Coastal vulnerability assessment using Fuzzy Logic and Bayesian Belief Network approaches

INTRODUCTION
Marine drivers such as the surge in the context of SRF, are threatening low-lying coastal plains. In order to deal with disturbances a deeper understanding of benefits deriving from ecosystem services management and planning (e.g. the role of dunes in natural disaster management and climate adaptation) can enhance the resilience of coastal systems. In this frame the vulnerability assessment is a key point of many Systems Of Systems (SoS; ecological, institutional) that deal with several challenges like the definition of Essential Variables (EVs). A top down approach exploiting ecosystem potentials (e.g. as called ecopotential) (now EU2020 EU funded project “ECOPOTENTIAL”, the Ecosystem Based Adaptation (EBA): the use of ecosystem services as part of an adaptation strategy. To provide insight in understanding regulating ecosystem services to surge-proof to make the best use of GEO products, in sites and modeling dunes, a multi-component surge vulnerability assessment, focusing on coastal sandy dunes as natural barriers is performed. This is to combine together geo-ecological and socio-economic variables with the hazard component on the base of different approaches.

FUZZY LOGIC BASED VULNERABILITY ASSESSMENT
Fuzzy logic applied to complex and imprecise problems enables to handle the non-ideal properties of ecosystems, which deal with several challenges like the definition of Essential Variables (EVs). A top down approach exploiting ecosystem potentials (e.g. as called ecopotential) (now EU2020 EU funded project “ECOPOTENTIAL”)

BOYANOV Belief Networks (BBN):

- A sand–dune ecosystem potential (Figure 1) was selected to follow the approach that is presented for assessing the vulnerability is a key concern of many actions, from the economic applications, like this application, stressing the role of ecosystems in surge and flood protection (i.e. mapping ecosystem services) by highlighting ecosystems characteristics.

ECOSYSTEM-BASED ADAPTATION APPROACH (EBA): EXPLOITING COASTAL PROTECTION ECOSYSTEM SERVICES
It is widely recognized that healthy ecosystems contribute to human well-being and the socioeconomic and nature of these resources play a key role in reducing climate related risks and vulnerability (EBA, 2018). The BBN is used for the basis of a framework to evaluate the risks to coastal systems (e.g. beach erosion, coastal flooding, and wave run-up) using the CPT diagram (i.e. probability distribution of the outcomes). The model is applied to the SABAUDIA CASE STUDY: real data and ideal hazard scenarios by means of combined approach of optical and radar remote sensing, Coastal Engineering. 10.1016/j.coastaleng.2013.11.001.

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COASTAL VULNERABILITY SYSTEM NETWORK IN AN ECOSYSTEM SERVICES PERSPECTIVE

COASTAL VULNERABILITY ASSESSMENT: GAP FILLING FOR EbA
Current costs range from simple geographic methods to complex software packages (coastal vulnerability indexes, Computer vulnerability index, Multi-scale coastal vulnerability index, ODV3D, GIS, 3D, SimGEO, etc.)

BAYESIAN BELIEVE NETWORK VULNERABILITY ASSESSMENT
A Bayesian Belief Network (BBN) is a directed acyclic graph (DAG), which can capture the interdependency of events. A BBN is a graphical model that represents a set of joint probability distributions over a set of variables. These distributions take the form of conditional probability tables (CPTs), which specify the conditional probability of each variable given its parents. The BBN is constructed by specifying the conditional probability table (CPT) for each node in the network. The CPT is a table that specifies the probability of each possible value of a node given each possible combination of values of its parent nodes.

SABAUDIA CASE STUDY: real data and ideal hazard scenarios
A sandy beach characterized by a dune system running parallel to the coastline whose elevation and characteristics varies from north to south. The coastal road that runs longitudinal to the system at the altitude of the dune crest. Coastal Engineering. 10.1016/j.coastaleng.2013.11.001.

CONCLUSIONS
The BBN approach is very useful to get a spatialized information whose detail depends on pixel resolution and it can easily manage a great amount of variables. The approach used in this paper is very powerful (i.e. the BBN approach presented in the study, allowing to model complex behaviors as a collection of simple “if-then” statements, and has the ability to model complex behaviors as a collection of simple “if-then” rules). The BBN approach can be used to predict the degree of vulnerability as the sum of all the input variables that contribute to vulnerability in different contexts and scales and in several context, data and variables site specific, and whose number and type is not defined a priori.

Each fuzzy operator (e.g. fuzzy AND, fuzzy OR, fuzzy NOT) is modeled by a set of thresholds values that are defined in a range relatively very high values, and very low values.

FUZZY LOGIC BASED VULNERABILITY ASSESSMENT
Fuzzy logic is a collection of mathematical models that are able to deal with the so-called grey areas or vague boundaries, that are common in real-life situations. This is due to the fact that the boundaries between fuzzy sets are not always sharp, but rather gradual, and the degree of membership in a fuzzy set is a matter of degree rather than a matter of absolute truth or falsity. Fuzzy logic is based on the theory of fuzzy sets, which was introduced by Lotfi A. Zadeh in 1965. Fuzzy sets are a generalization of classical sets, allowing elements to have a grade of membership in a set, rather than a binary membership (i.e., an element is either a member of a set or not). This allows for a more nuanced representation of the degrees to which elements belong to sets, which can be useful in situations where the boundaries between sets are not easily defined.

WAVEHEIGHT SUM represents the degree of vulnerability as the sum of all the input map inputs.

RESULTS
In both cases, the vulnerability decrease from north to south, in fact the probability of having low vulnerability increase from north to south.

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References
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