NIRAS

Your Global Partner in Earth Observation and Geographic Info Services

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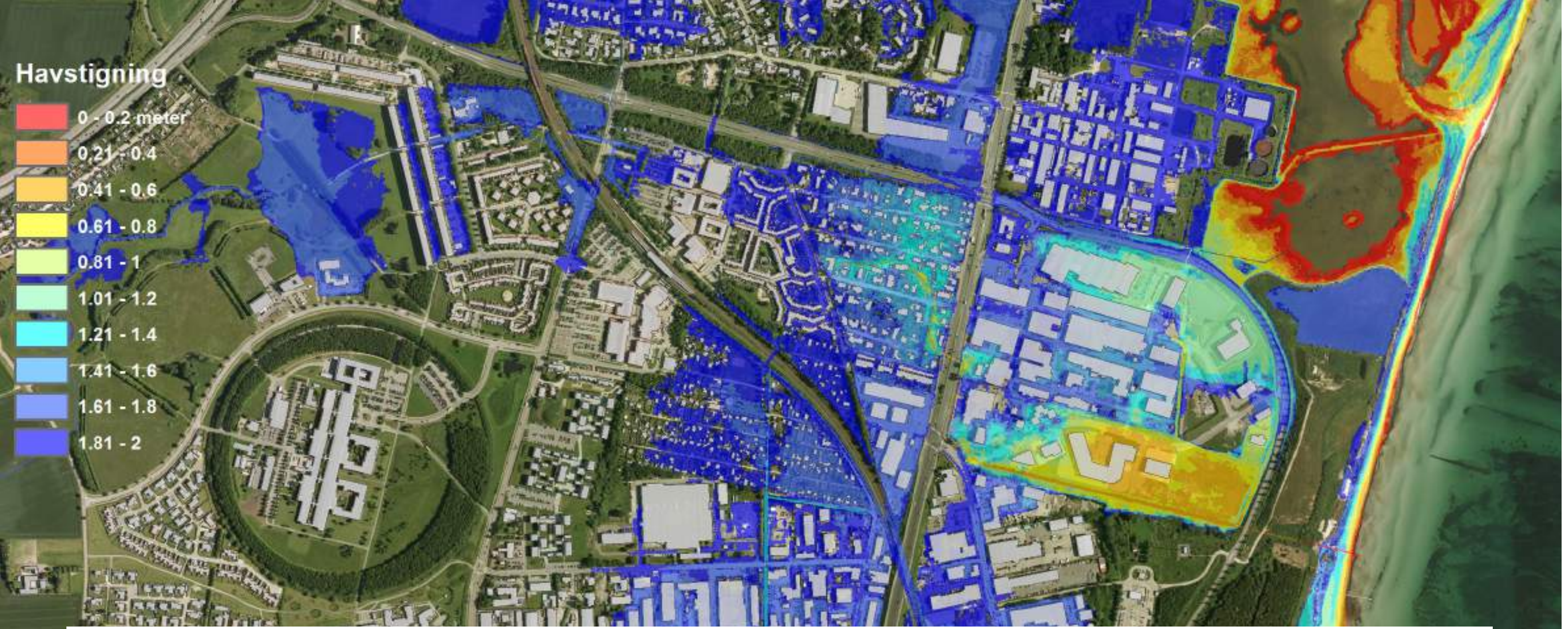


Earth observation and geospatic information: a quantum leap in tracking progress

Governments, industry, and scientists have long recognised the critical importance of earth observation (EO) as an information source that supports many sectors of society. EOs (from satellite, airborne, and in-situ sensors) provide accurate and reliable information on the state of the atmosphere, oceans, coasts, rivers, soil, crops, forests, ecosystems, natural resources, ice, snow and built infrastructure, and their change over time. EO programmes represent the largest investment globally in relation to applications of satellites by national governments – typically through their national space agencies – recognising their capacity to address such critical challenges as climate change, water availability, food security, natural disaster mitigation, safe and secure transport, energy and resources security, agriculture forestry and ecosystems, coasts and oceans, health issues, and national security.

Earth observations are directly or indirectly necessary for all functions of government, economic sectors and almost all day-to-day activities of society.

EO and geospatial information systems (GIS) have many advantages, including:

Scale. Satellites can provide data on all scales from local to national, regional and even global. Indeed, they are likely the only source of global information for many parameters. Depending on the application and resolution, large area (even global) datasets can be derived from satellites in relatively short timeframes, from daily to annually as needed and as the technology permits – allowing rapid refresh of indicator information day or night, in all weather conditions.

Long time series and continuity. The ongoing acquisition of data by satellites systematically and over long periods of time, with some mission series dating back to the 1970s and planned up to 2030 or later, provides governments with unique evidence with which to track progress, including the establishment of baselines for the determination of future trends, monitoring and compliance of agreements, improved predictions, and management and mitigation.

Consistency and comparability. Satellites provide the means for the effective comparison of results among different countries, which may otherwise suffer from lack of standardisation in measurements or methods, impeding attempts to derive meaningful comparisons or regional/global statistics.

Diversity of measurements. Advances in science and instrumentation have resulted in an increasingly diverse array of EO satellite missions with dozens of geophysical parameters being measured on a daily basis from a range of different satellite orbits. In the field of climate change alone, the Committee on Earth Observation Satellites (CEOS) has identified that, of the approximately 55 essential climate variables, more than half have a major contribution from satellite observations or simply would not be feasible without satellites (such as polar ice extent, and global sea level).

Complementarity with traditional statistical methods. While EO datasets can be used to monitor some specific SDG indicators directly, they can also offer a unique and complementary source of information to cross-check the validity of *in-situ* data measurements (such as survey and inventory data), communicate and visualise the geographic dimensions and context of the indicators as needed, and provide disaggregation of the indicators where appropriate.

Free and open data is on the increase. Not all nations are able to develop and launch their own EO satellites; only a relatively small (but growing) number having the capacity to do so. Hence the availability of the data from these missions is of fundamental importance, for all nations, to their uptake and global impact. US mission data has long been freely available, and with the advent of the free and open data policy of Europe's Copernicus programme of multiple satellite data streams, the prospects for access to the EO data required by developing countries have improved considerably.

High performance computing and cloud storage and processing capabilities are making it simpler to handle and apply EO satellite datasets, which can be large and complex. And space agencies are prioritising efforts to further remove the burden on potential users by making more data "analysis ready".

In adopting the 2030 Agenda for Sustainable Development, world leaders agreed that a global Indicator framework was necessary to measure, monitor and report progress towards the 17 transformational Sustainable Development Goals (SDGs). They also recognised the critical importance of "transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including EO and GIS, while ensuring national ownership in supporting and tracking progress".

To track SDG progress, the global indicator framework must capture the multi-faceted and ambitious aspirations for the continued development of nations and societies. Effective reporting of progress toward these indicators will require the use of multiple types of data, both what we have on hand – traditional national accounts, household surveys and routine administrative data – and new sources outside of national statistical systems, notably EO and GIS, using modern data processing techniques more appropriate for large volumes of EO data.

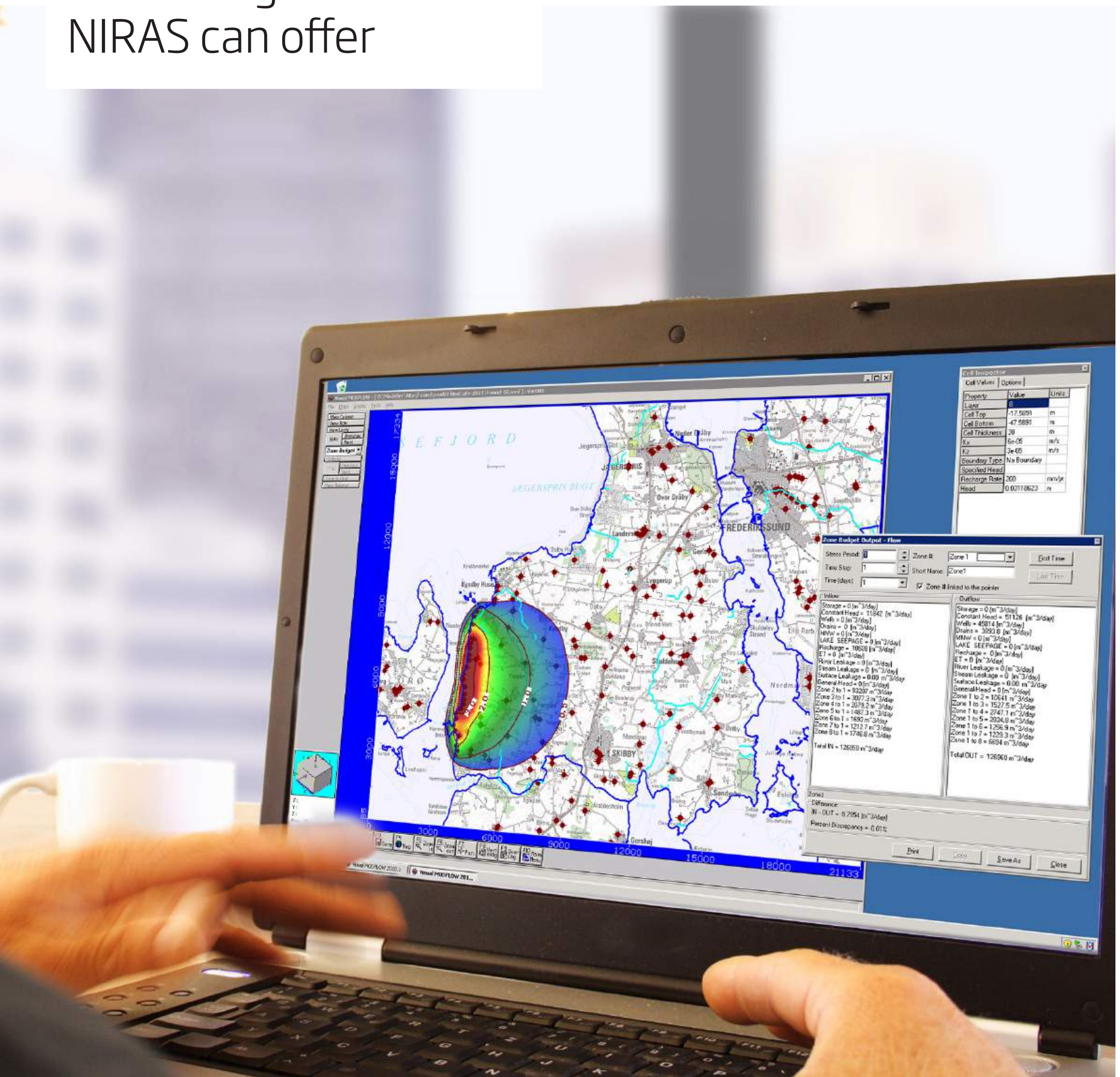
The integration of all these data can produce a quantum leap in how we monitor and track development and advance the well-being of our societies. Since EO and GIS are often continuous in their spatial and temporal resolutions, their use in SDG monitoring can prove essential in capturing the sustainability of developments underpinning the SDG framework. EO and GIS (including satellite, airborne, land- and marine-based data, as well as model outputs) will expand monitoring capabilities at local, national, regional and global levels, and across sectors. These tools can significantly reduce the costs of monitoring and reporting on the SDGs, making it viable within the limited resources available to governments.

NIRAS has been involved in creating, managing, sharing, and displaying spatial and remotely sensed information since 1988. Understanding where the environmental, social, and economic considerations are – and how they relate to each other in the spatial and temporal context – enable us to support our clients in making informed and timely decisions to achieve their goals.

Together with out network, we cover the whole geo-data value chain: from **data collection** with aircraft or drones; production of base **maps** and elevation **models**; **digitisation** of analogue drawings and maps; **data refining** (in the form of, e.g. geocoding of land registry information and flood maps); **data analysis** using webGIS solutions; and **data visualisation** to **IT solutions** that support a variety of decision-making processes.

Our experts can analyse and interpret changes in geospatial data over time and present the results graphically through a number of web-based as well as offline platforms. This allows clients to keep informed about projects as they progress, enabling regular information and analysis without the need to wait for final reports.

Our strengths: what NIRAS can offer



> "I am exceedingly delighted with the biomass distribution over the whole country because it's very good and reflective of what is found. This (data) is far better than what we used in the FREL report. I will write an official statement to explain this achievement under the collaboration with LTS [part of the NIRAS Group] and the University of Edinburgh through World Bank."

Abel Siampale, National SMFM Project Focal Point Person,
Zambia Forestry Department, Ministry of Lands and Natural Resources

Among a range of other software and coding packages, NIRAS uses MapInfo, ESRI ArcGIS and open-source GIS (QGIS, GRASS) to deliver data capture and analysis services that produce high quality outputs based on partner country and client needs. We use a variety of sources to capture data, including: hardcopy or scanned maps, aerial photographs, existing spatial and/or non-spatial data, as well as field and ground-truthing data.

NIRAS has a strong network of data quality experts, through in-house capabilities and our Data Futures Hub connections, we are able to assess the sources to determine the most relevant data resources and analysis approaches – based on agreed accuracies and scale – to ensure the data and subsequent analysis work meets specification and purpose.

Customised EO data analysis tools have been produced on multiple occasions – in-house and from scratch – to ensure that information produced efficiently meets project and client needs, particularly in the context of EO-based natural resource monitoring and management.

EO tools, packaging methodologies and approaches developed in-house

- **Online data/info sharing and storage.** *GeoNode platforms as well as customised and built-from-scratch webpages have been developed to display, host and interact with geospatial information online.*
- **Interactive PDFs.** *Offline display and interaction-of-map images has been developed through the exporting of PDFs that allows the user to interactively turn off and on layers and produce map images that are tailored to their interests.*
- **Multi-criteria modelling.** *This approach can be used to identify a huge number of geospatial attributes by combining relevant layers (e.g., this can be used to produce a hotspot analysis map).*
- **Regression analysis.** *This approach is used to find the correlation between two independent variables. Examples of variables that can be compared range from simple tree structural attributes (i.e., tree diameter with tree height and tree biomass) to more complex variables like monthly precipitation data with vegetation greenness, and entire raster images acquired by two different sensors.*
- **NDVI/SAVI tool.** *Time-series analysis to identify areas of vegetation and their change through surface reflectivity their 'greenness' values.*
- **RaVeN.** *A semi-automated tool to produce remotely sensed recordings of change in pasture quality and vegetation cover in remote rangeland ecosystems using a fusion of optical and radar data.*
- **XML form for high-quality surveys.** *These forms are firstly programmed and compiled into an Excel document and subsequently transferred into a suitable device (e.g., tablets and smartphones) that will be used for surveying. The acquired data is automatically saved in the device and then transferred back into a excel form to facilitate data analysis and visualisation of results.*
- **sen2mosaic.** *Semi-automated pre-processing of Sentinel-2 data for LU/LC classification, on a cloud-based platform (bitbucket.org/sambowers/sen2mosaic).*
- **sen1mosaic.** *Semi-automated pre-processing of Sentinel-1 data for LU/LC classification, on a cloud-based platform (bitbucket.org/sambowers/sen1mosaic).*
- **Biota tool.** *Annual forest biomass change and degradation mapping (2007–2010 and 2015-2016) using ALOS PALSAR mosaic and upcoming L-band radar data (bitbucket.org/sambowers/biota).*
- **Dense time-series analysis.** *Utilising dense time-series of Sentinel-2 for continuous change monitoring and proxies of forest change (bitbucket.org/sambowers/deforest).*
- **Forest change type mapping.** *Developing a method for identifying cause and drivers of forest change using earth observation.*

Our cross-cutting EO and GIS competencies

CARTOGRAPHY, VISUALISATION & MAPPING

There are a number of ways in which we can produce map outputs. This come through a number of different GIS interfaces and software, producing a number map images in a variety of different formats. Editing of these images can also occur post export, with tools like Adobe Photoshop able to add to and alter image outputs. There are a number of additional layout and styles options that can be changed and adapted to suit the output needs, including the use of logos and application of different styles through typical map annotations, such as scale bar and north arrow.

DEALING WITH FIELD DATA

We deal with field data that comes to us in a multitude of raw forms. This includes GPS data from field work carried out as well as data often stored in table form (e.g., in Excel), that has a geospatially allocated attribute, such as latitude/longitude reference. Household survey data, collected is a good example of where information can be attributed to a defined house/village.

CALIBRATION AND VALIDATION OF DATA

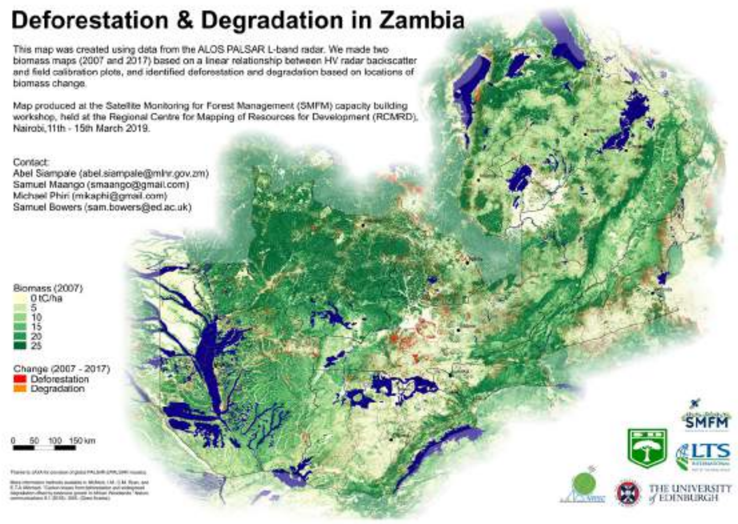
Field work to calibrate model work carried out in-house depends highly on what needs to be measured. Field data are necessary to calibrate and subsequently validate remotely sensed data. RS sensors measure characteristics of the Earth's surface that we firstly need to translate into bio- and geo-physical parameters such as vegetation greenness, forest biomass etc. To give a practical example in the forestry sector, radar sensors don't measure directly forest biomass, rather the so-called radar backscatter, which is the portion of signal that forests reflect back to the sensor. Field-measured forest biomass information is used to calibrate the radar backscatter through linear regression, so that forest biomass can be mapped where backscatter information exists. An independent set of field-measured biomass data is obtained from this analysis and used for the validation phase. During the validation phase, RS-retrieved biomass information is compared with field-measured biomass information to provide an indication of the model robustness and accuracy.

WEB-MAPPING PROGRAMMING LANGUAGES

There is a range of ways in which this can be carried out but the usual tools used at NIRAS involve SVG (Scalable Vector Graphics), an XML (Extensible Markup Language)-based vector image format for two-dimensional graphics with support for interactivity and animation, or web-mapping software, particularly MapBox, which can be drawn on to create online mapping tools. Making geospatial data available for download and the creation of an online spatial data/information storage system can be undertaken, with particular in-house experience of developing such stores through the use of open-sourced GeoNode software.

Management information systems and platforms

Connected to our work on web-mapping, we have developed a number of online platforms so help us implement and carry out our project work. This ranges from the geospatial information and data being displayed online and hosted on existing or custom made webpages /sites. This involves the use of hypertext markup language (HTML) and other related webpages.



DIGITISING

Digitising of imagery and other data can be carried out internally, almost every image can be digitalised and geo-referenced, deriving shapefiles (point, polygon or polyline) layers from the raw spatial state that can be more easily manipulated and used within GIS. An extra step may include scanning in images, if they are in paper form, to make them available on the necessary digital platform.

SPATIAL ANALYSIS

Spatial analysis is one of the most used sets of tools within NIRAS, being the process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques in order to address a question or gain useful knowledge. Spatial analysis creates new information from combining or extracting from different spatial data sets, through a variety of tools/techniques.

PROGRAMMING

Programming can be used on a huge number of platforms within Ubuntu (Linux) and Windows environments. Programming for GIS and RS play a key role because allows automating long and repetitive tasks and there-fore simple models can be applied multiple times (e.g. thousands) to a large number of data (e.g. hundreds of thousands of remotely sensed images). In-house, we can develop algorithms written with different programming languages, including the most commonly used in-house such as Python and JavaScript, which are also built into the most used GIS/RS software like ArcMap and QGIS. Programming work can be used outside these platforms to develop custom products for EO data analysis and interpretation purposes.

MODELLING

There are a number of GIS software packages that can be used to manually create flowcharts and models to process and analyse spatial data in a programmable way. ArcMap and QGIS are common software that allows us to do so and are available in-house. These can be exported and shared, and even packages as 'tools' if needed.

Thematic experience: NIRAS in-house sectoral capabilities

FORESTRY
Deforestation and degradation

There are a number of ways in which deforestation and degradation (DD) can be monitored at NIRAS. This ranges from the visual interpolation of optical satellite imagery to deploying algorithms to remotely sensed radar data to determine aboveground biomass changes (FoRAsT – Forest Radar Assessment Tool). There are a number of freely available toolsets that can be used to produce geospatial outputs that model areas of deforestation and/or degradation varying in scale as well as cost and time to carry out the work. A document that describes FoRAsT and comprehensively compares it with other existing products has been produced and made available to both BD and technical teams.

Biomass measurement and change

Tools can be used in-house to determine above ground biomass values at varying degrees of expected accuracies and precision. This includes applying generic biomass value calculations to collected data or modelling it from remotely sensed data, notably the FoRAsT tool, which was used in the ENRMI project in the Middle Shire project and Sierra Leone.

Below ground biomass can also be determined. One of the main ways of doing this is by using the smallholder agriculture mitigation benefit assessment (SHAMBA), which models the changes in carbon stocks in soils and woody biomass, and the greenhouse gas emissions from biomass burning, plant nitrogen inputs to soils, and fertiliser use over the accounting period for baseline and intervention activities.

Forest cover change

A number of methods that can be applied to identify and determine forest cover over reoccurring years, indicating patterns of change. These include using NDVI values, visually interpretation of optical imagery, interpolation of radar data, and modelling of land cover maps, from which future/predictive vegetation maps and scenarios can be drawn. The application of radar data helps in identifying forest cover, with structure of the vegetation being a distinguishing feature identified.

Canopy height measurement

Radar and lidar data can be used to determine the canopy and tree height of woodlands and forests. This does however depend heavily on the extent/density of the forest cover and the resolution of the data.

Example: NDVI tool uses in the Afar region of Ethiopia to determine change in vegetation through NDVI and SAVI values and their change over time. The modelling of land use change for Integrated Assessment of Land Use Options (IALUO) is an example of the work carried out in modelling forest change based on population growth scenarios.

Forest fire

There are a number of global forest fire datasets that can be relied on to obtain global information on events. The visual interpretation of optical data can also be used to identify areas that are covered by smoke and large areas of burnt land. There are a number of other remotely sensed data sources, such as thermal imagery, that can be used to identify areas of fire by looking at heat signatures.

CLIMATE CHANGE
Weather data analysis and interpolation

Raw weather data, if we have the weather station data available of adequate quality and coverage, can easily be digitised and used to depict the climatic conditions measured in a geospatially relevant area. These point vector layer can then be combined to produce an interpolated surface that models climatic conditions between weather station sites, extrapolating the data. Such data can include a variety of climatic measurements e.g. rainfall and temperature. This approach can be used for other point data and is not restrcted to weather data.

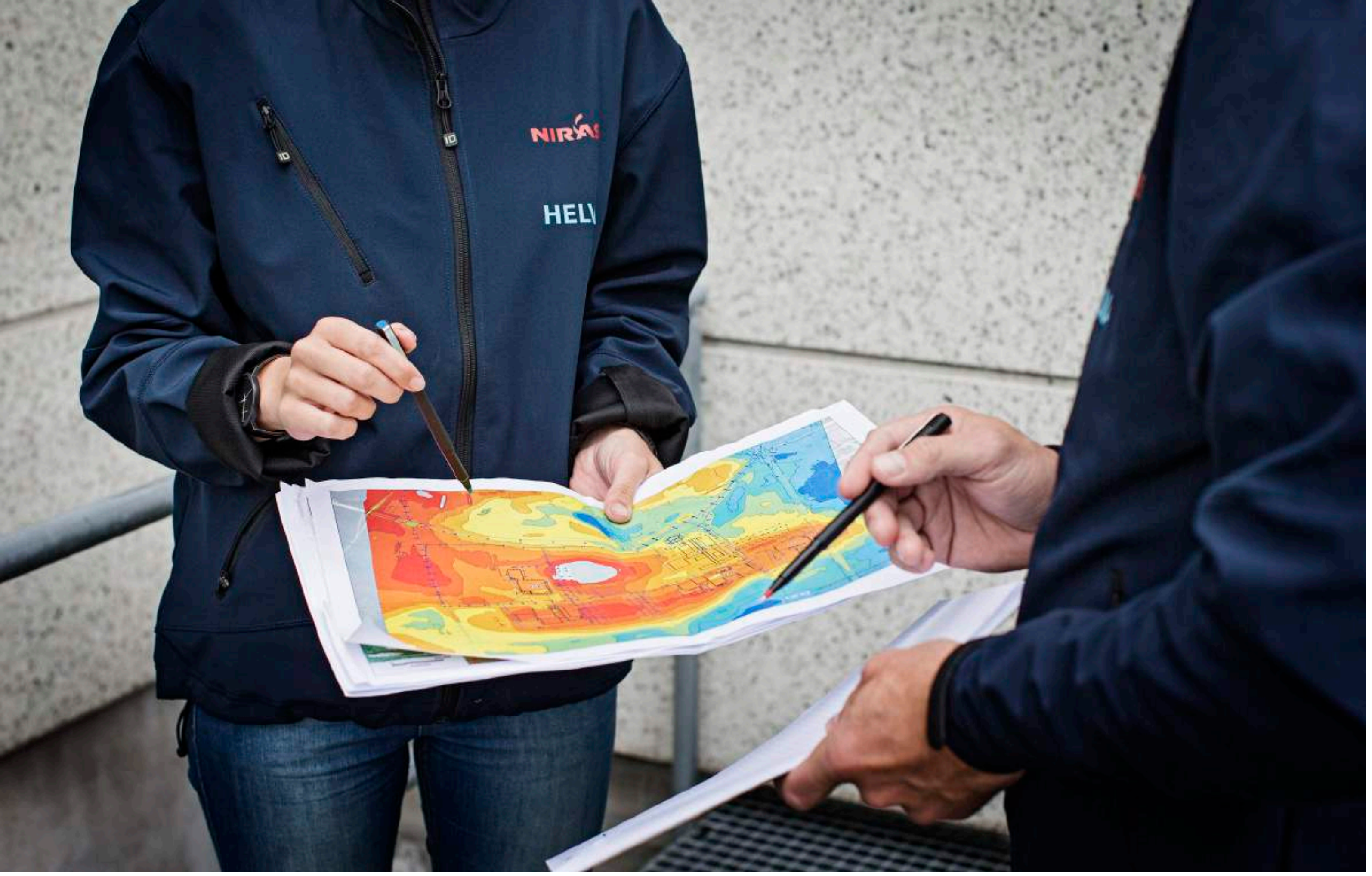
Example: Kriging interpolated surface for rainfall data from ≤20 weather stations from 1995–2015 for the Afar region of Ethiopia under monitoring and evaluation of the Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED-2) project.

Extreme events and hazard mapping

A range of in-house skills mean that extreme and hazard events can be mapped and, if the correct data is available, also monitored. This includes the interpolation of remotely sensed radar and optical data to determine area of flooding, as well as mass movements. Monitoring of these hazards are however limited to slower moving/occurring events.

Cloud cover monitoring

Freely available Landsat data from 1972 to the present and other optical data can be used to determine cloud cover over almost all landscapes, often described as the percentage of the individual tile coverage.



WATER
Catchment work

A number of projects have involved catchment work and scoping interventions to reduce sediment loss and their sustainable management. This includes topographic and geospatial analysis of a number of parameters but relies heavily on a high resolution DEM's (digital elevation models) to carry out the work. In-house abilities include the identification of the catchments themselves at varying scales as well as using data to determine sediment and hydrological circumstances.

Example: Some important projects that involve spatial catchment management work include:
- *Environment and Natural Resources Management Action Plan in the Upper Shire River Basin (ENRMAP).*
- *Environmental and Natural Resources Management Interventions in the Middle Shire River Basin (ENRMI).*
- *Implementing Service Provider for Catchment Management (ISP-CM).*

Flow Analysis
Tools can be used to analyse flow patterns within catchment areas and this can be used to identify areas of water accumulation and streams/river data from topography. There are a number of additional tools that can be used to find flow accumulation and direction as well as to derive areas of hydrological interest within a catchment context.

Flooding
Similar to the hazard/extreme events above, optical imagery can be used to determine areas of flooding. Using radar data can also help in identifying areas of flooding as areas of water show up as having minimum radar backscatter. This technique was used in our work with Atkin on the integrated flood risk management plan for Malawi's Shire Basin.

Body of water change monitoring
Changes in extent of bodies of water (including lakes, reservoirs, large rivers, seas and oceans) can be measured and monitored over time using radar or optical remotely sensed data. The size and scale of expected change of the water are main factor in determining the most appropriate datasets to use.

Monitoring and evaluation of the Earth and Sea Observation System
NIRAS is conducting a process and impact evaluation of the Earth and Sea Observation System (EASOS) programme. EASOS aims to prove informed and coordinated decision-making capability to government agencies in Malaysia through a satellite-information based dashboard. The dashboards will be used to identify marine polluters, illegal loggers and identify and prevent flood risks. The findings of the evaluation will be used on a real-time basis to inform how the dashboards can best be tailored and used by the Malaysian government agencies. This will be done by using a cutting-edge theory-based impact evaluation approach which combines the strengths of counterfactual and mechanism-based evaluation methods.

ECOSYSTEM
Soil erosion

Soil erosion models are used for a number of our projects at NIRAS, the main approaches used for modelling soil erosion are the Soil and Water Assessment Tool (SWAT) and the Soil Loss Estimator for Southern Africa (SLEMSA). A number of other models can be applied provided the correct data is available and methodology is clearly outlined.

Example: SWAT analysis has been used extensively across Malawi on a national scale for the Integrated Assessment of Land Use Options (IALUO) project and SLEMSA was used for the Environmental and Natural Resources Management Interventions in the Middle Shire River Basin (ENRMI) project.

Vegetation monitoring

There are a number of methods that can be applied to determine vegetation cover and related changes over time. The most common one is the use of NDVI values determined from optical data sources such as Landsat. This process can also be carried out through visually interpretation of optical imagery and can be used to model future/predictive vegetation in land cover change maps. The application of radar data helps to determine vegetation structure, and can be used to determine areas of different vegetation types (e.g., grassland versus scrubland versus forest).

Land use and cover
Land cover and land use maps can be derived from semi-automated land cover classification algorithms per-formed on optical data. We are able to predict and model future land use change derived from past land use change trends and with the inclusion of influencing factors affecting the rate of changes (e.g. population growth), based on probability modelling spatial software.

Example: Land use modelling was carried out extensively in Malawi on a national scale for the Integrated Assessment of Land Use Options (IALUO), including predicting future change patterns based on population and policy changes.

Agriculture monitoring
High resolution radar data as well as multi- and hyper-spectral remotely sensed data can help inform crop types by identifying patterns in the landscape that are clearly identified as agricultural/crop land. Optical im-agery and derivatives from this data can be used to identify changes in agricultural area, and conversion from other land type into agricultural land. In particular, the NDVI values derived from the optical data can be used to identify patterns of areas of agriculture and determine, to varying degrees, the quality of the crop and information on

the potential yield by looking at the greenness of a known agricultural area. A number of other vegetation indices are available and can be used to classify and identify different crop types.

Ecosystem corridors
There are a variety of tools and plug-ins that can be used in both QGIS and ArcMap to identify ecosystem corridors. These models rely on a number of datasets and a number of steps that can identify potential corridors. A number of ad-hoc ways of identifying potential areas of wildlife corridors can also examined, this is carried out producing a cost layer, with the inclusion of layers that contain key characteristics of the corridors, that are used to identify movements and the best route through this layer.

This type of work will be carried out strengthening the information base of natural habitats as part of the biodiversity and environmental services in the Shire River Basin.

Aquatic weed and plant monitoring
A number of mapping activities have been carried out that have been used to interpolate and identify areas of aquatic plants and the spread of invasive species. The use of radar data can also examine extent but thus far there is a need for high resolution optical data, through aerial photography or similar, to visually identify large areas of different aquatic weed species.

Example: Projects that involve aquatic weed monitoring work include:
- *Environment and Natural Resources Management Action Plan (ENRMAP) in the Upper Shire River Basin.*
- *Environmental and Natural Resources Management Interventions (ENRMI) in the Middle Shire River Basin.*

Invasive species monitoring
Through the monitoring of change in vegetation on land and aquatic environments, it is possible to identify which species are, if they have notable characteristics, invasive. Potential characteristics include a structure difference or environment characteristic in which they flourish. With past data, a trend can be seen in spread of invasive species.

Example: By analysing vegetation structure, the NDVI tool integrates Sentinel 1 radar data and NDVI values to distinguish grassland to scrubland/forest land, with the purpose of identifying optimal grazing areas.

Mangrove monitoring
Mangrove forests are a very rich ecosystem that contain large amount of carbon stored above- and especially under-water. Spatial mapping of mangrove forests can been performed with traditional pixel-based classific-tion algorithms on data from optical sensor such as Landsat, SPOT, and Sentinel-2, as well as with more advanced methods on radar data that exploit the unique characteristic of mangrove ecosystems being flooded and providing distinct patterns from radar backscatter.

Oil spill detection and monitoring
The identification of oil spill is possible due to the difference in composition characteristic between oil and water. Because of difference in densities and oils insolubility in water, it is possible to identify and subsequently monitor movements of oil spills floating in large bodies of water. By analysing high frequency radar data (small wavelength), oil spills in water show up as very dark as the radar signal bounces off the very smooth oil surface, whereas even small water waves reflect back to the sensor a portion the original signal. This results in patters in pixels in correspondence of water.

URBAN DEVELOPMENT
Urban expansion

Information on areas of urban development from land use maps can be used to monitor changes in these areas. Optical imagery can also be used to identify urban areas as they can be clearly distinguished from surrounding natural landscapes or farming areas. Backscatter from radar data can also show distinct patterns from the surrounding landscape for developed areas and can be used to identify changes in their size. Identification of new urban/village areas can also be carried out through analysis of the aforementioned datasets.

MONITORING EVALUATION & LEARNING
Cutting edge approaches

It is clear from a number of mentioned tools, approaches and methods that monitoring is a large part of NIRAS's in-house capabilities. The majority of the tools and methods can be repeated on data for previous or subsequent years and can, therefore, be used to create a baseline and monitor change. Data and information derived from these spatial layers and further spatial analysis can help inform and provide an evaluation of the changes and impacts that have occurred.

NIRAS has been involved in evaluating project and programmes, commissioned by space agencies and space-based organisations, which have strong earth observations approaches at the core of their design. Findings of the evaluations have been used on a real-time basis to inform how the dashboards can best be tailored and applied by the user. Combining the strengths of counterfactual and mechanism-based evaluation methods, we use cutting-edge theory-based impact evaluation approaches, for example in the Earth and Sea Observation System Programme.

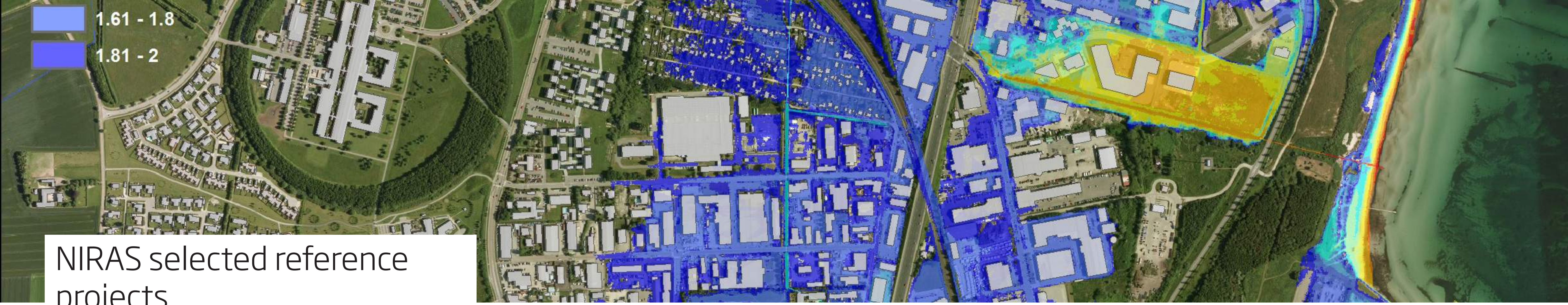
The need for a reliable account of the amount of forest carbon, including changes over time is clear for REDD+ activities. Assessing the land area covered by different forest classes is carried out with satellite monitoring and can be done within NIRAS. These measurements at different time intervals are used to estimate forest area changes. Measuring, reporting and verification of forest carbon changes over time is essential and required to assess REDD+ implementation effects and allow for performance-based payments.

Population growth analysis
Impacts of increasing populations can be modelled and taken into account as an attribute for land use changes while carrying out modelling work. This approach results in modelled land use layers that take into account the impacts from an increased population on the land cover. Population data that is attributed to certain areas can also be visualised, with the possibility for the population attribute data to be extrapolated to reflect future population sizes based on current growth rates.

Infrastructure digitising
Digitised paper map images or remotely sensed data can be utilised to determine infrastructure within a speci-fied area. This looks at digitising infrastructure such as urban areas, road networks, and facilities-such as hospital, schools etc. (by looking at data from varying years) it is possible to see changes in infrastructure over time.

Community mapping exercises
A large number of household surveys and data/information collecting techniques in the field have a geospatial component or are attributed to specific villages, regions or areas. To digitise this information and make it available in a GI system, it is often best to do mapping exercises on a community level while collecting survey information. This can be done through varying methods, from using laptop/tablets to create data layers on the spot directly over optical data to the simpler approaches of printing off a map of the areas of interest and filling out the details on a paper version to drawing maps from scratch on large pieces of blank paper. These hand drawn maps can then be digitalised at a later stage.

Network and movement analysis
Networks made from paths that can be used for movement (such as roads and rivers) can be analysed to look at the time taken to move to a specific point on the network from the rest of the network. This can also be used to determine the best place to allocate a facility (e.g. market place, hospital or school) in relation to greatest coverages of the network area, time taken to travel to the facility, or a number of different routing problem analyses. Additional layers such as DEM can be used to account for anisotropic movement frictions in correspondence to steep terrains/slopes when generating a realistic network/movement analysis.

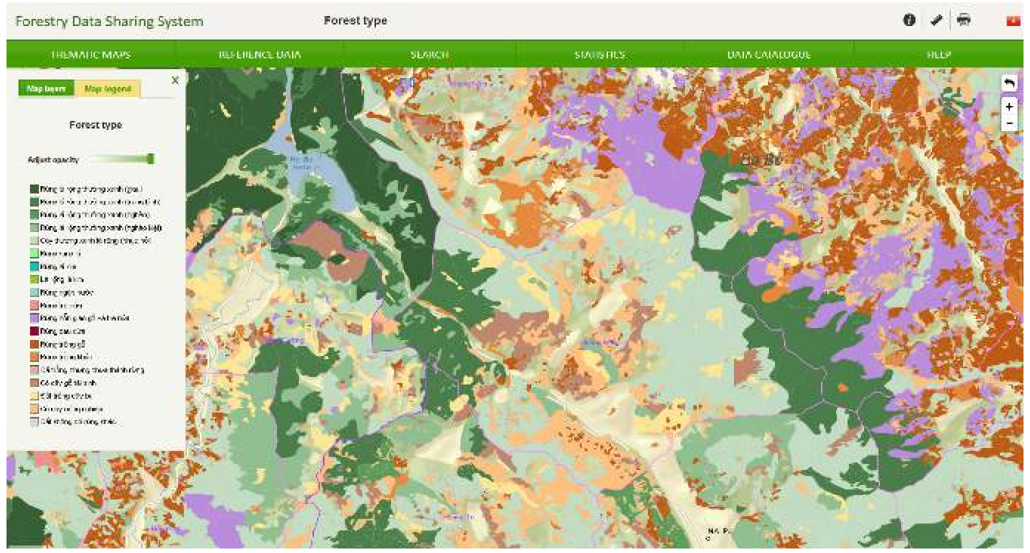


NIRAS selected reference projects

Location	Year	Project title	Client	Value (€ 000)
Global	2012 - 2013	Real-time Evaluation of Norway's International Climate and Forest Initiative (NICFI): Monitoring, Reporting and Verification (MRV)	Norwegian Agency for Development Cooperation (NORAD)	438
Africa region	2017 - 2018	Tree Fund for Africa	The Nature Conservancy	265
Mozambique, Namibia & Zambia	Dec 2016 - Dec 2019	Satellite Monitoring for Forest Management (SMFM)	World Bank / European Space Agency	1,000
Cameroon, Central African Repub-lic, DRC, Congo, Equatorial Guinea & Gabon	2016 - 2017	Evaluation of the Congo Basin Forest Fund (CBFF)	African Development Bank (AfDB)	266
Malawi, Mozam-bique, Tanzania, & Zambia	2015-2018	Climate Smart Agriculture Programme (Vuna)	UK Department for Internation-al Development (DFID)	367
Angola, Algeria, Egypt, Ethiopia, Ghana, Morocco, Nigeria & Senegal	2015 - 2018	Capacity building on monitoring, reporting and verifications of the GHG emissions and actions in developing countries.	European Commission	1,831
Djibouti, Ethiopia, Eritrea, Kenya, So-malia, the Sudan, South Sudan and Uganda	2014-2019	Technical Assistance to the Biodiversity Management Programme in the Horn of Africa Region	European Commission	1,320
Burundi, Kenya, Rwanda, Tanzania & Uganda try	Mar 2013 - Dec 2017	Planning for Resilience in East Africa through Policy, Adapta-tion, Research, and Economic Development (PREPARED).	USAID	1,737

Ensures the sustainability of Viet Nam's forests through an up-to-date management information system

Implemented by the Ministry of Agriculture and Rural Development (MARD) of Viet Nam, FORMIS (phases I and II) supported sector-wide forest governance through the development of a modern information system for decision making. The system integrates all forest-related EO and attributes data previously scattered in various organisations in a centralised platform through cloud technology and service-oriented architecture. Users can generate informed forest resource monitoring reports based on emerging needs as the technology allows for real-time data updating. Up-to-date forest resource data can now be used for effective policy development and easy reporting for international conventions, international finance institutions (IFIs), and other management purposes. Forest industries data overlaid on forest resources enables forest industry input/output analysis including wood procurement and investment plans against the availability of raw material. Integration of spatial socio-economic data enables development of relevant national development plans, poverty reduction and gender and ethnic minority strategies. Among her key activities, the project conducted training needs assessment, prepared training materials, data collection and ICT training courses in view of strengthened capacity both in selected provinces and at central levels. By combining EO data with other spatially linked attribute data from social, ecological, economic and administrative sources, the tool has been adopted by other departments within MARD as a core instrument in forest planning and management.



For more information, read the project description.

Location	Year	Project title	Client	Value (€ 000)
Burundi, Rwanda, Tanzania & Uganda	2011-2012	Kagera River Basin, Feasibility Study for an Integrated Water-shed Management Programme	Nile Basin Initiative / World Bank	454
Belize	2013 - 2019	Conservation and Sustainable Use of Selva Maya	GIZ	895
Brazil	2014 - 2020	Forest management for sustainable production in the Amazon.	German Federal Ministry for Economic Co-operation and Development (BMZ) via KfW; Ministry of the Environment; Brazilian Forest Service - SFB and Institute for Biodiversity -ICMBio	3,602
Cameroon	2017-2019	Further Development of a Common Mapping Platform and Methodology for local land use planning in Cameroon (Phase 2).	European Forest Institute (EFI)	242
Cameroon	2014 - 2016	Improving the transparency in spatial planning of commodity production in the context of palm oil development (Phase 1).	European Forest Institute (EFI)	162
Colombia	Mar 2018 - Mar 2021	Space Enabled Monitoring of Illegal Gold Mining	Satellite Appli-cations Catapult (Catapult)	240

Monitoring forest degradation from space

Implemented between 2016 and 2019 in collaboration with the University of Edinburgh, the Satellite Monitoring for Forest Management (SMFM) project aimed to improve global knowledge and capabilities for forest degradation assessment and monitoring dry forest landscapes by building upon and complimenting existing international programmes. Funded by the World Bank and the European Space Agency, SMFM supported selected countries in developing their EO capacity. The project tested new or improved methods to process and analyse new satellite EO datasets, with assessments of EO processing methods completed through practical implementation in Mozambique, Namibia and Zambia. SMFM developed methods and open access tools for monitoring of dry forests with EO data, including data pre-processing and compositing, biomass and biomass change mapping, time series analysis, and mapping drivers of deforestation. The project provided technical assistance to national government staff through remote support, training materials, and provision of capacity building workshops.

For more information, read the project description.

SMFM
Satellite Monitoring for Forest Management

Location	Year	Project title	Client	Value (€ 000)
Ethiopia	2017	Portfolio Review and Gap Analysis for the Multi-Sectoral Investment Plan for Climate Resilience	World Bank	38
Indonesia	2017 -2018	Participatory Mapping and Planning 4 (PMaP4) and 8 (PMaP8) under the Participatory Land Use Planning component of the Green Prosperity (GP) project	MCA Indonesia (MCC)	5,995
Indonesia	2014-2018	Implementation of Multi-Stakeholder Forestry Programme - Phase 3 (MFP3)	UK Department for Internation-al Development (DFID)	13,247
Indonesia	2014-2015	Provision of Baseline Data and Cadastral Maps for Priority Provinces in Aceh Province	UNDP	720
Indonesia	Sep 2017 - Feb 2018	Sustainable Forest and Biodiversity Management in Borneo	Asian Develop-ment Bank	3,295
Kenya	2018 - 2019	Field-level Baseline and Progress Research on IDH Landscape Programme in the South West Mau Forest	The Sustain-able Trade Initiative (IDH)	50
Kenya	2012	Conservation of Maasai Mau and Transmara Forest Blocks of Mau Forest Complex and Preparation of Project Investment Proposal	Nile Basin Initia-tive	206
Kenya	2009 - 2017	The 'Miti Mingi, Maisha Bora' Support to Forest Sector Reform	Ministry for Foreign Affairs of Finland	6,526
Lao PDR	2019 - 2026	The Village forest management project	KfW	190

Helps Laotian farmers find new sources of income while simultaneously improving sustainable land management practices

The Agro-Biodiversity Initiative (TABI) is a long-term programme (2009–2020) funded by the Swiss Agency for Development and Cooperation (SDC) focussed on reducing poverty and improving the livelihoods of upland Laotian communities while encouraging the sustainable and environmentally sound management of land and forest resources. In addition to supporting crop diversification, TABI involves the dispersement of grants to partner agencies and civil society organisations implementing subprojects to promote agro-biodiversity, zero deforestation, sustainable agricultural commodity value chains, agroecology initiatives, landscape-based management plans and enhanced food security/nutrition. Products developed with support from the fund include local rice varieties, wild honey, natural tea, bamboo shoots and other local non-timber forest products, native fruit, native livestock, organic vegetables, etc. Production groups have been formed and supported in production, processing and with finding appropriate market linkages and financing, as well in organisational management. Since 2009, TABI has identified, tested and disseminated numerous agro-biodiversity based livelihood models with a positive impact on local income, nutrition, ecosystem services, local resource governance models and agro-biodiversity preserving technical solutions. TABI has also developed a popular participative approach for forest and land use planning and management (pFALUPAM), that is based on specific agro-ecological zones and participatory land-use mapping of each village. pFALUPAM is conducted by District officials and villagers in a participatory process with the objectives to stabilise shifting cultivation, minimise land-related conflicts, and create long-term conducive conditions for the development of agro-biodiversity based livelihood activities.

For more information, read the project description.

Location	Year	Project title	Client	Value (€ 000)
Lao PDR	2009 - 2020	The Agrobiodiversity Initiative – TABI, Phases I, II & III	Swiss Agency for Development Cooperation (SDC)	4,083 Phase I 7,458 Phase II 4,526 Phase III
Lao PDR	2011 - 2016	Integrated Nature Conservation and Sustainable Management of Natural Resources in the Hin Nam No National Park Region (Phase 1, 2)	GIZ	1,697
Liberia	2018 – 2019	Development of National Guidelines on Community Consultation involving Forest Resources.	World Bank	150
Liberia	2015 – 2016	Development of the National REDD+ Strategy.	World Bank	434
Malawi	2015-2018	Strengthening the Information Base of Natural Habitats, Biodiversity and Environmental Services in the Shire Basin.	Ministry of Water Development and Irrigation	612

Providing baseline data and cadastral maps for priority provinces in Indonesia

This UNDP-commissioned project aimed to consolidate information of forest land use so that it can be utilised by all stakeholders in a combined effort to implement REDD+ projects in Indonesia. Through Aceh Government activities and support of NGOs, CSOs, academics and national and international institutions involved in community mapping and related field work, important information has been gathered regarding the communities and businesses directly involved in land use since the 1980s. Implementation of REDD+ is reliant on information about Indonesia's current landscape including demographic data on the communities who use the land and cadastral maps regarding the land's administrative and/or traditional boundaries. This information enables REDD+ to facilitate communities in designing sustainable methods whereby they can share the benefits of forest conservation and enhancement of carbon stocks through afforestation and reforestation.

Photo credit: Thomas Dubois

Location	Year	Project title	Client	Value (€ 000)
Malawi	2014-2018	Implementation Service Provider for Catchment Management	Ministry of Water Development and Irrigation	1,039
Malawi	Aug 2014 – Dec 2015	Analysis of Drivers of Deforestation and Forest Degradation in Malawi	Ministry of Economy, Trade & Industry; Malawi REDD+ Readiness Programme	157
Malawi	2013-2014	Environmental and Natural Resources Management Interventions in the Middle Shire River Basin	Millennium Challenge Account	816
Malawi	2011 - 2016	Enhancing Community Resilience Programme: M&E Services	UK Department for International Development (DFID)	1,706
Malawi	Oct 2011 – Jun 2013	Integrated Assessment of Land Use Options (IALUO)	World Bank	512
Malawi	Oct 2011 – June 2013	Integrated Assessment of Land Use Options for Climate Change Mitigation and Adaptation	World Bank	602
Malaysia	Apr 2017 – Dec 2021	M&E of the Earth and Sea Observation System	The Satellite Applications Catapult Ltd and the UK Space Agency	486

Location	Year	Project title	Client	Value (€ 000)
Mongolia	2015 - 2018	Sustainable Forest Management to Improve Livelihood of Local Communities.	Asian Development Bank	1,657
Morocco	2014 – 2018	Technical Assistance programme of the European Union to support the Forest Policy of Morocco	EU Delegation to Morocco	2,700
Mozambique	2019-2022	The Mozambique Planted Forest Grant Scheme	World Bank	3,981
Rwanda	2016-2020	Establishment and Management of a Technical Assistance Facility under the Programme of Support to Agriculture	UK Department for International Development (DFID)	645
Sierra Leone	2014	STEWARD Project – Technical Support	Bioclimate Research and Development (BR&D)	1
Sudan	2010 - 2015	Eastern Nile Watershed Management – Community Watershed Management Component (CWMP)	Ministry of Irrigation and Water Resources of Sudan	2,350
Tanzania	2005 - 2009	Sustainable Management of Land and Environment in Zanzibar (SMOLE), phase I	Ministry for Foreign Affairs for Finland	1,060
Tanzania	2010 - 2015	Sustainable Management of Land and Environment in Zanzibar (SMOLE), phase II	Ministry for Foreign Affairs for Finland	8,900

Location	Year	Project title	Client	Value (€ 000)
Tanzania	2011 – 2012	Estimating Cost Elements of REDD+	UNDP	118
Tanzania	2010 - 2016	Project on Lindi & Mtwara Agribusiness Support (LIMAS)	Ministry for Foreign Affairs for Finland	9,016
Tanzania	2010 – 2011	Mama Misitu: Addressing Forest Governance in Tanzania	Ministry of Foreign Affairs for Finland	16
Vietnam	2009 - 2019	Development of the Management Information System for the Forestry Sector in Vietnam (FORMIS) Phase I and II.	Ministry for Foreign Affairs for Finland	14,130
Zambia	2017-2022	Impact Evaluation of the Climate Smart Agriculture Zambia (CSAZ) Programme	UK Department for International Development (DFID)	176

Setting boundaries in a participatory mapping process to reduce conflict in Indonesia

The Participatory Mapping and Planning 4 (PMaP4) and 8 (PMaP8) projects were among the many PMaPs, implemented as sub-activities under the Participatory Land Use Planning component of the Green Prosperity (GP) project funded by MCA-Indonesia. The GP aimed to improve land use security and increased adherence to spatial plans by investors, governments, and communities through e.g. improved efficiency of the permit and licensing process and by creating better access to and use of district governments' land-use decisions. The PMAP4 project was specifically assigned to improve acquisition of geo-spatial data and prepare land use/land cover GIS databases, compile and geo-reference the existing and pending licenses and permits for land and natural resource use and enhance district spatial plans through building capacity of government agencies in spatial planning, enforcement, and management of land use information in spatially-enabled databases. The project supported the districts of Malinau in Kalimantan Utara, Mahakam Ulu and Berau in Kalimantan Timur, Kapuas Hulu and Sintang in Kalimantan Barat, Lombok Barat and Sumbawa Barat in Nusa Tenggara Barat, Solok Selatan, Pesisir Selatan and Dharmasraya in Sumatera Barat and Tebo in Jambi. The PMaP8 project supported 81 villages in Riau Province to agree on and demarcate village boundaries and map out natural and cultural resources through a participatory process. NIRAS and our local partner Sekala supported participatory village boundary setting and resource mapping in the districts of Kampar, Kuantan Singingi, Pelalawan, Rokan Hilir and Rokan Hulu, including surveying, mapping and geospatial data processing services. The final products were geospatial data and maps of village boundaries and natural and cultural resource areas within the villages. PMaP8 also provided reliable information on land-based risks and opportunities to renewable energy investors as well as up-to-date land use information to the national One Map Policy, which aims to bring together land use, land tenure and other spatial data into a single database for the whole country. For more information, read the project description.

Photo credit: Thomas Dubois

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