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Socio-Economic Regional Risk Assessment (SERRA) application to flood risk in the Vipacco Basin (north-east Italy)

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Abstract: According to EEA (European Environmental Agency), flood is the most dangerous natural hazard in Europe in terms of economic losses. TheKULTURisk Project (EU FP7) has developed a novel methodology for evaluating the integrated benefits of risk prevention of water related natural hazards: SERRA (i.e. Socio-Economic Regional Risk Assessment). The proposed methodology enhances the traditional flood risk assessment by integrating the missing socio-economic dimension into the established regional risk assessment. Several case studies across Europe allowed for the consolidation, validation, and refinement of SERRA. This paper presents the results of its application to assess the benefits derived from the installation of an Early Warning System in Vipacco river basin in Friuli Venezia Giulia (Italy). Social, economic and physical data are used to assess the total expected risk for several receptors such as economic activities, cultural heritage, people, etc. The collected socio-economic data are stored in Geographic Information System (GIS) and processed according to SERRA algorithms to produce maps of various categories of costs (beyond physical-environmental damages) in order to assist the Decision Makers (DMs) in making more informative decisions. The visualization of total risk through GIS maps allows the DMs to understand the spatial distribution of social vulnerability, risk, and associated costs.

Keywords*:* flood risk; GIS; socio-economic regional risk assessment; EWS.

1. INTRODUCTION

"Flooding along related storms is the most important natural hazard in Europe in terms of economic loss" (CRED, 2009 and EEA, 2010) and this is probably one of the reasons why a great interest is nowadays focused on risk mitigation and prevention. Moreover several researchers explored how risk may increase (Milly et al., 2002, DEFRA, 2003, Wilby et al.,2008, Weather and Evans, 2009,) in the future due to land use changes, climate change and socio-economic changes in the society.
This paper presents a case study of flood risk assessment. The study area is the Italian territory of the Vipacco River Basin, a small area (16 km^2) in the municipality of Savogna d'Isonzo, downstream to the Slovenian part of the watershed, tributary to the Isonzo River.
Risk assessment procedures are used in many fields like economics, environmental and social sciences and the purpose of these types of analysis is to estimate the expected risk in order to assess the feasibility and benefits of implementing potential risk mitigation strategies. It is customary to calculate flood risk considering the combination of three factors: hazard, vulnerability, and exposure (Cutter, 1996 and DEFRA, 2003).
The European Union in 2007 has produced the Flood Directive that summarizes the aims and the guidelines for the Members States (MSs) to develop flood management plans and risk reduction measures. In particular it suggests to the MSs to "address all aspects of flood risk management focusing on prevention, protection, and preparedness including flood forecasts and early warning system" (Art. 7 Directive 2007/60/CE). This directive is the cornerstone for interpreting the KULTURisk (Knowledge-based approach to develop a cULTUre of Risk prevention) methodology. KULTURisk

aims at focusing on risk prevention by trying to integrate the physical-environmental component and the socio-economic factors of a flood event. The physical environmental component of the risk is assessed through RRA (Regional Risk Assessment) (Marcomini et al., 2011) while the socio-economic factors are analyzed by SERRA (Socio Economic Regional Risk Assessment) methodology (Mojtahed et al, 2013). SERRA is basically a procedure that includes the human component of vulnerability and the economic value of the exposed elements in the risk assessment. It aims to provide a monetization of the flood risk in the baseline and in the alternative scenarios, thus capturing the benefits due to the risk reduction measures to be implemented. Several structural or non-structural measures might be taken into consideration as alternative scenario, but in this work the attention is focused on non-structural risk reduction measure, in particular EWSs (Early Warning Systems).

In this paper, we describe the risk to human receptors. The risk has been assessed with SERRA methodology and the damages have been calculated through depth-damage functions taken from DEFRA (2003) and reviewed by the KULTURisk research team. Depth damage functions create a relation between the percentage or economic damage and the depth of the water. Thanks to these functions, damage values of different scenarios can be expressed in monetary units and used to support decisions, typically within a Cost-Benefit or a Cost-Effectiveness analysis (CBA and CEA, respectively).

In order to have efficient communication with DMs and effective decision support, not only CBA or CEA results should be provided but also maps that are necessary to provide a clear perception of the results and can be later on translated into planning instruments or used to locate interventions.

For this reason all the acquired data are stored in a GIS (Geographical Information System) and processed by means of spatial analysis. Quantum GIS with the GRASS plug-in and the software GRASS 6.5 are both free and open source software and they have been used to calculate the total risk in the baseline and in the alternative scenario.

The environmental and hydrologic spatial data used in this work were mainly provided by the Eastern Alps Hydrographic District that is the competent authority for the implementation of the EU Flood Directive in the study area. Physical information was complemented with social indicators derived from several other sources such as ISTAT (Istituto nazionale di STATistica), Health Ministry, and Civil Protection. These data have been imported in the GIS software and then analyzed with ad hoc spatial analysis procedures developed for the application of the SERRA approach.

2. MATERIAL AND METHODS

2.1 Case study presentation: Vipacco river

The area considered is located in Friuli Venezia Giulia, near the border with Slovenia, and most of the data used in the application belong to the municipality of Savogna d'Isonzo. Actually Savogna d'Isonzo is not crossed by the river Isonzo, but by Vipava-Vipacco, a smaller river that flows into Isonzo near Savogna. Vipacco is a trans-boundary river and it flows in Italy only for 12 km across a karst area of eastern Friuli Venezia Giulia. Only this part of the river basin is subject of this study.

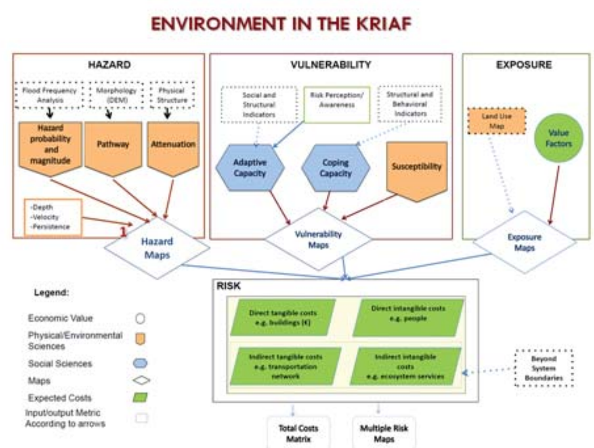

Figure 1 General KULTURisk Framework

2.2 SERRA methodology

In this section we present the theoretical methodology used for the socio-economic regional risk assessment of the Vipacco basin. The application of the methodology in this case study has required *ad-hoc* adaptations, due to the size of area and some data gap. In Figure 1 we present the general framework of the KULTUrisk project. Risk is divided into three components: hazard, vulnerability and exposure. SERRA includes the economic (green boxes) and the social analysis (blue boxes).

2.2.1 Social component

The social component is assessed considering the human component of vulnerability dimension that is divided into:

a) Adaptive Capacity (AC): "the combination of the strengths, attributes, and resources available to an individual, community, society, or organization (ex-ante hazard) that can be used to prepare for an undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities" (IPCC-SREX, 2012).
b) Coping Capacity (CC): "the ability of people, organizations, and systems, using available skills, resources, and opportunities, to address, manage, and overcome (ex-post hazard) adverse conditions" (IPCC-SREX, 2012).

These components of vulnerability derive from different social and ecological variables and these cannot be objectively measured only by using quantitative data and deterministic static or dynamic models (Giupponi et al., 2012). The SERRA methodology is basically a multi-criteria anaysis that makes use of indicators, normalization, weighting and aggregation procedures.

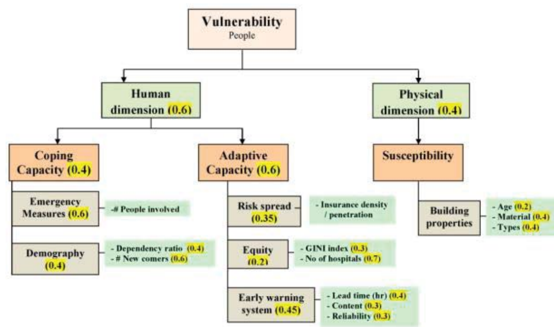

Figure 2 Aggregated Vulnerability

The KULTURisk Framework provides a preliminary list of the indicators chosen for adaptive and coping capacity, which were selected from the literature e.g. Cutter et al. (2003), Cutter and Finch (2008), Steinführer et al. (2008), MOVE (2011). In Figure 2 there are reported some of these indicators and the relative weight in the aggregated vulnerability.

After the selection of the indicators and the data collection, all the data are normalized, weighted and aggregated. Normalization "is the procedure of transforming indicator values with different units of measure into a dimensionless number" (Mojtahed V. et al., 2013).

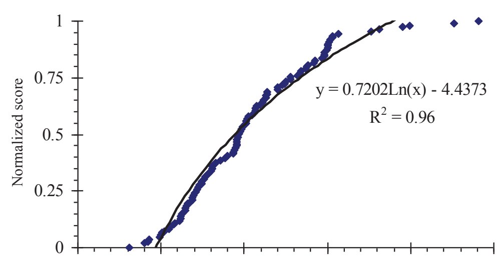

Figure 3 Insurance density normalization function

The aim is to obtain values between 0 and 1 in order to obtain a total vulnerability value that belongs to the same interval. Several normalization techniques exist in literature (OECD, 2008) but the Value function is the one chosen in this application. "Value functions are the mathematical representations of human judgments, which offer the possibility of treating people's value and judgments explicitly, logically and systematically" (Beinat, 1997).

The data regarding social indicators present several units of measurement and this characteristic makes them very difficult to compare to each others. After normalization procedure these data are transformed in a dimensionless number. In this way it makes sense to compare, add or multiply them. Value functions are created using different range of values for each indicator. The range of values chosen to create the functions represent the trend of that indicator in Europe, Italy or regional context. The lowest value is normalized as zero, which represents no vulnerability. On the other hand the highest value has given a value equal to 1 and represents a fully vulnerable situation. All the values in between are normalized following the function. The next step is weighting. Not all the indicators equally contribute to the aggregated vulnerability index of a certain receptor. For this reason, they need to be weighted and aggregated "in accordance with the logical conceptual model, but also according to the elicited preferences of the Decision Makers (DMs)" (Mojtahed V. et al., 2013). The weights given for each indicator should derive from the analysis of a questionnaire where the stakeholders could define the relative importance of each indicator. In this work weights are based on expert's opinion.

2.2.3 Economic component

The economic analysis of the SERRA methodology in addition to the GIS visualization of the results, helps the DMs to chose the best option, focusing on different scenario.

The first step of the economic analysis consists of identifying the costs due to a flood event of a given hazard in a given area. This evaluation allows the DMs and the stakeholders to know what are the costs associated with a flood event of a precise intensity without any prevention measure. This preliminary study is called *baseline scenario*. Further, several possible preventive measures that represent the different *alternative scenarios* can be considered, but in this case study the attention is focused on Early Warning Systems (EWS). In this case, the valuation of costs will take into account also the costs of implementing the preventive measure itself so that by calculating the difference between the *baseline* and the *alternative scenario* the DMs can understand the benefit derived from each option.
The economic analysis should consider several receptors in order to give the DMs a comprehensive synthesis of the total costs of a flood event but, as explained above, in this paper we will present just the costs for human receptors. The complete monetization of the risk means that an economic value should be given also to the people's life. This value is called Value of Statistical Life (VSL) and according to Biausque (2010) the VSL can be calculated using different parameters like the willingness to pay, the human capital, the sanitary costs, etc. This value allows us to monetize the economic value of fatalities and injuries using an algorithm containing the number of people at risk, the flood severeness, the vulnerability index of the receptors and the VSL. These algorithms have been elaborated in a GIS context in order to obtain the total values in monetary units.

2.3 GIS

According to the Flood Directive of the European Union, all the results of the flood risk analysis must be visualized in maps. According to the KULTURisk framework, such maps not only consider physical vulnerability, but also its social components and represent damages in economic term.
The map displayed in a GIS context can be shown to the DMs in order to make the results more understandable and deducible. The visualization of the results in a map is one of the crucial points of this work. The decision-makers, end-users or anyone that has some interest in this research will be able to see the cost of a flood event in each part of the municipality considered. The maps can immediately give an idea of the size of the damage just using different colors: red mostly stands for higher damages, while green or white represent lower costs.
The first part of the work has involved the collection of data of the area of study. This was a challenging task because the case study is of micro scale and hence not all the data were available. This part of the study was conducted together with the Eastern Alps hydrographic District.

3. RESULTS AND MAPS

3.1 Baseline Scenario 300 years return time

Figure 4 Baseline Scenario

	TR 300
N of people at risk	7.1
N of injuries	3.58
Cost of Injuries	2.220.000
N of fatalities	0.68
Cost of fatalities	2.100.000
Total costs people	4.320.000

Table 1 Costs

The baseline scenario represents the situation without any preventive measure adopetd. In the following table are reported the number of people at risk and the relative costs for people.

3.2 Alternative Scenario EWS

In this section of the results we will firstly present the alternative scenario considering the installation of an early warning system as preventive measure. The benefits deriving from the EWS depend on the relative weight assigned to the Early Warning component in the aggregate vulnerability index of the KULTURisk methodology. This weight should be calibrated following the opinion of the stakeholder's.

Figure 5 Alternative Scenario

	TR 300 EWS
N of people at risk	5.54
N of injuries	2.19
Cost of Injuries	1.358.000
N of fatalities	0.41
Cost of fatalities	1.270.000
Total costs people	2.628.000

Table 2 Costs

3.3 Alternative Scenario EWS first approximation changing weights

After the calculation of the results, it was clear that the weight given to the EWS in the methodology was probably underestimated. This means that in this particular case study, where the area is really small and the number of people at risk is also little, it is reasonable to think that a reliable EWS can be more effective. For this reason, in this context it was necessary to fine-tune the weights in the hierarchical combination of indicators of the people vulnerability, assigning to the EWS and the human component of vulnerability a higher value. This is just a first approximation and further research is needed to try to assess and recalibrate the weight of the EWS in this application of the SERRA methodology. The new values of the weights were chosen in collaboration with some experts (Ferri M., Autorità di Bacino and other flood risk experts of the University).

Figure 6 Alternative scenario

	TR 300 EWS TEST
N of people at risk	4.22
N of injuries	1.24
Cost of Injuries	770.000
N of fatalities	0.24
Cost of fatalities	745.000
Total costs people	1.515.000

Table 3 Costs

3.4 Cost-benefit analysis/Cost Effectiveness analysis

The costs of the baseline and the alternative scenario (EWS) was derived from the depth damage functions used in this case study. Moreover, to have an idea of the effective benefit that a EWS can give in a flood event, we have considered the possibility of false alarm and missed alarm in the final costs. To obtain reliable data uncertainty analysis is needed. The data used to calculate the probability of false and missed alarms derive from some expert's judgement (Eastern Alps Hydrographic District and University experts). Mostly based on a EWS already installed in the Bacchiglione River (a river that crosses Vicenza) the probability of a false alarm is calculated as 25%, while the probability of a missed alarm is considered about 5%. To obtain the cost we have multiplied the data of evacuation cost (Dr. Paolo Nonino, responsible of the technical area of Savogna d'Isonzo p.c.) for the probability of a false alarm, while in case of missed alarm we have considered all the baseline costs multiplied per the probability of a missed alarm.

	BASELINE	EWS	EWS TEST
Total costs for people	4.328.000	2.629.000	1.513.000
Total costs for EWS	0	137.000	81.000
Benefit	0	1.700.000	1.034.000

Table 4 Cost benefit Analysis

The complete monetization of costs to human receptors is widely debated. Assigning a value to the life of people that change from country to country opens to ethic issues. For this reason, we will propose also a cost effectiveness analysis. The following table summarized the rounded values of people at risk in the different situations and the EWS total costs. While in the costs-benefit analysis it's finally presented a benefit expressed in euro, in this case, the task to decide which could be the best solution is totally given to the DMs.

	BASELINE	EWS	EWS2
N people at risk	8	6	5
Total costs for EWS	0	137.000	81.000

Table 5 Cost Effectiveness Analysis

4. DISCUSSION OF THE RESULTS AND CONCLUSION

The first general consideration about the results concerns the dimension of the area of study and its relative importance. Savogna d'Isonzo is a really small municipality and, as the results have revealed, the number of people at risk is quite low in absolute terms, in the baseline there are 8 people at risk. On the one hand, for this reason, it was quite easy during the work making assumption over the results and assessing if they seem to be consistent or not. It's reasonable to think that a good communication system (alarm, SMS, web) can easily reach all the inhabitants and the evacuation procedures and the emergency measures should work well. The second issue has emerged during the results analysis. As already explained, the assignment of the weights in the aggregation procedure of SERRA was made in a first approximation consulting expert's opinion. During this work it was thought to give a questionnaire (Annex A) to the stakeholders in order to use their opinion to recalibrate the weights. In the middle of the discussion over implementation of the normative, it was not possible to propose the questionnaire to the stakeholders. Therefore we have used the weights derived from expert's opinion. This is just a first approximation and further studies are needed in this context. Another consideration, regards the ethical question about the complete monetization of the people's life. According to Biausque (2010) VSL can be calculated using different parameters like the willingness to pay, the human capital and the cost of indenisation. For this reason, this value is not equal for all the human being around the world, but changes from country to country. For instance, Miller (2000) has collected the results of many different researches and he has reported the VSL for different countries expressed in thousands of 1995 U.S dollar. Just to give an idea of the differences among countries, the value of life of a Japanese was considered as about 8 million dollar, while the life of a South Korean's was estimated at about 620 thousands of dollar.
In this context it makes sense to consider the VSL if we want to compare the cost of a risk prevention measure with the total cost of the flood event, but the decision makers should look also at the cost effectiveness analysis that takes into account the effective number of people at risk.
One of the most ambitious purposes of SERRA methodology is involving several disciplines in the study. It was not easy trying to put in communication to each other so many different approaches. In this work economists, engineers, environmental and social scientist have worked together. SERRA has incorporated through a trans-disciplinary approach several experts and this communication among different fields allows to go beyond the traditional risk reduction measure and makes SERRA a good instrument in the decision making process. The last and the most important reflection induced by

this study concerns the risk prevention measure, in particular EWS. Even if further research is necessary to assess the weight for the EWS in the aggregated vulnerability, the importance and the possible effectiveness of a non-structural risk prevention measure clearly come out from this work. People's life can be saved with a proper alarm system installed. The following step in the flood risk reduction analysis is the communication of the decision to the stakeholders, in particular to the population, the municipality, the emergency measures' responsible, the people involved in emergency and so on. Flood risk reduction must involve the citizen in a participatory process. the stakeholder needs to be informed by the experts and a great interest should be focused on the population's preparedness, attitude and behavior. Prevention measures need to be increased and improved, instead of spending a large amount of resources to response to the natural hazard.

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