# Natural risk assessment in environmental policy-making

## A conceptual approach towards sustainable policy actions

J. Bertens; V.M. Bruschi; J. Weichselgartner

*DCITIMAC, Faculdad de Ciencias, Universidad de Cantabria,*

*Avda. de los Castros s/n, 39005 Santander, Spain*

**Abstract** Both natural science literature and disaster management practice usually emphasize analysis of physical process and human infrastructure but pay less attention to human components. Furthermore, there is limited knowledge transfer between scientist and public authorities, communities, and policymakers. This paper is based on a poster presentation given at the Second EuroConference on 'Global Change and Catastrophe Risk Management: Earthquake Risks in Europe' at IIASA in Laxenburg/Austria 6-9 July, 2000. A conceptual approach towards natural risk assessment was proposed to synthesize physical and social components and to implement natural disaster management as a comprehensive and continuous activity, not as a periodic reaction to individual disaster circumstances. Vulnerability has been introduced to take into account the condition of a given area and the ability of its set of elements to cope with events of a certain physical character. These elements have been integrated in disaster management. Recommendations for policy actions were given in the fields of organization and planning, training and equipment, and systems and facilities.

KEYWORDS: Risk assessment, hazard mapping, disaster management, environmental policy-making

## Introduction

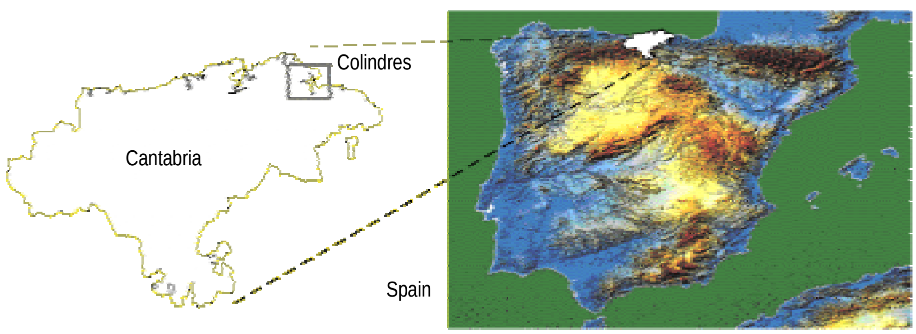
With the UN conferences on environment and development (Rio de Janeiro 1992) and natural disaster reduction (Yokohama 1994) it became clear that disaster management must become part of sustainable development strategies (GERMAN IDNDR COMMITTEE, 1999). The relevance of natural hazards has also been pointed out in Europe (EEA, 1998). Hazards affect areas settled by people, which are subject to certain social, political, economic as well as historical conditions and constraints to which they respond. However, natural science literature frequently ignores the socially constructed and culturally contextualized nature of natural hazards. Usually emphasis is placed on analysis of physical processes (hazard) and human infrastructure (exposure) but less concern is devoted to social components (vulnerability). Furthermore, there is limited knowledge transfer and information interchange between science and local authorities, communities, and decision-makers in environmental and mitigation policies. As a consequence, hazard and environmental policy is more reaction than control; it follows correcting and compensating independent social dynamics.

Since Chauncey STARR (1969) posed the question 'How safe is safe enough?', the field of risk studies has moved significantly away from the 'engineering-physical' paradigm towards incorporating perspectives from a range of disciplines. With delay European physical science literature, and as a consequence civil protection practice, begin to give emphasis to social variables, such as preparedness, non-structural mitigation measures, regional planning, and vulnerability. However, the hazard and disaster management 'community' is rather complex and multifaceted and setting up a constructive dialogue between different groups is a hard job for every discussion leader (HORLICK-JONES et al., 1995). The common 'probability concept' based on factors such as hazard and exposure is rather hazard analysis than risk assessment. Different approaches make evident that the problems involved in disaster management are multilayered and disordered – they are characterized by uncertainty and are often the subject of conflict and controversy.

## Study Site

The approach proposed here is applied to an area in the Spanish municipality of Colindres which is located 40 km east of Santander at the Cantabrian coast (Fig. 1). The economy of the area is based on fishing, manufacturing industry, and summer tourism; a nature reserve occupies part of the study site. The most relevant and frequent hazard in the study area are floods. Therefore, objectives, measures, and policy actions concern this type of hazard. However, it is evident that also other types of hazard need to be assessed. For instance, sea-level rise represents a significant hazard for the area (RIVAS & CENDRERO, 1994).

**Fig. 1: Study site in Colindres, Cantabria (Spain)**




## Conceptual Approach

Recently many researchers have incorporated new paradigms into their studies; paradigms that focus on vulnerability rather than on risk. At first, the concept of vulnerability in risk management was related to insurance. Risk, in an insurance context, is defined as the likelihood of losses involving the components hazard, exposure, location, and vulnerability defined as the sensitivity of the exposure to the hazards and the location relative to the hazards. Later on vulnerability studies were characterized by a focus on the distribution of some hazardous condition, the human occupancy of this hazardous zone, and the degree of loss associated with the occurrence of a particular event. Contrary to these views on vulnerability as a pre-existing condition, a perspective highlighted the social construction of vulnerability, a condition rooted in historical, cultural social and economic processes that impinge on the individual's or society's ability to cope with hazard effects: vulnerability as tempered response.

However, while establishing theoretical frameworks and drawing schemes is relatively easy, practical implementation is much more difficult. Natural disasters are characterized by relationships between physical hazard and society involving many social, economic, political, technological, organizational, and physical factors. These interactions, together with local context, cultural aspects, social and political activities, and economic concerns present difficulties in practical application of mitigation concepts and models. The nature and structure of natural disasters, therefore, transcend the methods of the 'exact' sciences associated with traditional 'hard' sciences. In order to take all these factors and associated high levels of complexity and uncertainty into account, 'softer', more flexible, methods and tools are required (HORLICK-JONES, 1995). A easy intelligible and – more important – applicable conceptual approach is described which should help to increase resilience and vulnerability and minimize the effects of natural disasters for communities.

While vulnerability as potential exposure (buildings) or social response is wide-spread, a third direction is emerging that combines elements of the two, but which is inherently more geographically centered (CUTTER, 1996). The proposed concept is primarily based on this integrated approach describing vulnerability as hazard of place. Consequently, by vulnerability we mean the condition of a given area with respect to hazard, exposure, preparedness, prevention, and response characteristics to cope with specific natural hazards. It is a measure of the capacity of this set of elements to withstand events of a certain physical character.

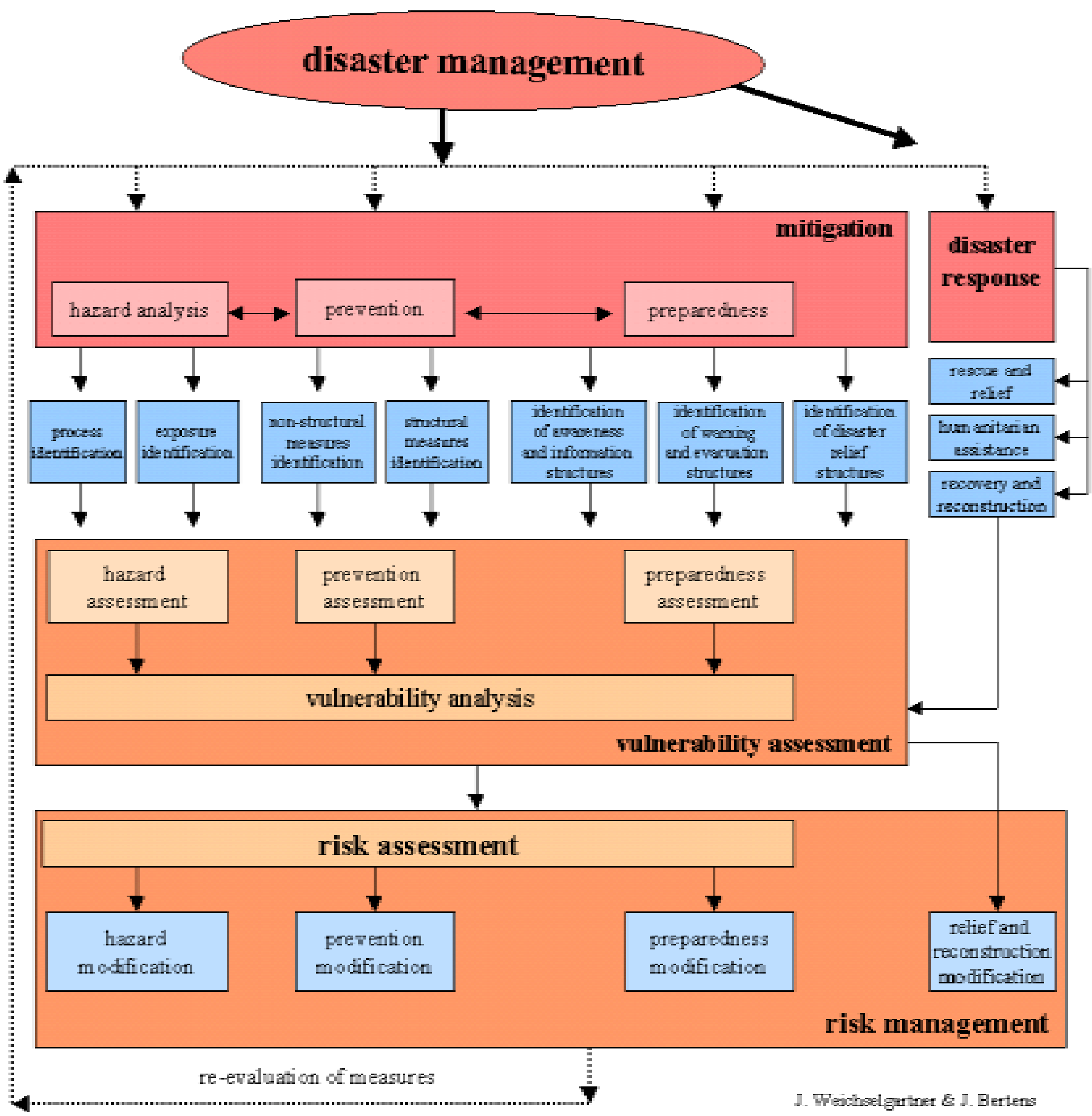
Figure 2 portrays the proposed synthesis of physical and social components in risk assessment and their integration in disaster management. Initially natural hazard, exposure, preparedness, prevention, and response characteristics are analyzed and assessed. Vulnerability is introduced to take into account the condition of a given area and the ability of its set of elements to cope with certain physical events. The analyzed variables are highly changeable. Therefore, a constant evaluation of these factors, best described as *Vulnerability Index* (COMFORT et al., 1999), is essential. As a last step modifications and measures need to be analyzed and assessed. This forms the input for renewed analysis and assessment (risk management). This cycle of renewed analysis and assessment should be repeated continuously.

Since years a world map of natural hazards is available, which shows the spatial distribution of geophysical events is available, but it will hardly reduce damage not any more than theoretical frameworks and models. We have also seen that social differentiation and globalization have led to complicated contextual issues in local and regional planning. Strongly connected with this is the problem of limited knowledge transfer and information interchange between science and local authorities, communities, and decision-makers in mitigation policies. However, without the incorporation and application of theoretical approaches and models in the decision-making and planning process sophisticated hazard mitigation programs and goals cannot be realized. Therefore, the approach is applied to an area in the Spanish municipality of Colindres (Cantabria) which results in the generation of maps illustrating hazard, exposure, preparedness, prevention, and response.

### Measurement, assessment techniques and policy actions

Prior to initiating the overall chain of steps illustrated in Fig. 2, inventories of respectively natural hazards and demographics are made. The first consist of listing and qualitatively mapping of all natural hazards occurring in the area considered. In general this will not pose many problems, since such maps are essentially qualitative and whether or not a particular hazard is relevant in an area will usually be based on a non-scientific knowledge base. If a particular hazard is known to have occurred in the area, it will usually be relevant.

Fig. 2: Natural disaster management process

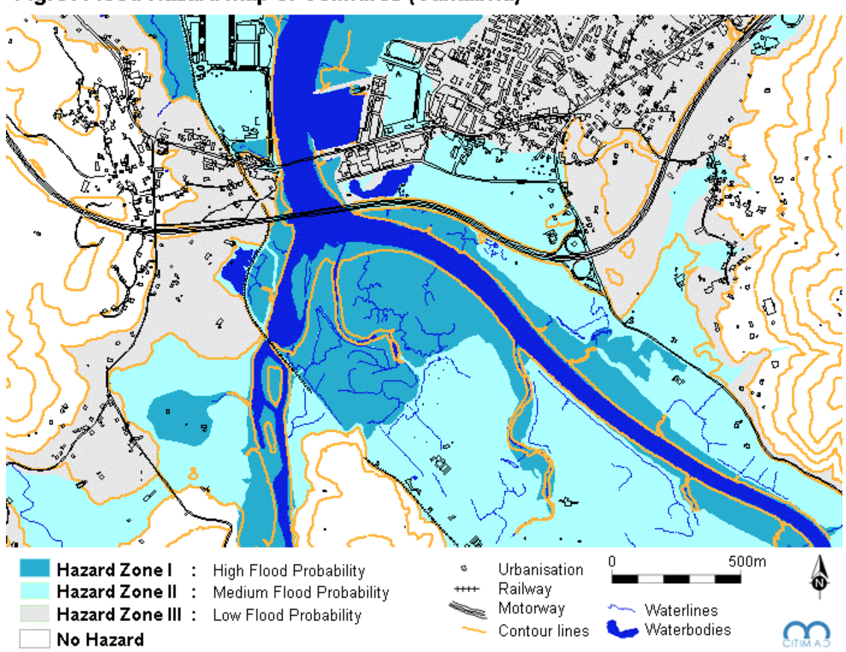


Apart from occurrence of a natural process, possible indicators for our example (flood hazard) could be discharge; runoff; water level; historical records; meteorological records etc. The second inventory concerns demographic aspects of a community. Here, socioeconomic factors are listed and quantitatively mapped. Examples of indicators are age; gender; population density and distribution; cohesiveness of local community; level of education; income; savings etc.

Once these inventories have been made, a number of components is analyzed. These steps correspond to the sections below, in each of which the analysis is described and possible policy actions regarding these phases are given. As these phases are strongly interrelated, suggested actions are equally interrelated and will have to be organized keeping in mind what is happening in other areas of the overall process. For each phase policy actions are divided into three groups: organization and planning; system and facilities; and equipment and training.

*1. Natural Hazard Analysis*

**Fig. 3. Flood Hazard map of Colindres (Cantabria)**



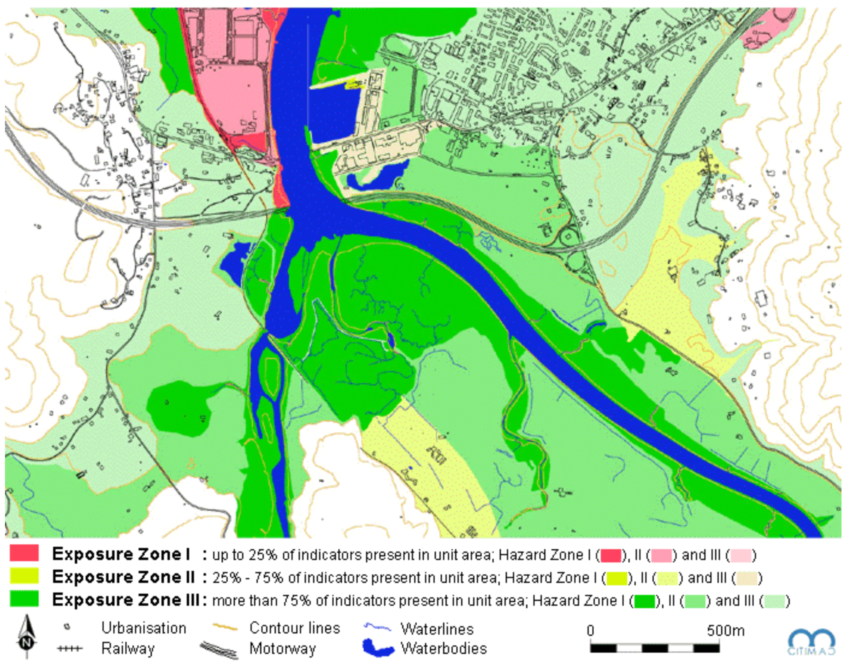

Once these inventories have been made, the first step in the disaster management cycle is natural hazard analysis. The objectives of this phase are the identification, inventory and assessment of all natural events in a given area that can potentially damage human life and property. Relevant physical processes are studied, on the basis of which a natural hazard map is created (Fig. 3). This map quantitatively and qualitatively indicates natural hazards, for example, portraying observed physical processes and characteristics or probability of occurrence and intensity. In regard to the study area the natural hazard map concerns flooding. Important factors with respect to the hazard are e.g. magnitude; frequency; duration; destructiveness; speed of onset; distribution and predictability of processes. For mapping of flood hazard indicators, such as peak flow; depth of flooding; duration of flooding; sediment concentration; pollution load of flood water; and wave and wind action are used. These indicators provide a spatially differentiated portrait of the hazard.

Policy actions that should be undertaken with respect to this phase are organization and planning of all actions concerning hazard analysis. The natural hazard maps and hazard task forces which identify problems should be implemented. Actions should be coordinated with other task forces (see below), and data delivered for a data center, where all information concerning hazard is to be gathered. With respect to system and facilities, an infrastructure ought to be designed for continuous data collection (e.g. gauge stations and public data centers). Technical equipment and training for monitoring and quantification of natural hazards should be available.

*2. Exposure Analysis*

The objectives of this analysis are identification, inventory, and assessment of infrastructure, property, individuals etc in a given area and both direct and indirect consequences in case of hazard occurrence. To realize this, social structure and infrastructure variables are analyzed, which forms the basis for an exposure map (Fig. 4). This map shows the probable area extent of a single event and social structure and infrastructure variables that may be affected. Important factors that concern exposure are susceptibility of building contents to damage; robustness of building fabric; key installations and public supply services; transportation systems; population distribution and density; land-use activity. The indicators that are used for creating the exposure map are expressed in binary form (is the indicator present: yes/no; positive/negative). In the case of flood exposure, if an indicator is present or is positive, exposure is less. Indicators for flood exposure are: 2 or more floors (higher floors are not likely to be affected directly); 100 or less industrial workers/km$^2$; value of households less than 106 Euro/km$^2$; more brick/stone constructions than timber/plasterwork constructions; no power supplies; no hospitals; no airport or railway station; less than 1 km motor- and railway lines/km$^2$; less than 300 habitants/km$^2$; more farmland than agrarian use.

**Fig. 4. Flood Exposure map of Colindres (Cantabria)**

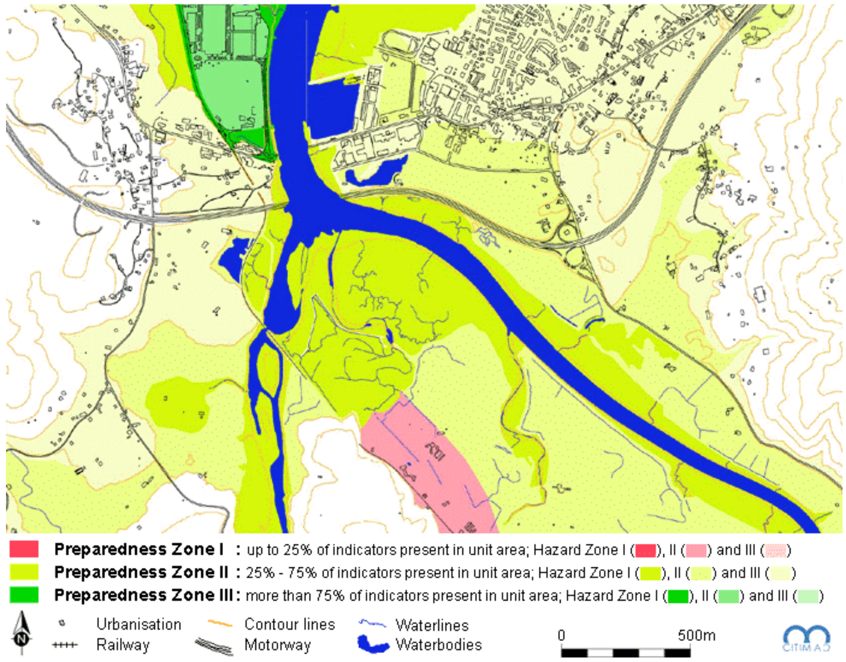



Recommended policy actions are the implementation of exposure maps and task forces to identify problems, co-ordinate actions with other task forces, and deliver data for the data center. Enforcement of building codes, land-use regulations, laws, relocation etc is also recommended. These actions concern organization and planning. Regarding system and facilities, quantitative and qualitative assessment of damage potential, indirect and secondary costs should be undertaken. Other possible measures are cost and benefit analysis of potential structural measures and developments in infrastructure and systems to protect key installations and vital communications. Concerning training actions, protection guards ought to be educated for regular control of structural measures.

*3. Preparedness Analysis*

The objectives of preparedness analysis are identification, inventory, and assessment of all precautionary activities and measures in a given area to be prepared best for natural disasters. This concerns the analysis of awareness, warning, evacuation, and disaster relief variables and should lead to a preparedness map (Fig. 5). In this map precautionary preparedness activities and measures are portrayed. The indicators that are used for this map (binary) to characterize the factors awareness, warning, evacuation, and disaster relief are: more than 50% of population has personal hazard experience; hazard information and education programs exist; an operative warning system is present; warning time is more than 1 day; warning includes specific advice; evacuation plans and routes established; disaster relief centers are available in the area.

**Fig. 5. Flood Preparedness map of Colindres (Cantabria)**




Recommended policy actions regarding organization and planning are the implementation of preparedness maps and task forces to identify problems, co-ordinate actions with other task forces, and deliver data for the data center. Operational guidelines are formulated along with standard operating procedures, programs and plans at different governmental levels, e.g. with respect to disaster relief, warning, and evacuation. Assistance should be provided in the development and establishment of risk and disaster management organizational structures or key points at different governmental levels, e.g. the Federal Association for Self-help, flood emergency action groups, neighborhood schemes and citizens' initiatives. With respect to system and facilities early warning systems should be implemented, provision of or assistance with warning provided. Also emergency broadcasting systems, emergency operations centers should be installed and key installations and infrastructure protected. Legislative safety regulations and codes relating to, for example, flood-proof buildings, land-use activity, transportation systems should be formulated. Regarding equipment and training, stockpiling of emergency items ought to be organized (e.g. generators, shelter materials, medical equipment, food storage etc), technical protection equipment, such as mobile flood walls, provided. Local training initiatives, information campaigns and awareness training for different social groups should be deployed.

*4. Prevention Analysis*

The objectives of prevention analysis are the identification, inventory, and assessment of all activities and measures in a given area to prevent hazards and their effects and provide permanent protection from their impacts. For the creation of a prevention map (Fig. 6) structural and non-structural measures are analyzed and portrayed. Factors as water control measures; land-use and infrastructure control measures; financial relief and loss reduction measures are considered. The indicators for this map are: dikes, dams, levee banks, reservoirs, retarding basins, channel and catchment modification in the river basin; drainage and flood protection; terracing and flood-proofing works; zoning and planning controls; acquisition and relocation; flood insurance schemes established; public prevention information and education. These indicators are, as was the case in the previous two maps, binary indicators.

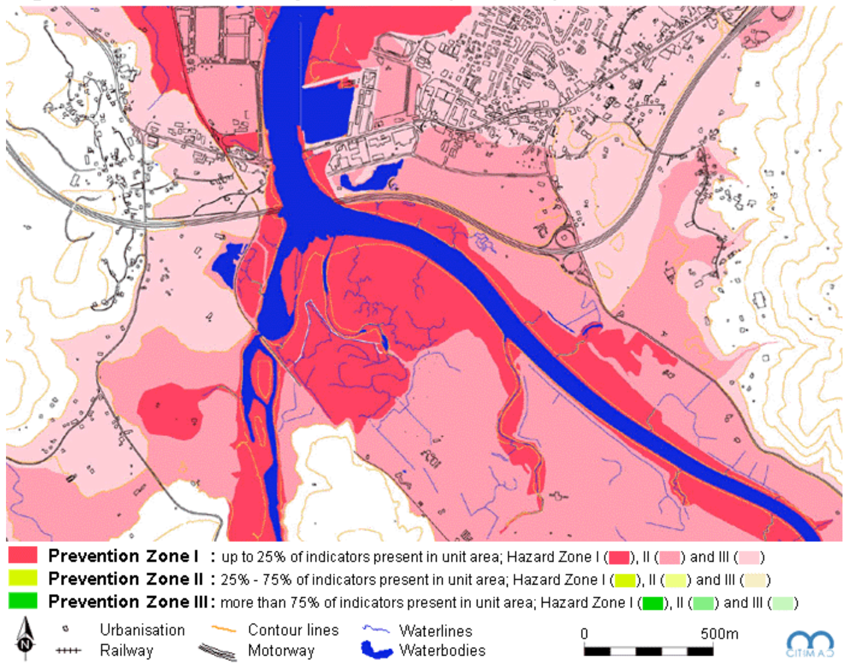



**Fig. 6. Flood Prevention map of Colindres (Cantabria)**

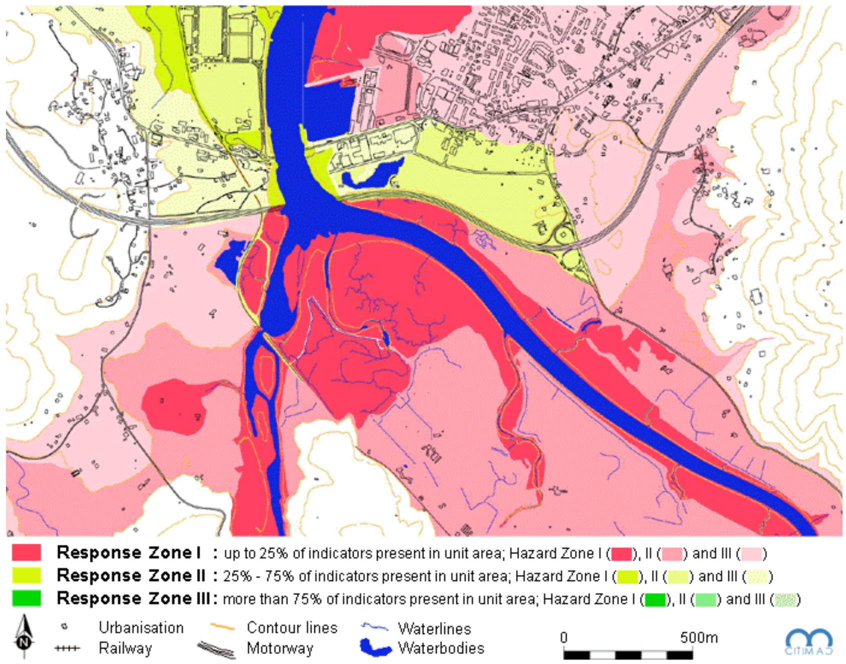
Policy actions related to organization and planning are the implementation of prevention maps and task forces to identify problems, the co-ordination of actions with other task forces, and the delivery of data for the data center. Legislative measures to control land-use and urban planning in hazard-prone areas should be drawn up and appropriate local measures funded. With respect to system and facilities the following actions are recommended: implementation of channel and catchment improvements, flood-proofing measures (e.g. terracing, raising buildings, retarding basins and reservoirs, levee banks, dams, dikes, drainage systems, relocation) and designated community shelter areas and facilities. Insurance policies with premiums based on danger zones and personal prevention measures should be provided. Systematic actions should be undertaken to inform the public about individual prevention measures and technical equipment provided, e.g. water pumps.

*5. Response Analysis*

The objectives of response analysis are the identification, inventory, and assessment of all response activities and measures in a given area to reduce social and economic damage and losses. Measures for the creation of a response map (Fig. 7) are analysis of search, rescue, humanitarian assistance, recovery, and reconstruction structures. This map is emergency-orientated and shows existing disaster response structures. Important factors are rescue, relief, and humanitarian assistance facilities and measures.

Indicators for this map (again binary) are: evacuation paths defined; emergency personnel and standard equipment available within 20 km; 50% of population has previous disaster experience; gas station and emergency power generation units available; hydrants and water points, disaster protection authorities, and medical relief services established.

**Fig. 7. Flood Response map of Colindres (Cantabria)**



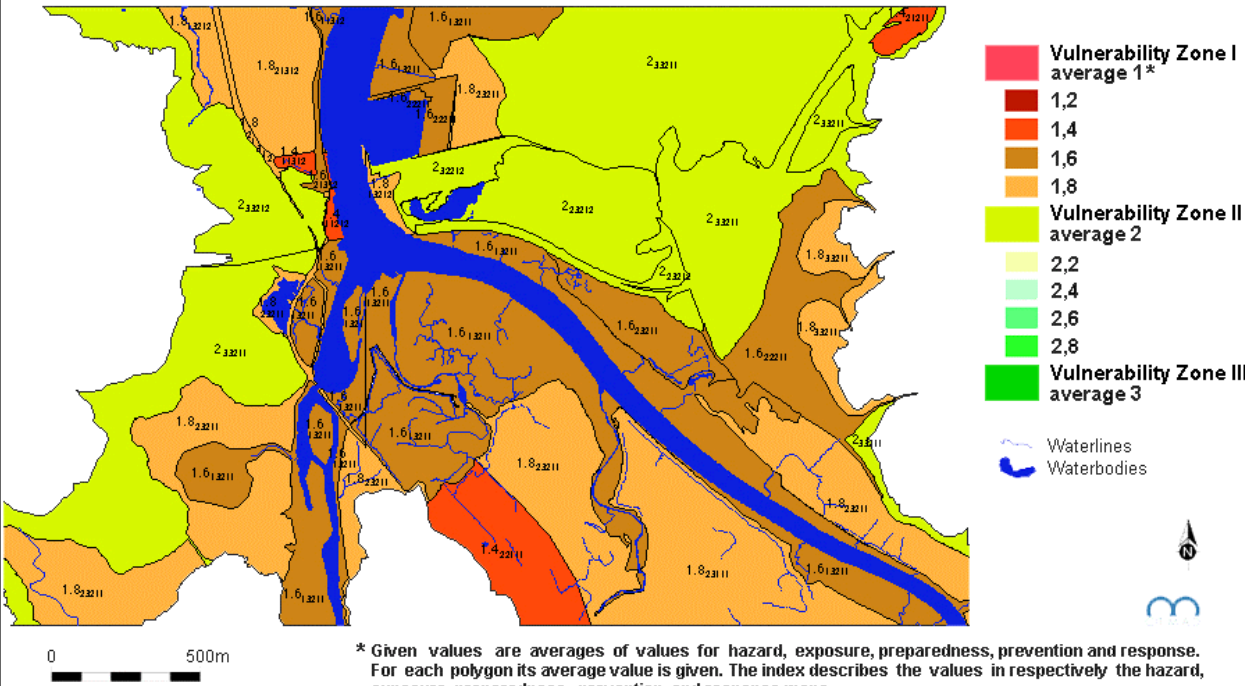

Policy actions for organization and planning should consist of the implementation of response maps, plans, and task forces to identify problems, the coordination of actions with other task forces, and data delivery for the data center. All previous measures should be re-evaluated, improved and modernized building systems and programs introduced, and disaster experience applied to future activities. Implementation of clear decision and command structures is regarded as crucial. With respect to system and facilities, possible actions are the staffing of mobile emergency operations centers and the provision of emergency infrastructure and logistics, e.g. shelter buildings. Regarding equipment and training, the training of personnel, implementation of information interchange mechanisms and decision processes for emergency situations are recommended. Also emergency food, shelter, medical assistance, auxiliary power supplies etc should be provided.

## *6. Vulnerability Analysis*

The objectives of vulnerability analysis are the assessment of the existing condition of a given area and its ability to cope and withstand to specific natural hazard events and their impacts. Measures are analysis of hazard characteristics; socioeconomic, exposure, preparedness, prevention, and response variables. In this phase a vulnerability map (Fig. 8) is created. This map can be described as a natural hazard map which shows the degree of ability to cope with and respond to specific natural hazard events. Vulnerability is determined through the overlay of the former maps. 'Average class value' obtained are based on the assumption that all factors are equally important. Since this map is based on the previous maps, indicators are the same used for the hazard, socioeconomic, exposure, preparedness, prevention, and response maps.

The vulnerability map shows a number of areas that are uniform with respect to the 'value' of the considered factors. Inside each uniform a synthesis of values from the previous maps is given, which gives an impression of the overall vulnerability of the unit. The values that contribute to this synthesis are shown as a sub-index for each area. Thus, each uniform area in the vulnerability map has a 'vulnerability class' and (as sub-indices) the corresponding values for hazard, exposure, preparedness, prevention, and response. Since each of the five indices corresponds to a specific factor, the vulnerability map shows not only the degree of vulnerability of an area, but also the reasons for that vulnerability. Consequently, if one desires to reduce the vulnerability of a particular area, the vulnerability map shows where changes could be introduced. E.g. if high vulnerability is caused mainly by low preparedness and high exposure, one can focus on these two in order to reduce vulnerability.

**Fig. 8. Flood Vulnerability map of Colindres (Cantabria)**




* Given values are averages of values for hazard, exposure, preparedness, prevention and response. For each polygon its average value is given. The index describes the values in respectively the hazard, exposure, preparedness, prevention and response maps.

Recommended policy actions in the field of organization and planning are the implementation of vulnerability maps and indices. Task forces should identify problems, co-ordinate actions together with other task forces, and deliver data for the data center. Organizational structures or key points at different governmental levels to control vulnerability factors and reduce vulnerability in specific cases and areas should be established. With respect to system and facilities, centers for continuos data collection should be implemented and affected populations and infrastructure enabled to improve local conditions in vulnerable areas, e.g. through 'self organization centers', monitoring dike condition, building improvements, insurance policies with premiums based on vulnerability. Regarding equipment and training, relevant programs for disaster-related training, information campaigns, and public awareness should be formulated (for different social groups separately) to improve hazard knowledge and to change attitudes and behavior towards hazards (information management).

*7. Risk Analysis*

The overall objectives of this last step are the assessment of possible damage and the planning future actions to reduce these possible damage. Therefore, 'elements at risk' and their interdependencies must be analyzed.

A recommended policy action in the field of organization and planning is the implementation of risk task forces. They should identify problems, co-ordinate actions with other task forces, and deliver data for the data center. Standard forms for statistical records to enable consistent comparisons, assessments, and reactions should be developed and applied. Periodic reviews of actions and accomplishments in vulnerability assessment should be undertaken, information interchange and knowledge transfer between different governmental levels and social sectors established. Evaluation of all measures and feedback to the task forces is strongly recommended. Regarding system and facilities, potential resources with respect to specified objectives, such as increasing preparedness or reducing exposure in a unit area, should be identified and assessed. In the field of equipment and training, personnel, information interchange, knowledge transfer mechanisms, and decision processes should be trained to identify critical actors at each organizational level, risk assumptions, and (different) types of information needs. With other words: an information infrastructure should be designed. Establishment of continuous evaluation and improvement procedures to assess previous equipment and training measures is also recommended.

## Final Remarks

The approach demonstrates both need and possibility to synthesize physical as well as social factors in natural risk assessment and disaster management. Natural disasters are rather the result of a cumulative set of social decisions taken over long periods in a number of fields than the result of physical hazard characteristics. They serve as evidence of the need for changes in public policy and practice. Consequently, the process by which these choices are made become a focal point for potential change and sustainable development. The approach considers disaster management practice and policy as a comprehensive and continuous activity; not as a periodic reaction to individual disaster circumstances. However, listing the solutions is simple; it is the implementation that brings the problems. Both maps and recommended policy actions aids in bridging over the gap between science and practice. All in all, these is regarded an essential contribution to sustainable policy.

The conceptual approach proposed here it is based on the assessment of a series of easy-to-determine factors or indicators, combined in a simple way through a series of clearly defined steps. The result of this combination is a 'measure' of vulnerability. Various conceptual and theoretical issues can be incorporated. For instance, adequate prevention measures can be found more easily after vulnerable areas have been identified. Afterwards, cost-benefit-analysis can support more accurate the search for measures and the decision finding process. Furthermore, the hazard of place approach can facilitate a single or multihazard approach with differing hazard characteristics, contrasting contexts, and diverse methodological approaches.

A major advantage of the approach presented here is that it is intelligible; no expert knowledge is needed for its comprehension. In this way a theoretical scientific framework can be linked more easily to concrete policy actions than is generally the case. Many theoretical approaches fail to link successfully to practice, which is vital in light of the ultimate goal of disaster management: reduction of damage to human life and property. A further advantage lies in the fact that the indicators for the larger part of the maps (with the exception of the hazard map) are expressed in binary forms which greatly facilitates the collection of necessary data. Furthermore, in the vulnerability map not only values for vulnerability are given, but also the cause of high vulnerability is shown. By means of a sub-index, the map interpreter is directed to a specific factor (hazard, exposure, preparedness, prevention, and response) which requires modification. Improving the state of specific factors is facilitated by proposed policy actions. Although theoretically a combination of vulnerability maps for different hazards is possible, the interpretation of such a map would be much more difficult. Therefore, it is advisable to prepare a separate vulnerability map for each hazard considered.

## Acknowledgements

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