Space for ecosystems newsletter

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Earth Observation for ecosystem service assessment

Mapping and monitoring our world's natural assets from space promotes economic development in an environmentally sustainable manner.

Earth Observation provides objective and repeated data collection over the same area making it possible to follow both seasonality and landscape change over time. The information collected by satellite sensors makes it possible to distinguish between different land cover types and to detect degradation of e.g. forests and grasslands as well as marine habitats.

The Ecoserve project funded by the European Space Agency (ESA) has explored and showcased the possibilities to use Earth Observation (EO) services and EO-derived data for ecosystem service assessment and valuation to estimate amongst others the economic benefits that nature provides to humans. An ecosystem is the interaction between the environment and the living organisms. The processes benefiting human well-being from these ecosystems are the ecosystem services.

Five trials have been conducted focusing on ecosystem services in different parts of the world. Ecosystem services in forested ecosystems have been explored in the trials at Lombok (Indonesia), in Huong Son (Vietnam) and in Ucayali (Peru); in agricultural and forest mosaic landscapes at Lombok and in Vinh Tu (Vietnam) as well as different aspects of marine ecosystem services at the Northern Yucatan (Mexico) and Lizard Island (Australia) coral reef and sea grass ecosystems.

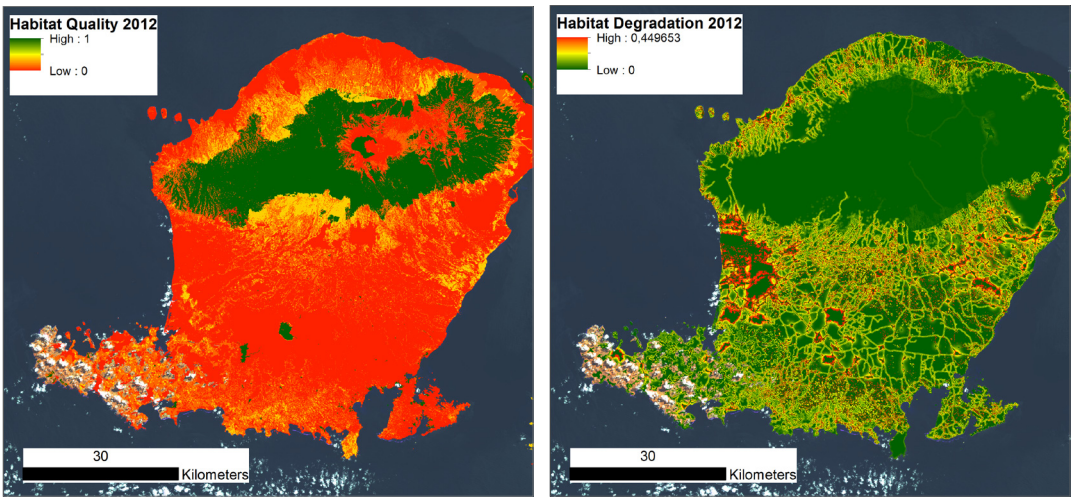
The EO products and services delivered within the Ecoserve project range from land cover and forest classifications, biomass estimates and digital elevation models of the terrestrial sites to bathymetric maps, benthic classification and primary production estimates in the water columns of the marine trial sites. These services have been produced to form a knowledge platform for the analysis of ecosystem services in the trial sites. Most ecosystem services can be analysed based on local knowledge and with relevant information on land cover and landscape composition.

Topics

In total 5 demonstration studies, covering various geographic regions and targeting marine, coastal and land ecosystems and their services, have been carried out in the Ecoserve project.

Ecosystem service assessment from space

Biodiversity



The spatial distribution of land cover and land use is one of the major factors influencing species distribution and biodiversity in a landscape. The land cover maps over Lombok were used to create a map of unfragmented natural habitats (green in the first image) and of areas with high human influence (red in the last image). Together, these maps show the areas with potential for high biodiversity.

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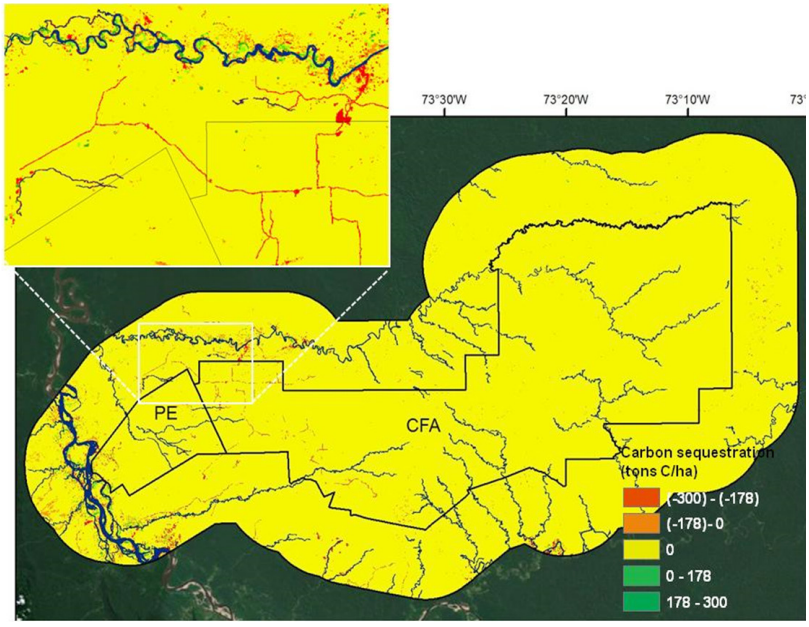
The multitude of processes, genes and habitats constituting ecosystems are referred to as biological diversity. The biological diversity is the backbone of the ecosystems services delivered to promote human well-being. When biological diversity diminishes it is an indication of ecosystem change and hence an indication of a change of the ecosystems capacity to deliver services for human well-being. EO-data provide important information on the distribution of habitats as well as the distribution of threats to species and landscape processes.

Energy



Carbon sequestration is an important ecosystem services. The results from the change analysis and the forest classification were used to calculate the carbon balance in the pilot studies. In this image the carbon sequestration in Ucayali between 2006 and 2010 is displayed. The establishment of a road network is evident within the concession as well as the agricultural and hydrological dynamics close to the river. Red is the loss of biomass, visible as timber roads and clearings. The riverine forest dynamics are also visible as red and green (gain) areas along the rivers.

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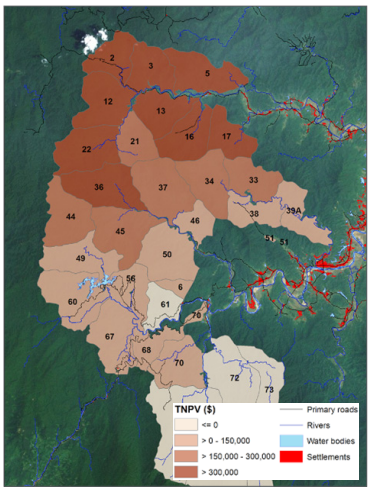
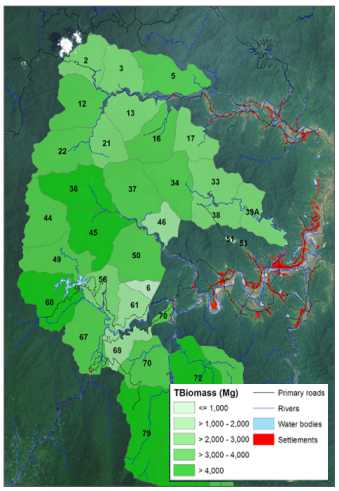
Photosynthesis transforms carbon dioxide and water into sugar and oxygen utilising solar radiation. This is a crucial ecosystem service providing human with some of the most important components for well-being, carbohydrates as energy container and oxygen as agent to release the energy. If the carbohydrates are not utilised the carbon will be kept in the biomass during the life span of the organism, i.e. hundreds of years for trees, and during the decomposition of the biomass. This storage of carbon in the ecosystem is in turn an ecosystem service. Carbon dioxide is withdrawn from the atmosphere during the process, compensating human influence on the atmosphere. Changes in land cover result in changes in carbon stock. EO based monitoring of land cover makes it possible to follow the flows of carbon originating in the increase or decrease in biomass.

Food, fibre, fuel and feed





Information on land cover, market values and forest management was used as input to the managed timber production model of the Invest toolkit and applied to the Huong Son forest concession. The left image displays the total net present value of the forecasted timber extraction until 2045 (based on averaged values), the darker the greater value. The legend of the right image display the biomass foreseen to be extracted by the forest operations within each parcel, the darker green the more biomass is foreseen to be extracted in the pa. Numbers correspond to the parcels listed in the forest management plan of the Huong Son Company.

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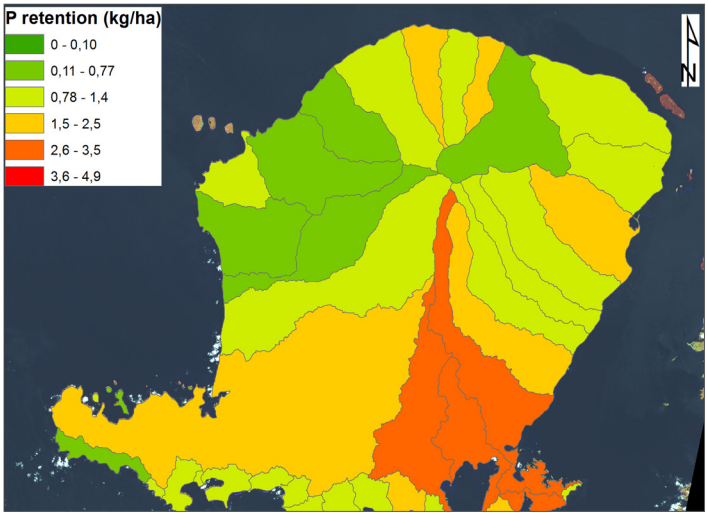
The main use of biomass, if extracted from ecosystems, are as food, fibre, fuel or feed, the four F's that are the main goal of agricultural and forestry operations. The produced commodities are targeting specific markets and certain aspects of human well-being. It is thus possible to value both the raw material delivered by the ecosystems and the added value from human refinement and processing chains. If the management of a landscape, a patch or a region focuses on the delivery of food, fibre, fuel or feed, other ecosystem services are likely to diminish. This will of course be both, site and system specific. Focus on one aspect of ecosystem services will in general diminish other services. The biomass based ecosystem services can be assessed with EO based information on land cover, crown height and change.

Forestry activities focus on the production of fibre, sometimes with fuel as a by-product mainly extracted from the residues of the fibre production or from stumps and branches. The forestry sector and the ecosystem services connected to it are a major focus of the Ecoserve project as two of the pilot sites are forest concessions, Ucayali and Huong Son, and plantation forestry is important in Vinh Tin. For timber production the species composition, age and size of the geographic distribution of preferred tree species are important as well as the production potential of the soil. EO data in combination with data from forest management plans and information on market prices and revenues are a good base for the assessment of the ecosystem services providing timber.

Water purification



In order to assess the nutrient retention potential on Lombok the land cover classification, a digital elevation model and metrological data on rainfall and soil characteristics was used as input to the Invest water yield and nutrient retention model. The results are calculated per watershed. This figure displays one of the outputs, a phosphorous retention map, where green areas have low retention and orange areas a high one. The retention is closely connected to the nutrient load on the land but to a large extent dependent on the vegetation close to the water courses.

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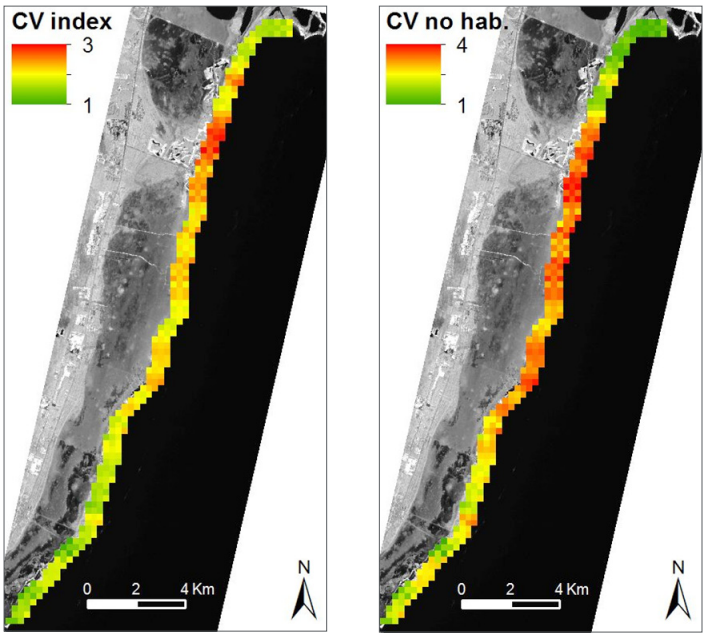
Water falling on land is filtered by vegetation, soil and to some extent bedrock. Purification of water is one of the most important and basic ecosystem services. Pure water is a prerequisite for human well-being as drinking water, source of irrigation and for healthy aquatic environments. The aquatic environments provide services such as recreation and populations of edible fish and other aquatic organisms. Clean water, in lakes ponds and rivers, is important for game populations. Clean water availability is one of the most important factors for primary production. Water filtration hence provides the base for a cascade of ecosystem services at landscape and global level. EO derived data is important to estimate the ecosystem services delivered, serving as key information to support policies on nutrient retention.

Erosion control



The coast line on Yucatan is susceptible to wave erosion and the coral reef and sea grass beds provide important ecosystem services protecting the coast line. The importance of the ecosystem services was assessed running the Invest model for wave energy and coastal erosion assessment. The input data was EO-derived data on benthic habitats and depths and the results were compared with a scenario without these habitats. The map displays coastal vulnerability in the absence, right, and presence, left, of marine vegetation and coral reefs. Red marks high vulnerability and green low.

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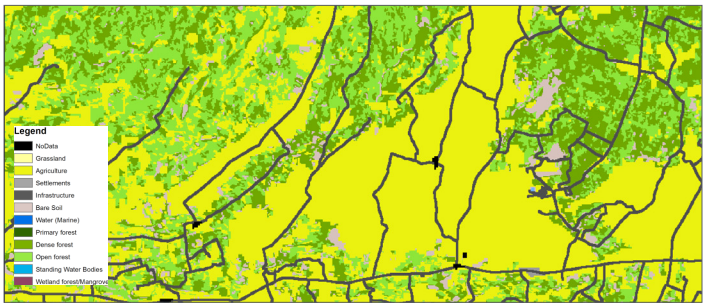
Vegetation gives substrate stability in both terrestrial and aquatic environments as the root system establishes a three dimensional matrix in the substrate. The roots do not only stop erosion, they also help to accumulate organic matter and are important for soil establishment. The vegetation in itself reduces wind speed and wave energy as well as surface runoff. EO provides important information to assess the erosion reduction potential of vegetation and other land covers. Actual erosion can also be monitored using time series analysis of both vegetation change and actual changes in land form, evident on e.g. shorelines.

Earth Observation services for ecosystem service valuation

The main EO services produced within the Ecoserve project are based on semiautomatic classification of high resolution and multispectral EO-data. The main data sources are SPOT 5 with a resolution of between 2.5 and 10 meters and Rapid Eye with a resolution of 6 meters.

Forest classification



Forest classification with different density classes and differentiation between primary in dark green and secondary forest in lighter green colours. The untuched rainforest is high up at the caldera the more accessible areas further down are degraded or transformed to agricultural alnd.

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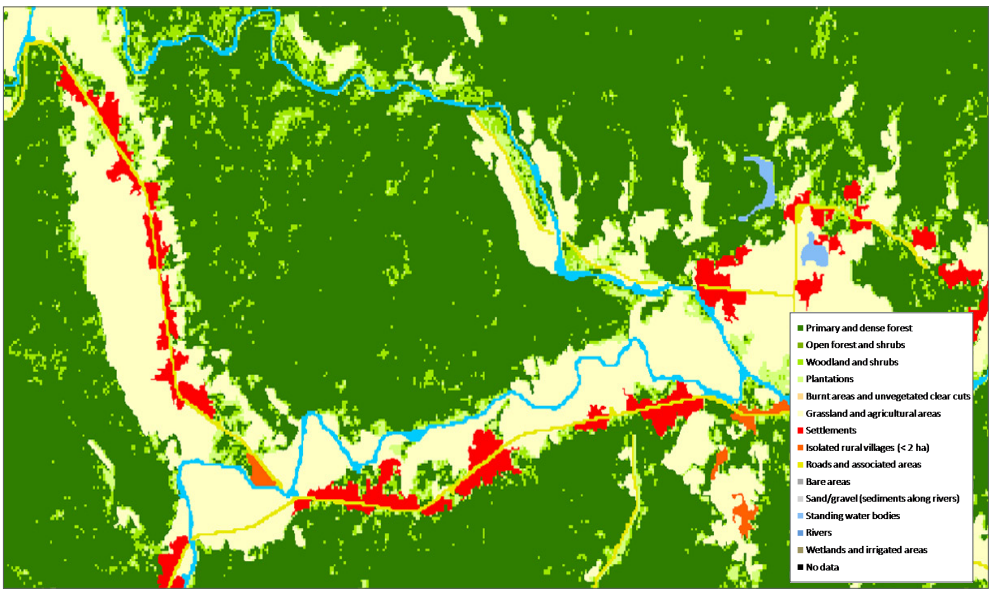
Forest classification based on multispectral high resolution imagery has been conducted in the Lombok, Huong Son & Vinh Tin and Ucayali trials. The classification is based both on the crown density of the forest but also on the spectral characteristics differentiating between dense forest with or without primary forest characteristics. Crown density analysis of high resolution imagery is based on the transition of spectral signatures from patches with only signatures of tree crowns to patches dominated by ground vegetation.

This range is divided into different density classes. The larger the contrast is between the crowns and the ground the higher accuracy is achieved. Spectral characteristics of forest patches differ depending on species, species composition, crown size and growth phase etc. Diverse forests with large crowns and a closed understory differ accordingly considerably from managed forests and plantations with only one or two species. This makes it possible to distinguish between young and old forest and managed and unmanaged forests. Information on local conditions significantly improves quality of the classification. The forest classification was used for biomass estimates, water purification, nutrient retention, carbon sequestration calculations and timber production potential.

Land cover and land use



Land cover map of an area close to a river ben d in the Huong Song, Vietnam. The narrow floodplain with the meandering river can beeasily identified. The fertile floodplain's main land cover is agricultural land or grassland, and the road network connects the settlements, at the transition zoon between the open land and the forest, to each other. This is important information to understand the ecosystems services of this particular landscape.

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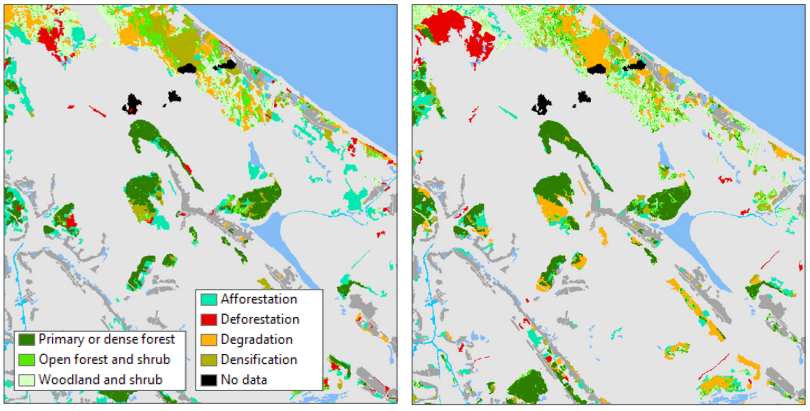
Analysis of land cover outside the forest was made in the Lombok, Huong Son & Vinh Tin and Ucayali trials. The classification is based on the spectral characteristics of the open areas in the respective trials. Areas outside the forest have no or few trees and the main land cover types are shrub land, grassland, water, marches and sparsely- or non-vegetated areas. Most of the open areas are open as a result of human land use and are referred to different land use domains, e.g. the agricultural domain and infrastructure.

The agricultural domain is dynamic with regard to land cover. A rice field can shift accordingly: from non-vegetated to water and vegetated and back to non-vegetated during a couple of months. Infrastructure on the other hand is permanent non vegetated areas stretching out in a narrow interconnected mesh over the landscape. Local knowledge and image analysis techniques together with some degree of visual interpretation make it possible to collect information on both land cover and land use with multispectral high resolution imagery.

Combined with in situ data and other mapping sources the accuracy of both the classification of both land use and land cover classification could be increased. The land cover land use information produced was used for biomass calculations, water purification, nutrient retention and carbon sequestration potential.

Change detection



Change detection is a powerful technique to assess the pressure on and the dynamics of a landscape and the ecosystems within it. The Vinh Tu case study area has a strong anthropogenic influence with agricultural land and plantation forestry. The dynamic in the landscape is high in accordance with this. The images display the forest cover transitions between 2005-2010 and 2006-2011.

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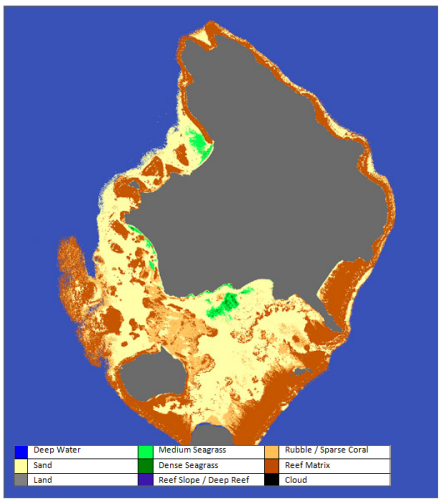
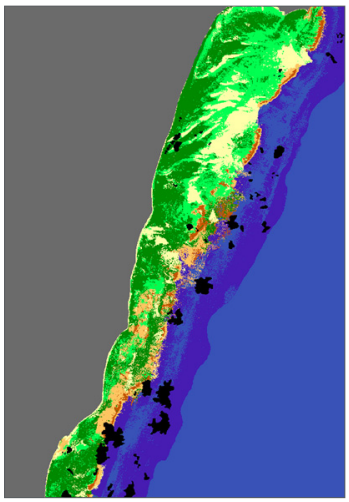
Land cover changes and land use dynamics are manifested as changes of spectral reflectance in satellite images. Changes are mainly analysed in four different ways: 1) comparison of two maps or land cover classification with each other; 2) comparison of a map or land cover classification with a satellite image; 3) comparison of two satellite images with each other or 4) analysis of time series data from multiple satellite images. The change analyses that have been performed within the Ecoserve project are based on an image to image approach. Image to image give more reliable results compared to analysis of maps with maps or maps with satellite images. Time series analysis give reliable results but demands much more data and should be preferred if changes are supposed to be detected with high temporal accuracy, e.g. establishing when a clearing took place, the change is subtle or the regrowth is quick. If the information required is to know whether changes have taken place between two predefined dates or not, image to image analysis is preferred. The results of the change analyses were used to calculate changes in carbon stock and landscape composition.

Substrate mapping

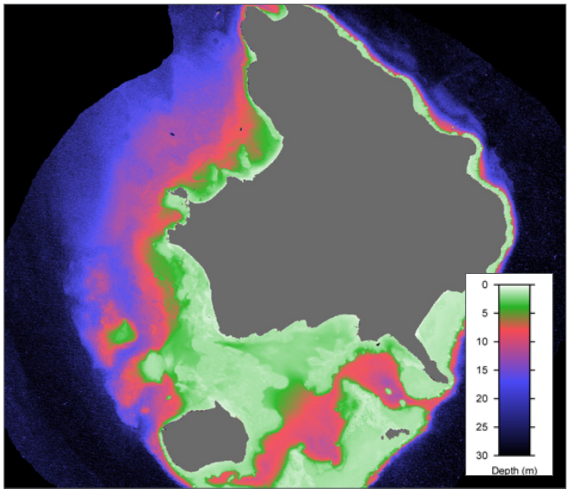




Benthic habitats can be classified as long as they are within the visibility range. The benthic habitats are important as feeding grounds as well as for spawning and have important effects protecting the coastline from erosion. A map of the benthic habitats is thus a prerequisite to make ecosystem service assessments. Substrate and vegetation map of the areas inside of the reef in the Northern Yucatan and Lizard Island trial sites

Substrate and vegetation in shallow water can be mapped as long as they are situated within the visibility range of the water column. Multispectral imagery helps to differentiate between substrates as the reflectance differ between for example sand, sea grass and coral reef. Very high resolution multispectral imagery was used to produce the current extent of sand, sea grass and corals, World View 2 in Northern Yucatan and Quickbird at Lizard Island. The resulting substrate and vegetation maps have a resolution of 3.6 and 2.4 meters respectively. Historic conditions were mapped using high resolution SPOT (4 and 5) data as very high resolution data is none occurring for the historic dates. The substrate and vegetation maps were used for analysis of carbon sequestration and coastal vulnerability.

Bathymetry



Bathymetric analysis of shallow waters are based on the absorption of light in the water column as well as taking into account the difference in reflectance between substrates. The same very high resolution imagery was used for the bathymetry as for the substrate classification. The resulting bathymetric map was based on the imagery with input from local echo sound data. Depths down to 30 meters were detected with good accuracy. Bathymetric maps were used to analyse the coastal vulnerability and are of great value both as input to other analyses but also as a general support to the management of marine areas.

Conclusion

The Ecoserve project has proven that EO can provide important information on a wide range of ecosystem services. State of the art EO-techniques have been utilised and the resulting services have been combined with input on local conditions as well as local and global dataset on climate and soil conditions. Training and involvement of local stakeholders as well as iteration of the results are important to for the provision of relevant decision support and for implementation of the results into actual policies and guidelines.

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