person training, but due to the limited time and the resources available in the project, it was not possible to deliver such output. Nevertheless, should future resources be allocated for this purpose, the assessment of specific crop locations could be improved significantly. Excluding Palm Oil, Maize, and Sugar Cane crops, all the other agricultural production increased significantly in the period observed. Among the crops considered in this analysis, the Mango production is the only crop relying largely on pollinators for its growth, and it increased its production by almost 1% in Nasarawa and by almost 6% in Kaduna, in the period 2015-2020. Nevertheless, this should not be interpreted as an increase in the quality of the quantity of the ecosystem pollination service supply, but rather as a sign of the importance of this service for human well-being. Indeed, the service should be preserved to allow the production of this agricultural product.

Image 4.1 - Ecosystem contribution to Kaduna's crop production in 2015

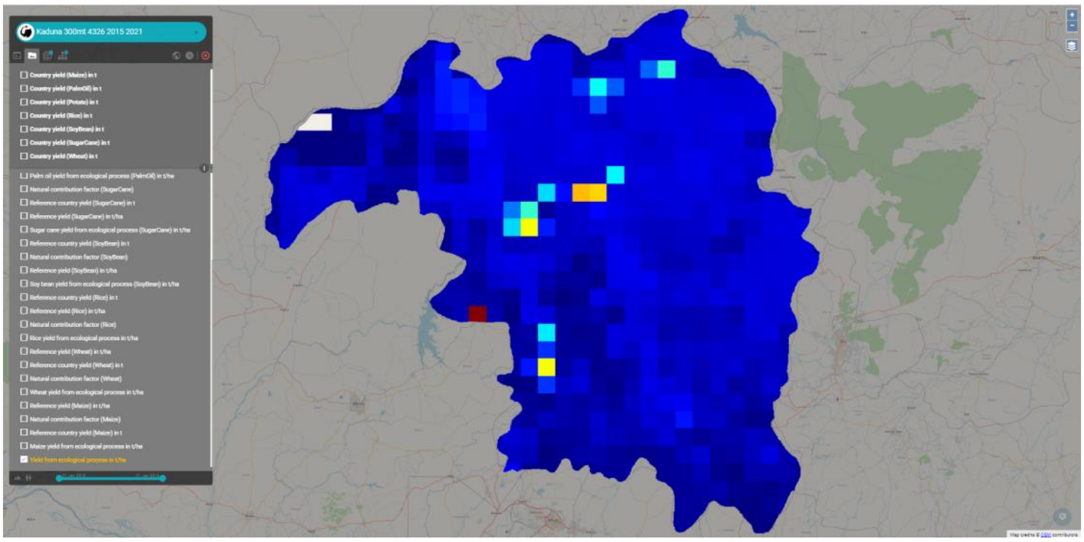


Image 4.2 - Pollination contribution to Kaduna state's crop production in 2015

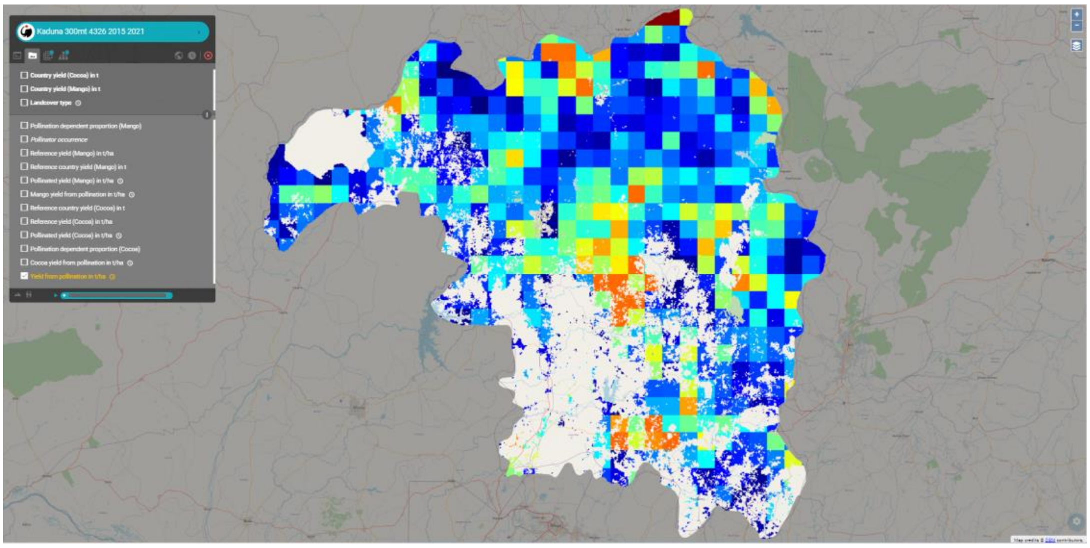


Image 4.3 - Ecosystem contribution to Nasarawa state's crop production in 2020

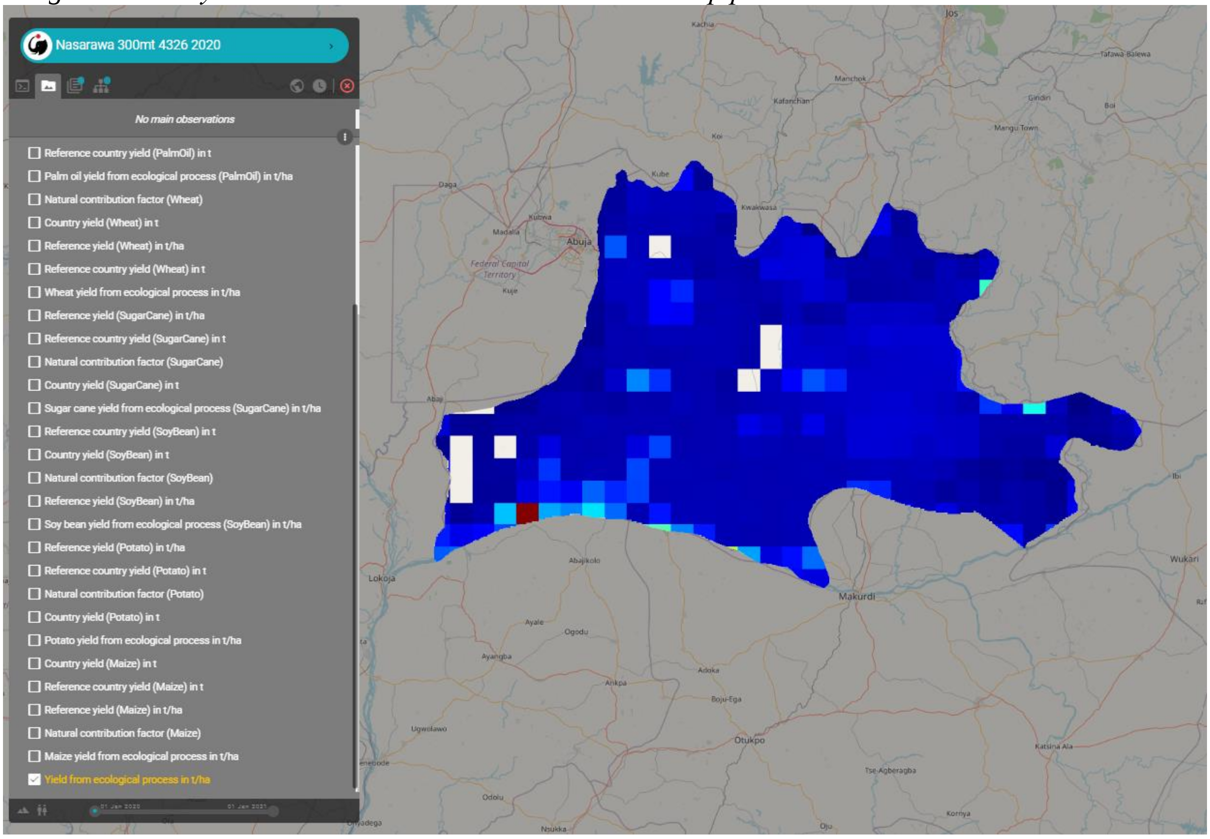


Image 4.4 - Pollination contribution to Kaduna state's crop production in 2020

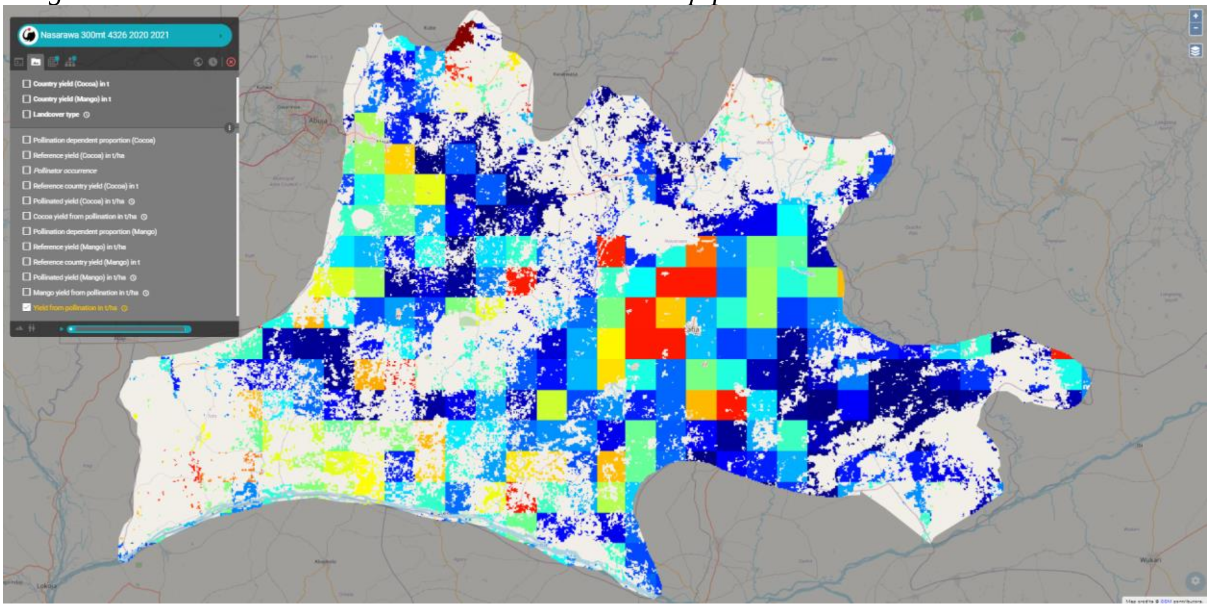


Table 4.1- Crop production in Nasarawa in 2015, 2020 and comparison with overall national production

	Nasarawa					
Crops	**in 2015**	**in 2020**	**net change**	**% change**	**% national production (in 2015)**	**% national production (in 2020)**
Potato	6049,87	6648,86	598,99	9,9%	4,93%	5,56%
PalmOil	262,19	261,01	-1,18	-0,45%	0,02%	0,02%
Maize	31742,62	30519,38	-1.223,24	-3,85%	2,28%	2,22%
SugarCane	14360,02	14093,83	-266,19	-1,85%	5,03%	5,01%
Rice	27591,23	30030,51	2.439,28	8,84%	2,53%	2,93%
Wheat						
SoyBean	1256,52	1618,43	361,91	28,8%	11,87%	14,01%
Crops pollinators-dependent						
Mango	3387,96	3418,79	30,83	0,91%	0,58%	0,55%

Table 4.2- Crop production in Kaduna in 2015, 2020 and comparison with overall national production

	Kaduna					
Crops	**in 2015**	**in 2020**	**net change**	**% change**	**% national production (in 2015)**	**% national production (in 2020)**
Potato	10232,68	11245,78	1.013,10	9,9%	8,33%	9,33%
PalmOil						
Maize	180023,16	173085,72	-6.937,44	-3,85%	12,91%	11,19%
SugarCane	62243,07	61089,31	-1.153,76	-1,85%	21,79%	21,26%
Rice	178046,91	193787,64	15.740,73	8,84%	2,53%	3,12%
Wheat	19,98	21,79	1,81	9,06%	0,%	0,%
SoyBean	25555,16	32915,72	7.360,56	28,8%	26,64%	28,01%
Crops pollinators-dependent						
Mango	15511,52	16430,10	918,58	5,92%	2,67%	2,66%

5.5. Water supply (runoff and baseflow)

The results for water supply (both runoff and baseflow) record substantial changes from 2015 to 2020. On the other hand, the negative trend over time shows a significant decrease in both the runoff and baseflow volumes of the components of the water supply services. The physical quantities reported in the tables should be calibrated to offer more robust estimates.

Table 5.1.1 - Runoff in Nasarawa in 2015 and 2020

Lancover class	Runoff Water Supply (m^3) in 2015	Runoff Water Supply (m^3) in 2020	Net change	% change
Artificial surface	9.18E+07	9.23E+07	537552.0366	0.59
Water body	2.97E+08	2.74E+08	-22294070.01	-7.52
Wetland	1959463.284	1072971.958	-886491.3257	-45.24
Mangrove	1.01E+07	1.14E+07	1377400.464	13.69
Permanently irrigated arable land	2.24E+07	1.91E+07	-3293817.686	-14.72
Non irrigated arable land	3.19E+09	2.46E+09	-726280983.6	-22.76
Non irrigated arable land herbaceous	1.22E+08	1.32E+08	10571454.12	8.68
Agricultural land with natural vegetation	5.76E+09	4.42E+09	-1333189607	-23.15
Complex cultivation patterned land	7.99E+08	6.02E+08	-197614084.7	-24.72
Closed savanna	5633610.508	7134824.315	1501213.807	26.65
Open savanna	617235.0234	454333.2695	-162901.7539	-26.39
Shrubland	6.42E+08	4.32E+08	-210034999.3	-32.7
Deciduous shrubland	2.19E+08	1.36E+08	-83812265.05	-38.18
Grassland	1804672.678	1515906.848	-288765.8301	-16
Evergreen broadleaf forest	9630.138672	14588.91797	4958.779297	51.49
Open evergreen broadleaf forest	4080753.247	3189784.427	-890968.8193	-21.83
Closed evergreen broadleaf forest	8525833.742	6708383.033	-1817450.709	-21.32
Deciduous broadleaf forest	1.80E+08	1.76E+08	-4365273.894	-2.42
Open deciduous broadleaf forest	1.59E+09	1.21E+09	-377367050.4	-23.8
Closed deciduous broadleaf forest	2.59E+07	5.70E+07	31039174.93	119.66
Bare area	248883.2637	226173.7378	-22709.52588	-9.12
Bare rock	612364.1902	366905.9678	-245458.2224	-40.08
Total	1.30E+10	1.00E+10	-2917535143	-22.5

Table 5.2.1 - Baseflow in Nasarawa in 2015 and 2020

Landcover class	Baseflow Water Supply (m^3) in 2010	Baseflow Water Supply (m^3) in 2020
Artificial surface	44478994645	33647383398
Water body	7.04E+12	5.47E+12
Wetland	38401619452	28151584704
Mangrove	4.10E+11	3.22E+11
Permanently irrigated arable land	29320009875	32840514784
Non irrigated arable land	3.69+12	2.37E+12
Non irrigated arable land herbaceous	1.46E+11	2.25+11
Agricultural land with natural vegetation	7.24E+12	5.35E+12
Complex cultivation patterned land	1.35E+12	8.04E+11
Closed savanna	143856769.8	28876684970
Open savanna	61084568	
Shrubland	2.41E+12	1.33+12
Deciduous shrubland	4.81E+11	2.73E+11
Open evergreen broadleaf forest	33667037.66	26522104.84
Closed evergreen broadleaf forest	2281910695	2003871912
Deciduous broadleaf forest	2.93E+11	2.82E+11
Open deciduous broadleaf forest	1.33E+12	1.06E+12
Closed deciduous broadleaf forest	24443296510	66358338650
Bare area	17516872.25	13256160.09
Bare rock	12813261320	9510642528
Total	2.45E+13	1.77E+13

The Water Supply model in Nasarawa takes into account three watersheds, as shown in the figure below.

Figure 5.1. - Nasarawa states's water supply volume calculation

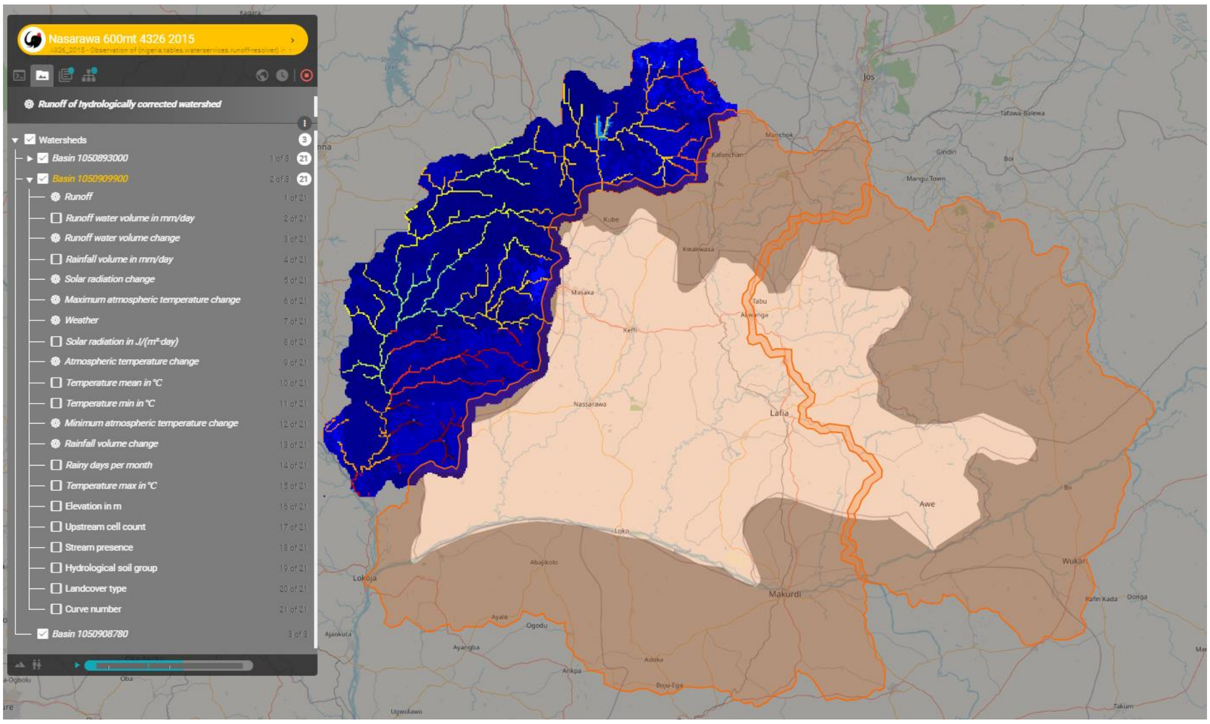


Figure 5.2 - Nasarawa states's Runoff volume in 2015

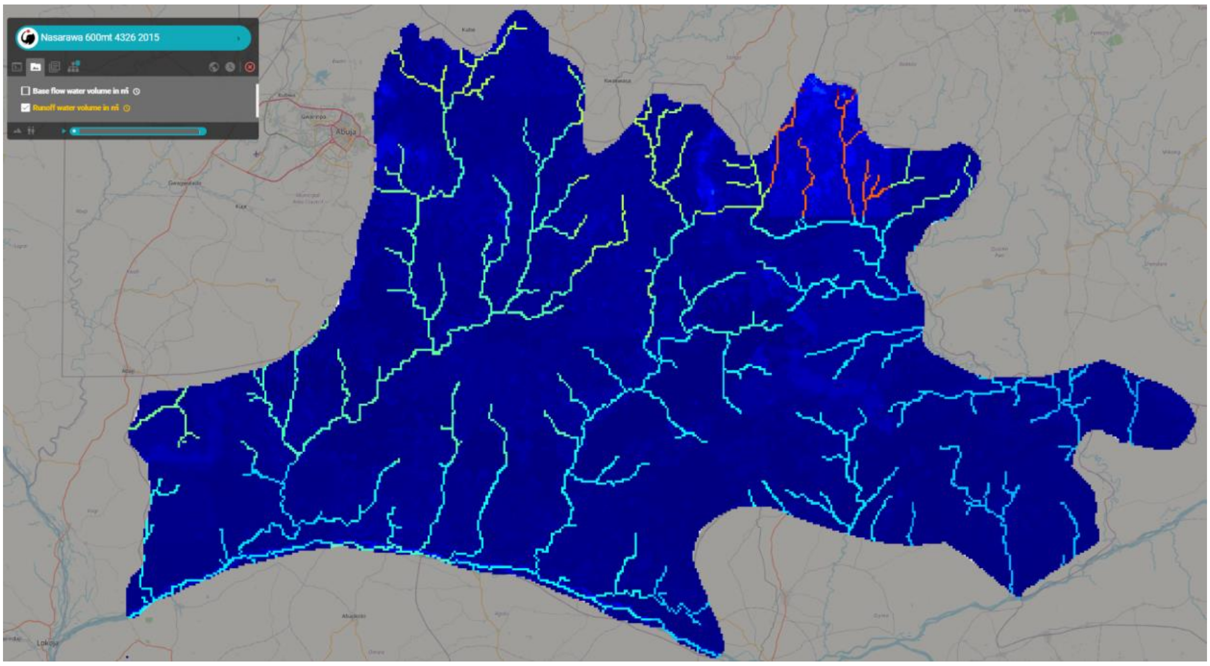


Figure 5.3 - Nasarawa state's Baseflow volume in 2015

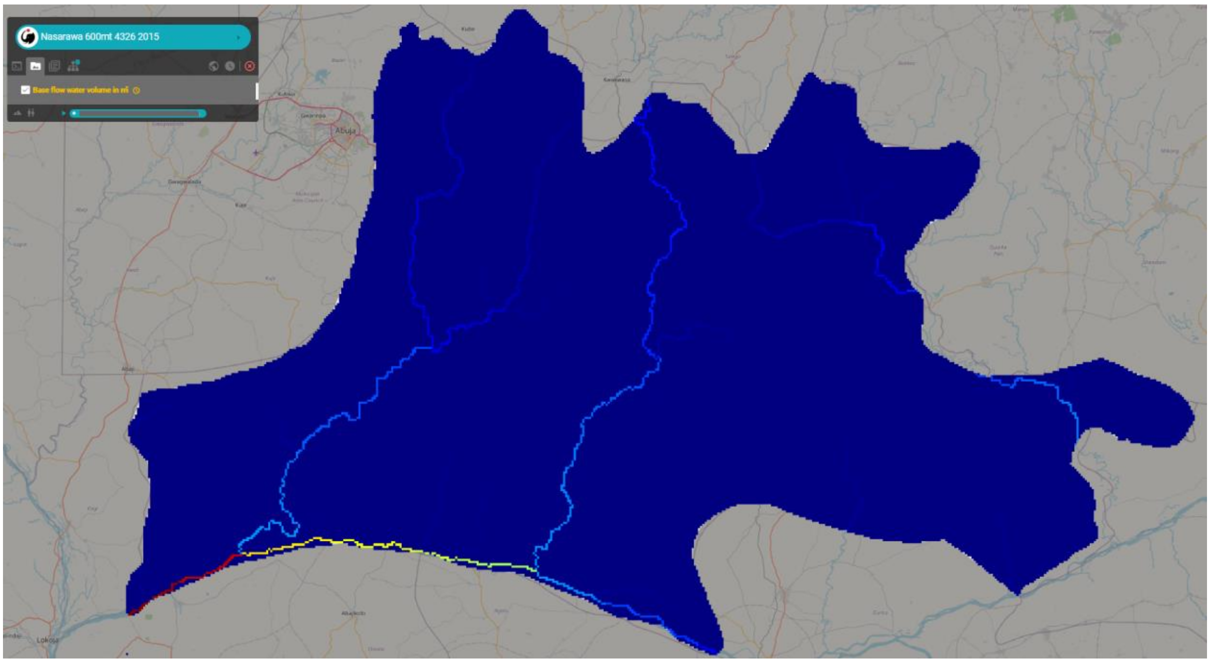


Table 5.1.2 - Runoff in Kaduna in 2015 and 2020

Lancover class	Runoff Water Supply (m^3) in 2015	Runoff Water Supply (m^3) in 2020	Net change	% change
Artificial surface	1.66E+08	2.76E+08	109376678.7	65.74
Water body	4.64E+08	3.43E+08	-121015611.5	-26.06
Mangrove	29535.72266	22901.32813	-6634.394531	-22.46
Permanently irrigated arable land	3.66E+07	3.17E+07	-4906368.735	-13.39
Non irrigated arable land	1.13E+10	9.89E+09	-1375158128	-12.21
Non irrigated arable land herbaceous	1.53E+09	1.72E+09	184447557.1	12.02
Agricultural land with natural vegetation	6.10E+09	4.71E+09	-1390096264	-22.79
Complex cultivation patterned land	1.60E+09	1.25E+09	-353245726.1	-22.02
Closed savanna	4918988.287	8325106.142	3406117.854	69.24
Open savanna	2525814.808	2117621.064	-408193.7437	-16.16
Shrubland	3.91E+09	2.89E+09	-1014466892	-25.96
Deciduous shrubland	2.82E+08	1.88E+08	-94603075.06	-33.5
Grassland	1137928.812	810109.9033	-327818.9087	-28.81
Open evergreen broadleaf forest	2125416.859	1044747.856	-1080669.003	-50.85
Closed evergreen broadleaf forest	152524.0439	573191.1433	420667.0994	275.8
Deciduous broadleaf forest	5.64E+07	6.79E+07	11528779.68	20.44
Open deciduous broadleaf forest	1.30E+09	1.01E+09	-286631927	-22.06
Closed deciduous broadleaf forest	5.00E+07	9.86E+07	48620991.89	97.25
Bare rock	929464.1875		-929464.1875	-100
Total	2.68E+10	2.25E+10	-4285075980	-16

Table 5.2.2 - Baseflow in Kaduna in 2015 and 2020

Landcover class	Baseflow Water Supply (m^3) in 2010	Baseflow Water Supply (m^3) in 2020
Artificial surface	3.89E+11	7.23E+11
Water body	1.18E+12	8.63E+11
Mangrove	60461064	42662280
Permanently irrigated arable land	66909860517	48732857473
Non irrigated arable land	7.02E+12	4.92E+12
Non irrigated arable land herbaceous	2.77E+11	2.40E+11
Agricultural land with natural vegetation	4.96E+12	3.57E+12
Complex cultivation patterned land	1.09E+12	8.19E+11
Closed savanna	73273851.38	79440580.09
Open savanna	1.11E+11	82498324480
Shrubland	2.78E+12	1.97E+12
Deciduous shrubland	96749875920	67420018295
Grassland	6515936.25	4652771.688
Open evergreen broadleaf forest	5484460.75	4460160.313
Closed evergreen broadleaf forest	6671058.5	4943527.75
Deciduous broadleaf forest	4489479921	14817374600
Open deciduous broadleaf forest	1.65E+11	1.36E+11
Closed deciduous broadleaf forest	20231459326	41041604474
Total	1.82E+13	1.35E+13

The Water Supply in Kaduna takes into account five watersheds, as can be seen in *Figure 5.4.*

Figure 5.4. - Kaduna state's water supply volume calculation

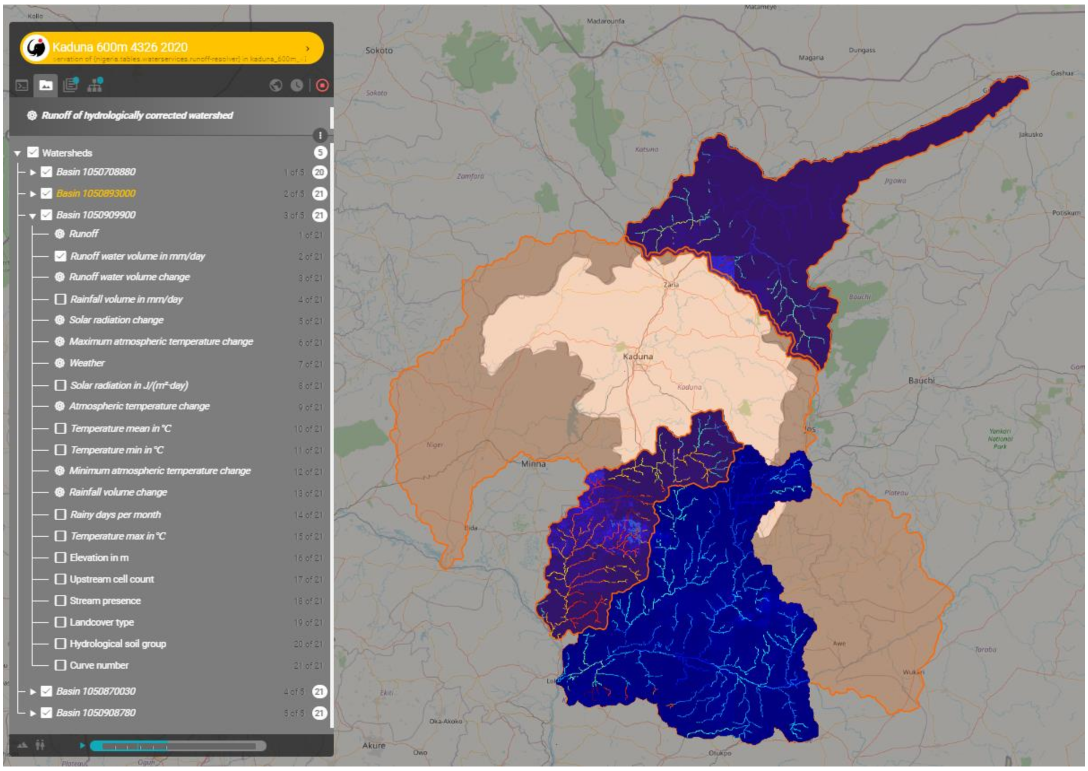


Figure 5.5. - Kaduna state's Baseflow volume in 2020

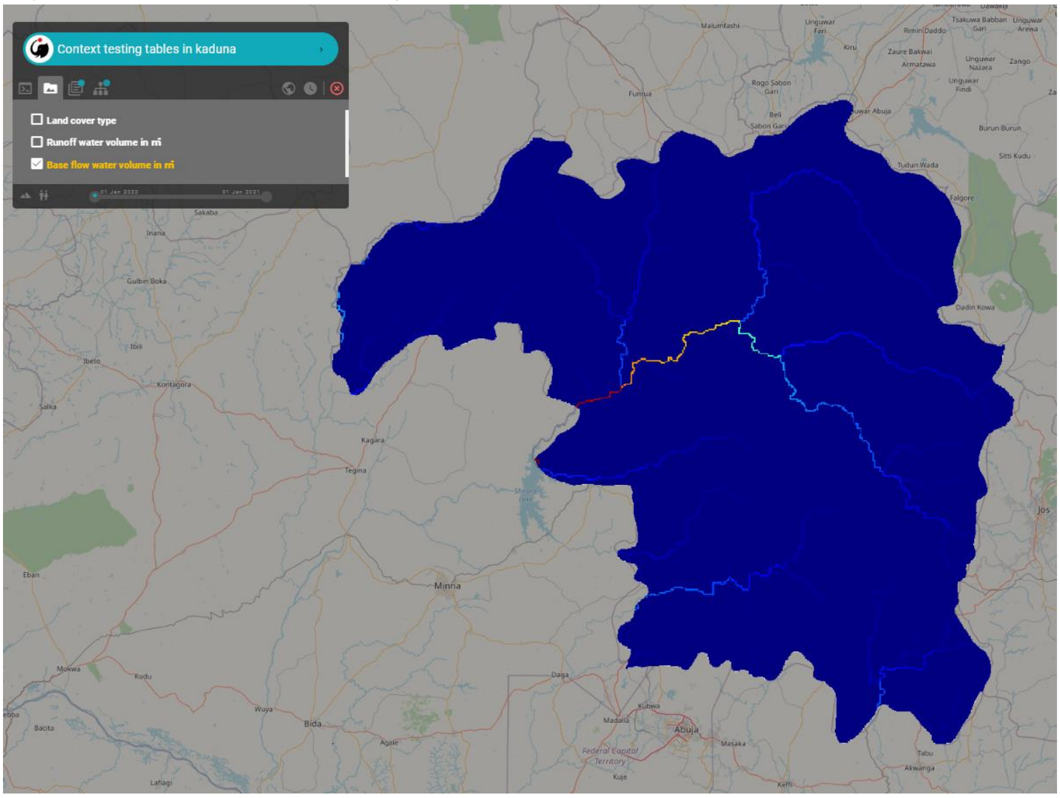
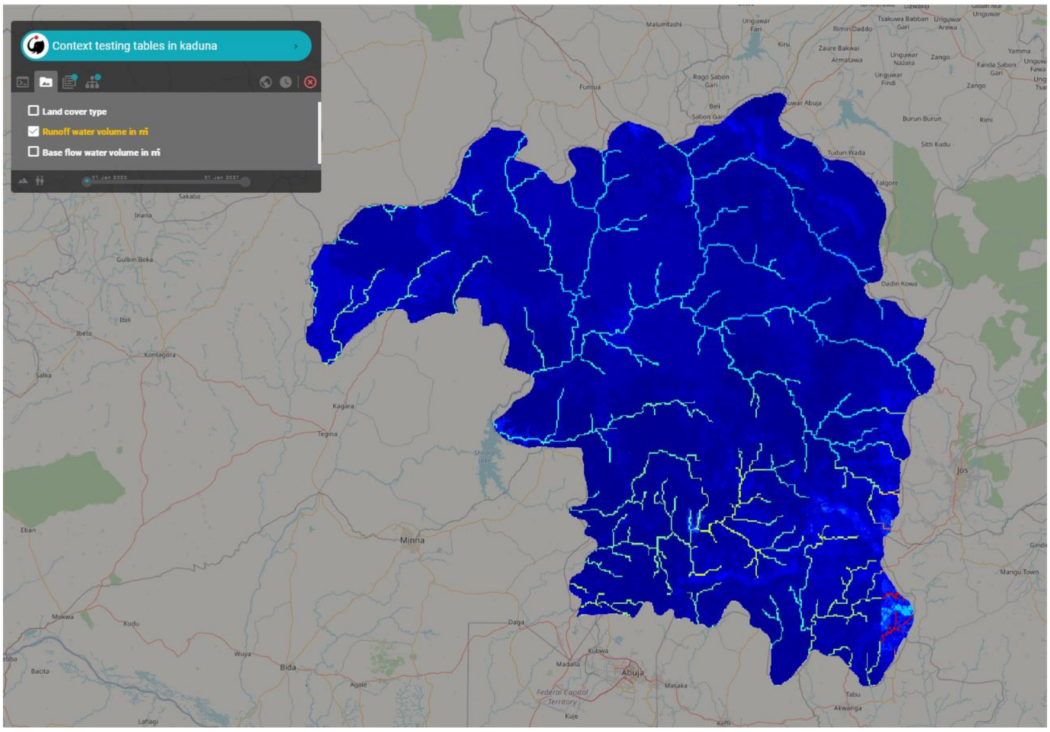


Figure 5.6. - Kaduna state's Runoff volume in 2020



6. Lessons learned

This project has highlighted the opportunity to enhance the availability of spatial information essential for producing environmental economic accounts. Recognizing this, there is a valuable opportunity to establish an institutional framework that fosters collaboration among various agencies. Such a collaborative approach would facilitate the production of the necessary data and statistics for comprehensive environmental reporting, benefiting the pilot states and setting a precedent for future endeavours in environmental accounting.

To produce valuable environmental economic analysis at national and state levels, an early assessment of the availability of the required inputs necessary for the analysis should take place. This appraisal should follow best practices and involve experts in the NCA practice and geospatial analysis, which could assess at an early stage the available information to produce environmental accounts. This preliminary study has the potential to steer the work so that the time and resources allocated to an activity or specific project are used as productively as possible given the resources available.

There is a strong interest from all the parties and stakeholders involved to continue and improve the work started, which was agreed to be just a first step towards a process that would lead Nigeria to independently assess its environment and economic context, based on nationally owned knowledge and products. This project helped by providing the possibility to compile future ecosystem services accounts with much greater ease. The generation of results for accounting periods different from those analyzed can take place already as the datasets used in this project are updated and published. Moreover, in case further datasets are published, and their quality endorsed by the TWG, the additional information can be integrated into the current workflow with minimal effort. This is equally true in case an entirely new model or the calibration of some of the parameters used in the current models become available and are endorsed by the TWG. This new information would get prioritized, replacing the current data, and allowing the compilation of new accounts based on the new national or locally owned inputs.

Embarking on this activity was a challenging task, one of the greatest hurdles to overcome is the ability to combine information coming from several disciplines, particularly to integrate geospatial data with statistics, which implies different departments, with different perspectives and objectives, to work cohesively to produce these accounts. This project was important to lay the ground for generating the first set of environmental accounts. Leveraging on the work done and the information already integrated into the modelling platform, the process of consistent and regular generation of results is greatly facilitated.

7. Conclusion

The results produced in this project are useful to start building the process to guide policymakers toward more informed decisions. Those should take into account the environmental dimension and strengthen conservation efforts and sustainable use of natural resources, to ensure they are used efficiently. The tables and maps generated can help to identify areas needing intervention and highlight locations where efforts have substantial ecological and economic impacts.

To conclude, there are three essential points that emerge from this project experience:

(1) It is important to bring the institutions together and the establishment of a TWG is a very good first step to build on for future compilation efforts
(2) It is necessary to strengthen the compilation of LULC maps and other environmentally related data through the identification of responsible instruction, making it a regular programme on this and collaborating with others (National and State level, and across institutions)
(3) Training was provided through the project on using national maps and integrating different information, and it is important to continue building and strengthening this expertise for the country to continue with a regular compilation of the accounts in the future.

The creation of Nigeria's first Pilot Ecosystem Services Accounts in those States marks a notable milestone, shedding light on the dynamics of land use and cover and the estimated services offered by Nigerian natural resources and ecosystems throughout the specified period in the two pilot states. This achievement was made possible through the collaborative efforts of the TWG members, the provision of specialized training to staff, the use of ARIES as a modelling platform and data provider, and the use of the SEEA EA framework. Since the models used in ARIES are independent of the context to be analyzed, both in spatial and temporal terms, the results obtained for the two pilot states can be scaled up to the rest of the states in Nigeria, and accounts compiled for future years with minimal efforts. These results can be obtained when the time series of the data used in this analysis is extended. However, this initiative was useful in identifying future areas of improvement, to build on the results produced in this project, which were highlighted in the different sections of this report. The most important areas for enhancement of the results can be summarized in two main points:

1. generate a more accurate mapping of the type of Ecosystems present in Nigeria, which is characterized by a very rich and diverse landscape in this regard,
2. generate a complete Supply and Use table by bridging the ecological and social information of the ecosystem service to the social information that describes their final use by society.

   The biophysical results could not be refined due to the lack of reliable statistical information, especially at the regional level.

This work underscored the necessity for a more cohesive strategy in generating national maps and statistics.

For this purpose, agencies should make better use of available data and improve the validation processes. By appointing specific lead agencies responsible for environmental data and promoting cooperative efforts, the precision and uniformity of the data, and in turn of the indicators produced using that information, can be significantly improved. Such improvements are crucial for the successful incorporation of natural capital accounting into the realms of economic analysis and policy development. While LULC and ecological maps are a fundamental input in environmental analysis, this work shows how other economic and social data, such as crop location, statistical crop production, and water use, are equally important and relevant to estimating ES accounts, and the same process should be implemented to obtain them at the state level. This approach is in line with the national inventory reports, providing a framework that is not only scalable for analyzing time series but also adaptable for incorporating additional greenhouse gases, with pertinent data supplied by the climate change department.

The process of collecting, analyzing, and interpreting relevant data should be designed to yield outcomes that effectively contribute to the compilation of relevant statistics. In this regard, the process could be designed to incorporate the expertise of natural capital accounting specialists, who may offer valuable insights and propose preliminary solutions tailored to the definition of classifications or the observation of specific landscape features. Such features are critically important in the production of a high-quality product aimed at accurately modelling environmental economic accounts. These sophisticated products stand as the ultimate goal, serving a pivotal function in providing policymakers with the comprehensive and accurate information they require. As technology advances and new data and models become available in the scientific community, due to the modularity of the models in ARIES, such inputs can also be integrated into the workflow with minimal effort. This process ensures that the decision-makers are well-informed, enabling them to craft policies that are both effective and sustainable, ultimately benefiting the environment and the economy alike.

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