A new multifunctional coastal classification for eco-system-service assessments

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Abstract

Based on GIS data sets an add-on for a coastal classification system was developed which takes Ecosystem Services (ESS) into account. The coastal area is segmented and afterwards classified. The segmentation is based on Google Earth. Each segment can be characterized by 10 different features including ecosystem services perpendicular to the coastline. If one of the features is changing a new segment will be specified. Therefore, a world-wide application is possible. Tests show that the classification can be easily done. The included ESS can be used to develop a vulnerability index for future development, e.g. for the years 2050 and 2100, based on scenarios for climate and demographic land use change.

Introduction

A coastline is the transitional area where terrestrial and marine processes interact in a fairly narrow zone and on very short to long time scales. Thus, coastal areas are very highly dynamic regions. The configuration and development of a coast is associated with various factors, such as the geological setting, substrate, ecosystem characteristics, regional climate, wave and tidal regimes, sediment dynamics, human development and near shore infrastructure.
To conduct a generic and widely useable coastal classification is a fairly complex task, depending on the objective of the work. Many different concepts have been applied to coasts in attempts to characterize dominant features in terms of geologic, morphologic or biological properties, modes of evolution, geographic occurrence, among others (Finkl 2004), as well as socio-economics. Also, the need for better coastal management due to world-wide human pressures on the coastal zone and the resulting vulnerability motivated the development of coastal classification criteria that fit different purposes (Finkl 2004; Ihl et al. 2006; Appelquist 2013; Appelquist & Balstrøm 2014). Some of the earlier classification approaches were broad in scope but lacked important details while other specialized systems were topically too much focused. As a result of more comprehensive studies of coasts and the increasing availability of digital information, such as Geographic Information System (GIS) frameworks, integrated and systematic approach to coastal classification are now the preferred options (Finkl 2004; Scheffers et al. 2012). Present-day management demands require problem solutions, which integrate the marine, littoral and terrestrial as well as the socio-economic sphere and human infrastructure of the coastal zone.

There was and still is only little research in mapping and estimating Ecosystem Services (ESS) in the coastal zone, especially the impact of climate and demographic change to ESS for different time steps e.g. in the year 2050 and 2100 (MA 2005). Climate change will also modify the kind and the potential of ESS but recent human activity on the coastal environment has a very strong influence on the development of ecosystem units and their services ahead. With an intelligent and suitable management of economic activities, coastal protection as well as nature protection measures etc. in the coastal zone one can have influence on the supply and demand of ESS in the future.

Objectives

In this context, the aim of our work is to develop a comprehensive GIS-based coastal classification scheme in order to provide a basis for a general characterization of the coastal area. This tool is meant to be open for use over coastal regions world-wide and can be further developed e.g. through expert knowledge. An applicable classification should be developed taking as few as possible and as many as necessary features of a coastal strip into account. The classification should describe the current state of natural and socio-economic features. On the other hand new coastal sections and ecosystem services may be assigned to the classification scheme for the future (Burkhard et al. 2014), e.g. for the year 2050 and 2100, under the assumption of climate change and socio-economic change. There are a lot of climate and demographic change projections. Numerical values based on ESS (Jacobs et al. 2014) may be used to quantify the current ESS and the ESS in the future (Werner et al. 2014). The movement of these values, decreasing (degrading) and increasing (improving) can be a basis for a vulnerability index leading to an integrated coastal zone management starting nowadays. As basic GIS we used Maptitude by Caliper.

Method

The framework uses a simple assessment methodology, considering data and computing requirements, allowing application by any kind of user. For the segmentation the coastline is defined as the area where land and water meet. At coastlines without tide it is the visible line between land and water. At coastlines with tides it is the high water mark. The basic assumption is that we have coastal segments with identical perpendicular conditions, land and seaward of the coastline. If one or more of the elements changes, we have a new segment. Through a GIS software the littoral sections are segmented and classified according to 10 categories: (1) Dominant natural feature, (2) substrate at the coastline, (3) dominant man made features, (4) additional man made features, (5) nearshore environment, (6), seaward environment, (7) landward environment, (8) predominant land use, (9) other land use and last but not least (10) ecosystem services for each segment. In the experimenting phase of the project we work on a scale of 1:20.000; however, the scale is flexible and requires adjustment, depending on the overall length of the coastal segments under consideration. In the application phase we changed to a flexible scale.
The segmentation and classification of the coastline is based on Google Earth maps and includes a self-developed add on for the GIS. Figure one shows the start screen in the GIS.
The software is running under a common windows system. It was tested for the coastline of the province of Buenos Aires and for the Baltic Sea coastline of Germany.

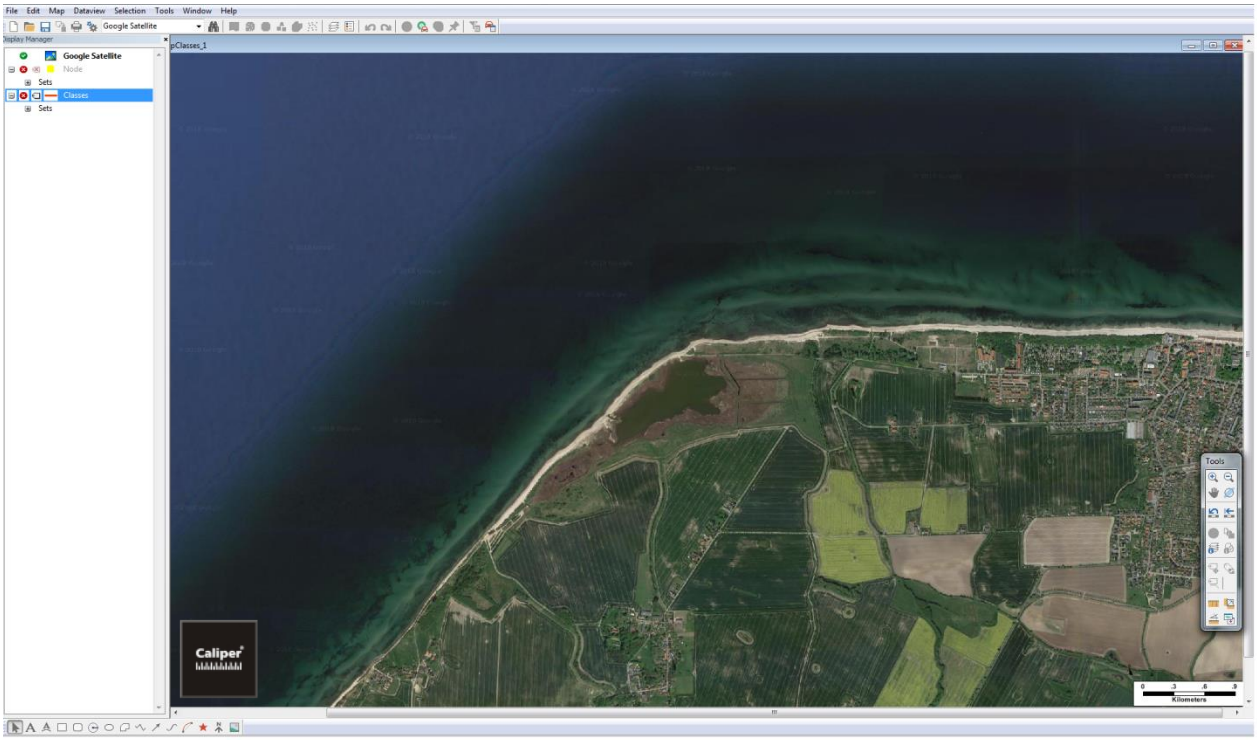

Fig. 1: Start screen of the GIS

Three basic steps are necessary: The first step is the segmentation of the coastline. A segment with the same structural features is classified by the visible features of the coastline. This means that questions have to be answered, such as: What type of substrate is present? Are there longshore bars or reefs? Is there an active or inactive cliff present? What for a sort of land use is visible, etc.? If one of these features is changing along the spatial digitalisation sequence, the sector is interrupted and we have a new segment. The landward extension is 100m from the coastline and the seaward extension depends on the visibility of the sea ground in Google Earth. Figure two shows a coastal strip in Argentina as example for the segmentation.

Fig. 2: segmentation of a coastline

The next step is to fill in the 10 categories for each segment. In detail these are:

(1) dominant natural characteristics of the direct coastline as e.g. beach and dunes, beach, muddy coast/wetland, spit/beach ridge, cliffs (soft or rocky), barrier island, artificial coastline, atoll, delta, etc.

(2) substrate as e.g. muddy (salt marsh, mangroves, swamps…), clastic sediments (compact, loose, gravel, sand, dunes, stones and rocks…), hard rocky coastline, artificial coastline, etc.

(3) dominant manmade features as harbor, coastal protection structures (parallel to the shoreline as seawall, revetment, dike, artificial reef/breakwaters…, perpendicular to the shoreline as groins, jetties…), residential and urban infrastructure, nourished/artificial beach, land reclamation structures, etc.

(4) additional man made features the same as dominant man made features if there are more than one man made feature,

(5) nearshore environment e.g. lagoon, stream (mouth), spit, bay/inlet/gulf, longshore bars, tidal flats, mangroves, coral reefs, marshes, rocky platform, continuous slope, steep slope, land reclamation structures, breakwaters, etc.

(6) seaward environment e.g. open sea, lagoon, delta, fjord, spit, estuary, etc.

(7) landward environment e.g. dunes, marsh, barrier island, spit, cliffs (active/inactive), headlands, coastal plain, lagoon, continental plain, obscured by human development, etc.

(8) predominant land use e.g. urban, rural (includes forestry and agriculture), industrial, transport, scattered settlement (villages), nature reserve, etc.

(9) Other land use the same as predominant land use

(10) Ecosystem Service (ESS) based on MA 2005 and extended by own specified services

a) provisioning services as P1: food, products derived from plants, animals and microbes; P2: fiber; wood, jute, cotton, hemp, silk, and wool, materials serve as sources of energy; P3: genetic resources; genes and genetic information used for animal and plant breeding and biotechnology, bio-chemicals, natural medicines, and pharmaceuticals; P4: mineral resources (sand, gravel, stones etc.), wave- and/or thermo-energy;

b) regulating services as R1: climate regulation, climate both locally and globally; R2: water regulation, timing and magnitude of runoff, flooding, and aquifer recharge; R3: erosion regulation, vegetative cover plays an important role in soil retention and the prevention of landslides; R4: water purification and waste treatment, source of impurities but also can help filter out and decompose organic wastes; R5: natural hazard; such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves, longshore bars, active cliffs, erosions-platform (tilt ridge), pebble, stones (on beach and foreshore), beach ridge, spit, beach wrack etc.

c) cultural services as C1: aesthetic values, beauty or aesthetic value in various aspects of ecosystems; C2: cultural heritage values, many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species; C3: recreation and ecotourism, spend leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area (bathing, diving, angling, sailing etc.).

For practical and conceptual reasons we did not include the supporting services. Figure 3 shows the classification for a coastal strip at the German Baltic Sea near Kiel.

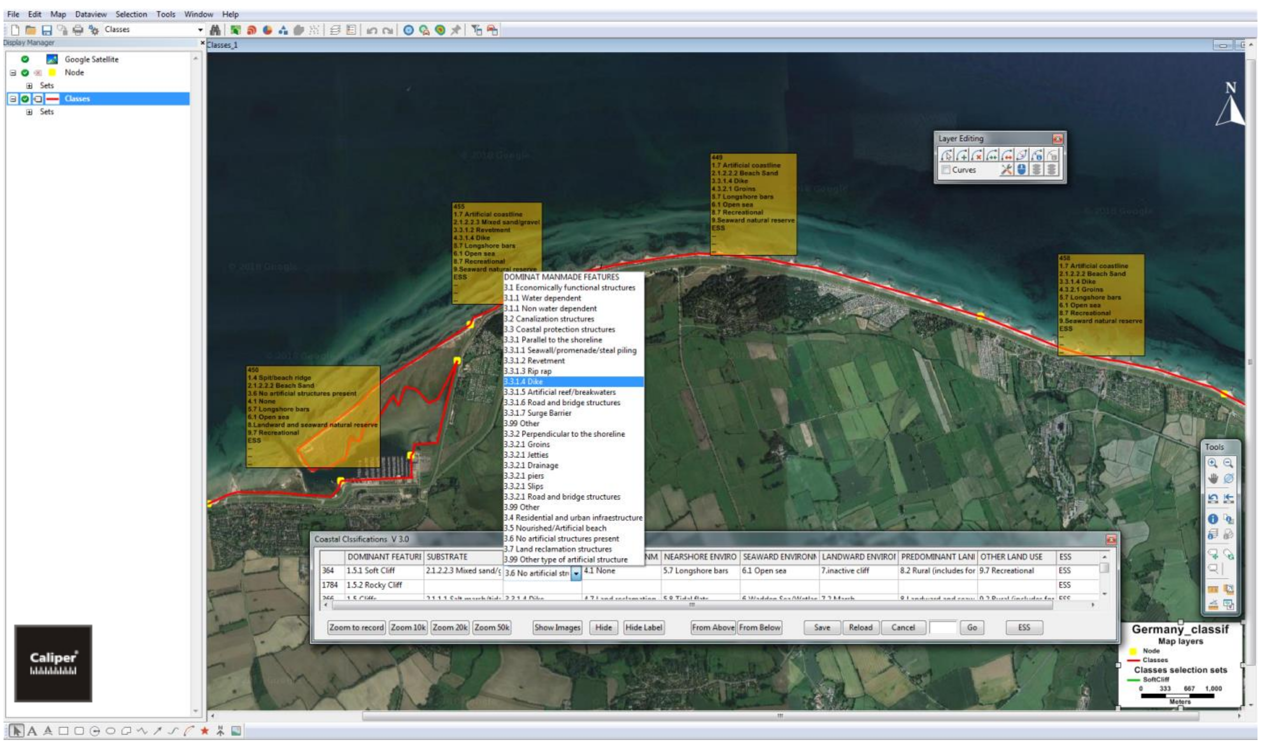

Fig 3: Example for the classification of a coastal strip at the German Baltic Sea (Marina Wendorf near Kiel)

ESS can be specified for each category perpendicular to the coastline for each segment. With this structure we can have more than one ESS providing structural item for the individual coastal segments. This approach can be taken to describe a coastal strip as a much broader, integrated transitional area looking at the coastline as only one feature. ESS values are none, less, medium, high and very high (Jacobs et al. 2014) but real values, e.g. from 0 to 100, can easily by implemented. Figure four shows the editing screen for ESS.

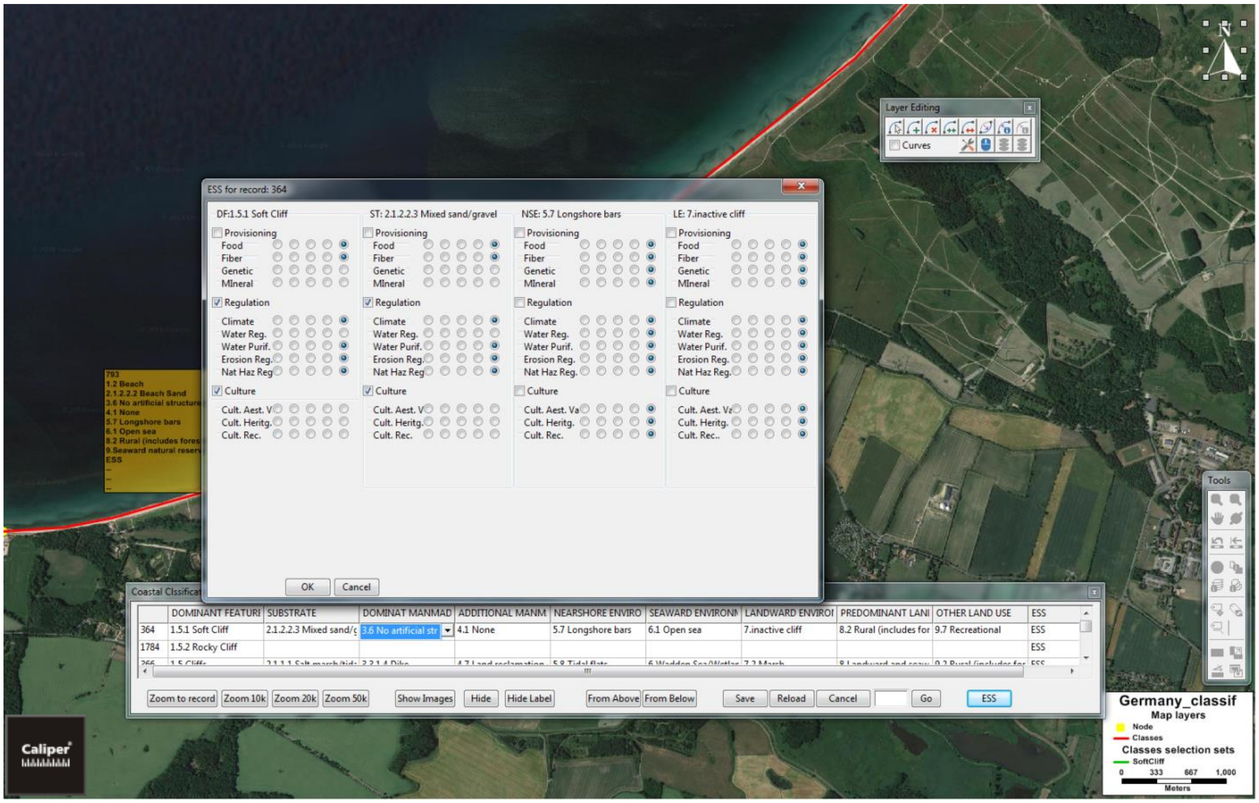

Fig. 4: Editing screen for ESS

Results

At this preliminary stage, coastal areas of Argentina and Germany are classified, with a wide variety of coastal characteristics: the first region has an open coast in the South Atlantic Ocean, whereas the German Baltic coastal region shows environmental conditions typical of a nearly closed sea. Based on the differences between these coasts and the lessons learned in this comparative analysis, the proposed coastal classification method has been developed and improved and its general applicability has been tested. As a preliminary result, the Argentine coast is mainly distinguished by two distinct regional sectors, the Buenos Aires and the Patagonian coastlines. In the first region the classification tool describes extended modifications due to the development of industrial and recreational infrastructures, geomorphologically dominated by sandy beaches and tidal plains, whereas the Patagonian coast, in general, preserves a natural setting without intensive human intervention. The coastal landscape there is characterized by gravel-sand beaches, cliffs and coastal platforms. In comparison, the classification for the German Baltic coast identified a high degree of human intervention along the coast; thus, in certain segments the original coastal landscape is modified by commercial and military ports, dikes, artificial beaches and marinas, among others.
In general the coasts of Schleswig-Holstein and Mecklenburg-Vorpommern in Germany are dominated by glacial deposits. There are active and inactive cliffs and more or less sandy beaches. Spits, lagoons and sometimes river mouths are present. All these features occur in short alternation. A medium length of a segment at the Baltic Sea is much shorter than in Argentina. It was identified, that a scale of 1:20.000 makes no sense for the coastline of the Baltic Sea. Too much information will be lost using a fixed scale.

The segmentation and classification of the Schleswig-Holstein coastline was done by the authors. Due to this “expert” knowledge it was easy to do that work. The coastline of Mecklenburg-Vorpommern was segmented and classified by a student of the Institute for Nature- und Resource Protection of the University of Kiel. The student did not know the coast of Mecklenburg-Vorpommern. With little assistance by the author the work was well done. This indicates that this setup of segmentation and classification is not only practicable for experts but also for non-experts. Helpful are pictures from Google Earth, which are linked directly to the GIS and the very well established information system about nature protected areas in Germany. Figure 5 shows an example of the classification of Kiel Fjord without ESS.

Fig. 5: Resulting classification for Kiel Fjord

Conclusion

The classification method presented here intends to provide a tool for scientists to advance the understanding of coastal systems world-wide and to compare regional coastal settings, e.g. with respect to vulnerability from climate change and sea level rise. The tool may also assist coastal managers in assessing the environmental state of specific coastal areas and in choosing appropriate options for sustainable development there in years to come. The tool can be operated by scientist and non-scientist and is very flexible in resolution depending on the problem to be solved.

For the aim of a development of a vulnerability atlas, a lot of research still must be done. Especially the knowledge about ESS in the coastal zone is in the beginning but research is in progress 61(Albert et al. 2016).

Scenarios about the influence of climate and demographic change in the year 2050 and 2100 on ESS must be developed. Through clustering the recent ESS values and the potential values for the scenario conditions one can develop vulnerability maps and long-term management concepts can be set-up. This task is still under progress.

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