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MANGMAP: A NEW PLATFORM FOR MANGROVE MAPPING AND MONITORING USING EARTH OBSERVATION DATA

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ABSTRACT

Mangroves are a vital natural heritage. Our ability to ensure their preservation is a key issue in the fight against global warming, the preservation of biodiversity and the livelihoods of a growing human population concentrated along the coasts. Over the last half century, mangroves have suffered an alarming loss of global cover. To improve the understanding of mangrove dynamics, up-to-date mangrove mapping and monitoring tools are crucial assets. MangMap is a new online monitoring platform dedicated to the production and dissemination of specific products and services useful for mangrove monitoring at local scales. MangMap is based on generic processing services using Sentinel-2 data. MangMap is an end user driven, easy-to-use portal designed to support and document scientific studies as well as to help institutional actors and stakeholders involved in mangrove conservation and management.

Index Terms— Mangrove, extent, change, MangMap, Sentinel-2

1. INTRODUCTION

Mangroves are tropical forests that are uniquely adapted to the intertidal zone. Found in the coastal zones of 123 countries and territories in the tropical and subtropical regions [1,2], mangroves support the way of life and subsistence of growing human populations concentrated along the coasts [3,4]. Mangroves play a vital role as habitats and breeding grounds for fish and invertebrates, providing natural resources for local people and economic security for fishermen and their communities [5]. This ecosystem of great ecological and economic values also acts as a natural barrier, protecting coastlines from storm surges and erosion [6]. Nevertheless, mangroves are among the world's most threatened ecosystems due to climate change and human activities [7]. In particular, forests have been extensively altered or cleared for aquaculture, food production, and coastal development, processes that continue in many parts of

the world today [8,9]. Some estimates suggest that the global mangrove area has declined by 30 to 50% over the last half century [10, 11]. To invert this trend, a growing number of initiatives aims at protecting and restoring mangrove forests. To improve knowledge and conservation of mangroves, accurate and recurrent mapping or monitoring tools have been developed. At the global level, several maps of mangrove extent and change estimates have been published (e.g. [12, 7]), and to date the Global Mangrove Watch (GMW) provides the highest quality data available at the global scale, with an online platform that disseminates products useful for mangrove monitoring and mapping. It provides global extent and change data for 1996, 2007 - 2010 and 2015 - 2020 periods at a spatial resolution of 25 m [13]. It offers tools for mangrove analysis and monitoring, derived from satellite imagery and global geospatial datasets, to estimate changes in these ecosystems.

In this context, we have developed a new interactive online platform for mangrove forests monitoring, focusing on a complementary approach to existing platforms and products. Our platform, called MangMap, provides an interactive dashboard dedicated to mangrove remote sensing applications: ready-to-use-space-born products derived from Sentinel-2 time series, online services at end user request, dissemination of images, indexes and statistics in specific end user Areas Of Interest (AOI), useful to actors of mangrove monitoring and conservation at local scales.

The goals of this initiative are to: (1) improve scientific knowledge and contribute to the preservation of mangrove distribution and health; (2) offer to communities a dedicated online tool that disseminates standardised, reliable, automatically updated and easily accessible space-born information characterising the state of the mangroves (diagnosis) and the current dynamics (retrospective analyses); (3) aggregate a network of end users interacting with the initiative, expressing needs and feeding the basis for further developments and upgrades of the platform, seeking new services to address risks and threats to the mangrove ecosystem.

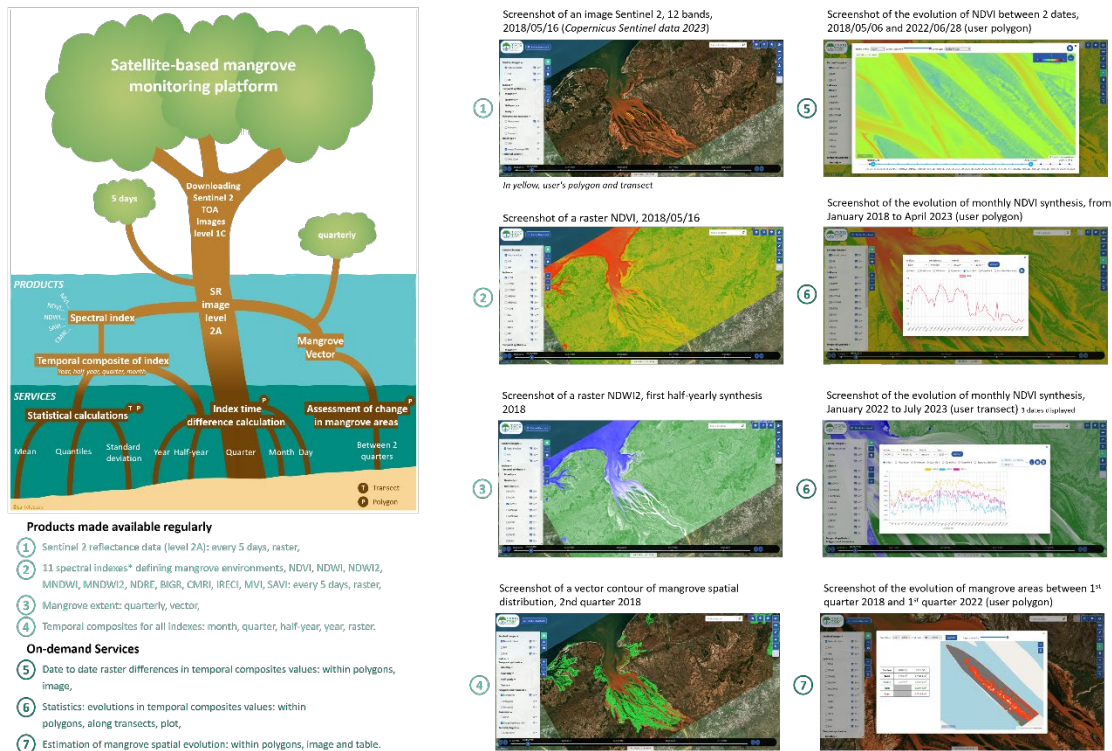


Figure 1: On the left side, the processing chain of the MangMap platform, from Sentinel 2 imagery to products and services. On the right side, illustrations of the eight products currently offered by the MangMap platform (Bombetoka Delta, Madagascar).

MangMap as a whole (platform and website) has been designed to support and document scientific studies as well as institutional diagnosis needed by actors and stakeholders involved in mangrove conservation and management. Our aim is to facilitate decision making in mangrove conservation and management, and to provide these communities with a web space dedicated to user-friendly applications of remote sensing for mangrove monitoring. The Space Climate Observatory (SCO) led by the French Space Agency (CNES) certified the MangMap initiative in 2020.

2. MANGMAP METHOD, PRODUCTS & SERVICES

The MangMap platform is based on generic and recurrent processing services using standardised products from Sentinel-2 satellite image time series starting in 2018, at 10m resolution, updated every 5 days. MangMap is an easy-to-use free portal to consult, retrieve or produce information useful to data analysts at local scales, allowing end users to request specific data processing in specific AOI.

It automatically retrieves new Sentinel 2 imagery in specified tiles. Each image is converted to reflectance levels (2A), cropped to mangrove extent, and made available for viewing (timeline) and download, along with 11 automatically processed spectral indexes characterising the

mangrove environment. Every quarter, an automated vector contour of mangrove spatial distribution is calculated, and made available for viewing and download. Temporal composites of all indexes are processed monthly, quarterly, semi-annually and annually, feed the viewer and are available for download. End users can set up specific on-demand analysis requests, within their own areas of interest uploaded to the platform or drawn on the products on-screen, for a chosen period of time: indicator of mangrove spatial evolution; calculation of index differences; statistics on index evolutions. All results and all datasets can be retrieved using simple download tools. The global method shown in Figure 1 illustrates the variety of processing steps applied to the Sentinel-2 time series.

2.1 Reflectance and mangrove extent cropping

From each Sentinel2 L1C image downloaded by the platform every 5 days, a L2A image is generated together with its associated cloud mask (an image mask identifying pixels altered by the presence of clouds or cloud shadows). The Sen2Cor algorithm, developed by ESA, is used for this step (<https://step.esa.int/main/snap-supported-plugins/sen2cor/sen2cor-v2-10/>). Then, the Sentinel-2 tile is cropped into a rectangular spatial extent that includes areas where the mangrove is present. This first product proposed by

the platform is a raster with 13 spectral bands in the visible and near-infrared light with a spatial resolution of 10 to 60 metres, like the Sentinel-2 image from which it is derived. This raster product is called a Region Of Interest (ROI).

2.2 Indexes and temporal composites

From the ROI, eleven spectral indexes characterising the mangrove environment were calculated using the Sen2Chain algorithm (<https://framagit.org/espace-dev/sen2chain>): Normalized Difference Vegetation Index (NDVI, [15]), Inverted Red-Edge Chlorophyll Index (IRECI, [16]), Normalized difference Red edge index (NDRE, [17]), Brightness Index Green Red, (BIGR), Normalized difference water index (NDWI, [18]), Normalized difference water index 2 (NDWI2, [19]), Modified Normalized Difference Water Index (MNDWI [20]), Normalized difference water index 2 (MNDWI2, [21]), Soil Adjusted Vegetation Index (SAVI, [22]), Mangrove Vegetation Index (MVI, [23]) and Combined Mangrove Recognition Index (CMRI, [24]). Cloudy areas are masked out. The second proposed product is a set of 11 spectral index rasters with a spatial resolution of 10m. Temporal composites of spectral indexes are calculated from spectral index rasters generated every 5 days: monthly, quarterly, semi-annually, annually. A temporal composite corresponds to the average of the index values for each pixel, weighted by the number of dates used in the calculation. The third proposed product is a set of these temporal composite rasters with a spatial resolution of 10m.

2.3 Vector mangrove mask

The fourth proposed product is a vector of mangrove extent. This vector is computed quarterly. A processing chain for the delineation of mangrove areas has been developed (Figure 2). The mangrove detection methodology was designed to be applicable on a global scale but adapted with specific settings at the local level. Thus, for each geographical location (ROI raster), the settings are adapted to the local characteristics of the mangroves (e.g. height of trees, vegetation type, see below). It is iterative: each quarter, a mangrove contour vector is calculated from the least cloudy ROI raster of the quarter (Figure 2). For a given quarter and a given ROI, the input data are: 1) A mangrove extent reference vector (Mang_Ref). The Mang_Ref reference vector is a mangrove contour vector from the scientific community; 2) The SWIR1 band (B11) of the ROI raster, with a spatial resolution of 20m; 3) The NDWI2 raster, with a spatial resolution of 10m; 4) NDVI raster, with a spatial resolution of 10m; 5) The Copernicus DEM (Global Digital Elevation Model - COP-DEM, <https://doi.org/10.5270/ESA-c5d3d65>), with a spatial resolution of 30m. The following procedures are applied (Figure 2):

1. Creation of the Raster_M raster in which the search for mangrove pixels is carried out. A 4-band raster (NDWI2, NDVI, SWIR1 and COP-DEM) with a resolution of 10m is created;

2. Definition of “land” and “vegetation” thresholds using the NDWI2 and NDVI indexes. The NDWI2 is used to detect flooded areas, and ranges from -1 to 1. Pixels with an NDWI2 value below a threshold S1 define land surfaces. The NDVI is used to detect vegetated areas. It ranges between -1 and 1, with pixels with an NDVI value greater than a threshold S2 defining vegetated surfaces;

3. Selection of vegetation pixels. Double thresholding is applied on SWIR1 and COP-DEM bands. Vegetation pixels have an NDWI2 value < S1 AND an NDVI value > S2;

4. Definition of the values of the mangrove pixels in the SWIR1 band. From the SWIR1 band and in the geographical extension of the Mang_Ref vector, two thresholds are extracted: the 1% quantile (Q1) and the 98% quantile (Q98). These thresholds define the range the mangroves are located;

5. Define the values of the mangrove pixels in the COP-DEM band. From the COP-DEM band and within the geographical extension of the Mang_Ref vector, the maximum mangrove height threshold (Hmax) is extracted;

6. Selection of mangrove pixels using the SWIR1 band and the COP-DEM band. Double thresholding is applied. Mangrove pixels have a COP-DEM value $\leq Hmax$ AND a value of $Q1 < SWIR1 < Q98$;

7. Vectorisation of the mangrove raster. Creation of a vector shapefile of mangrove contours.

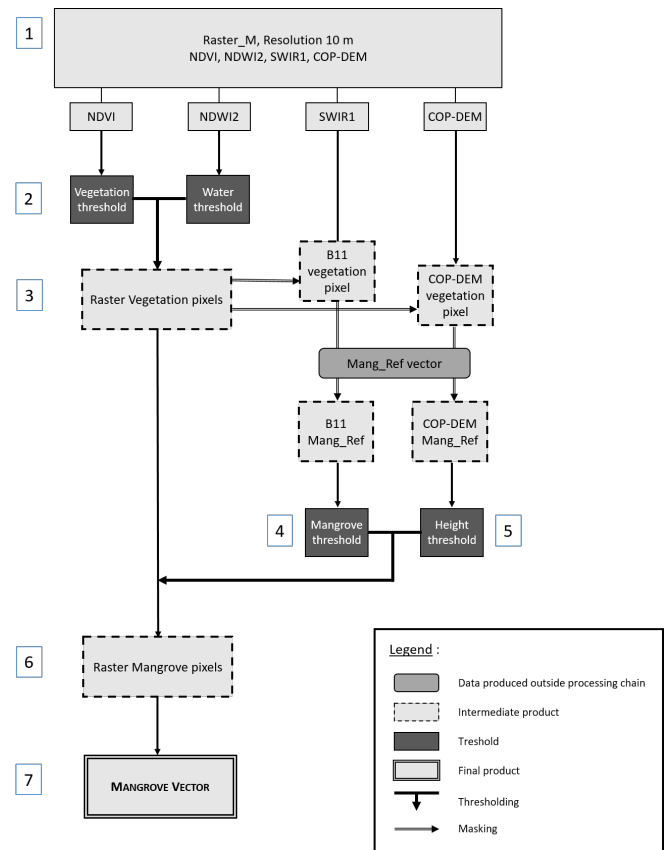


Figure 2: Algorithm of the mangrove detection methodology.



Figure 3: The platform gathers 16 pilot sites spread over South America, Africa, Asia and Oceania regions.

It is important to note that the platform administrator can adapt all the thresholds according to the geographical location (ROI raster). The user can view the raster products on the platform and download them free of charge in TIFF or JPEG format, and the vector product in SHP format. From the products created, the platform offers the user three online calculation services (Figure 1).

2.4 On demand services

After creating a local account on the platform or using Theia Land Data Centre account (Theia is a French public national data centre dedicated to Earth Observation applications for the study and monitoring of Continental Surfaces), the end user has access to a set of services for the temporal analysis of mangrove changes. To carry out the different processes, the end user must 1) upload its specific Area(s) Of Interest or draw polygons or transects on the screen and 2) specify two dates (start/end dates). The processes are stored in the end user's personal profile information as they are carried out. All results can be easily downloaded. The services consist of (Figure 1):

1. Calculation and restitution (graphs, .csv tables) of statistics showing the temporal evolution of spectral index values or its temporal composite values within polygons or along transects: mean, standard deviation, minimum, 1st quartile, median, 3rd quartile and maximum;
2. Calculation and restitution of differences of spectral index values or its temporal composite, as an indicator of potential anomalies in the time series: raster images of differences between two dates;
3. Calculation and restitution of mangrove extent evolution: simple merging of two mangrove vector files, with attribution of the three labels: "Stable area", "New area", "Eroded area" (mangrove extents that have disappeared and no longer consisting of mangrove areas).

These initial services are subject to continuous improvement and upgrading. All products and services are executed on specific Sentinel 2 tiles previously installed on the system, in line with MangMap's development plan: progressive expansion to new sites around the world, with a first target of 16 sites opened in 2024 (Figure 3).

3. CONCLUSION

Open to all end users in a simple open data approach, MangMap is mainly aimed at scientists, whether experts or non-experts in remote sensing, land managers, technical staff of protected areas or government services seeking geo-information useful for generating knowledge and documenting conservation actions in favour of the mangrove ecosystem. MangMap, with its interactive website and technical platform, is designed to support studies and institutional diagnosis with simple tools, services and products. Ultimately, MangMap's main objective is to contribute to decision-making and policies for the conservation and restoration of coastal ecosystems. As the community of end users grows, MangMap will gather needs and suggestions to plan and develop news services, such as alert systems in case of deforestation or mangrove degradation, new indicators or new end user functionalities. Further upgrades, in preparation with the first end users will identify actions to improve the end user experience and provide new Earth Observation products and services based on very high spatial resolution imagery and radar data time series.

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