9 Methodological deepening for flood-risk analysis in cross-border regions: a case study for the Lima catchment (NW Spain/Portugal) according to the implementation of the European Water Framework Directive

Francisco da Silva Costa[1,2], Andréa Marques[3], Gilles Arnaud-Fassetta[4], Joaquim Alonso[5], Ivone Martins[5] and Carlos Guerra[6]

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Mots clés : DCE, Directive 2007/60/CE, fleuve Lima, inondation.

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Approfondissement méthodologique pour l'analyse du risque d'inondation dans le bassin transfrontalier du Lima (NW de l'Espagne/Portugal) dans la perspective d'application de la Directive Cadre européenne sur l'Eau. Le Conseil du 23 novembre 2006 a approuvé la directive du Parlement Européen relative à l'évaluation et à la gestion des risques d'inondation. Le Conseil admet que *« les crues sont des phénomènes naturels qui peuvent être évités »* et reconnaît la nécessité de réduire les risques associés aux inondations, spécialement pour la santé, l'environnement, le patrimoine culturel, les activités économiques et les infrastructures. La directive 2007/60/CE du Parlement européen et du Conseil du 23 octobre 2007 (Journal officiel L288/27 du 11 juin 2007) est un complément important à la législation de l'UE dans le domaine de la ressource en eau et des risques d'inondation et devrait être mise en œuvre par les Etats membres d'ici 2015. La première étape, qui est constituée par une évaluation préliminaire des risques d'inondation dans les bassins hydrographiques et les zones côtières, devait être achevée d'ici 2011. Suivra d'ici 2013 (deuxième étape) la réalisation des atlas de zones inondables et des cartes de risque d'inondation pouvant comporter des éléments tels que la profondeur de l'eau, les activités économiques affectées par les inondations, le nombre d'habitants exposés au risque et les dommages environnementaux prévisibles. Dans la troisième et dernière étape, d'ici 2015, les États membres devraient élaborer des plans de gestion des risques d'inondation devant comprendre des mesures de réduction des probabilités d'inondation et de leurs conséquences. Les plans se concentreront sur la façon 1) dont les régions pourront se protéger des inondations et 2) de minimiser l'impact potentiel du phénomène en restaurant les plaines inondables et les zones humides. Un autre aspect important

1 Universidade do Minho, Braga, Portugal. E-mail: francisco@geografia.uminho.pt.
2 Centro de Estudos em Geografia e Ordenamento do Território (CEGOT), Coimbra, Portugal.
3 Université Paris-Est Créteil Val-de-Marne (Paris 12), Créteil, France.
4 Université Paris-Diderot (Paris 7), CNRS-UMR 8591 LGP, Meudon, et CNRS-UMR 8586 PRODIG, Paris, France.
5 Escola Superior Agrária do Instituto Politécnico de Viana do Castelo (ESA-IPVC), Ponte de Lima, Portugal.
6 Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Évora, Portugal.

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des plans de gestion des risques d'inondation est la nécessité de mieux informer les populations des risques qu'elles encourent.

Dans cette étude des grandes inondations dans le bassin transfrontalier du Lima (NW Portugal), on vise à développer certains aspects méthodologiques qu'il serait nécessaire de prendre en considération dans le respect de la Directive 2007/60/CE. Cet article propose donc de faire un bilan sur la façon dont est considéré et traité le risque d'inondation dans la partie portugaise du bassin du Lima et dans la ville de Ponte de Lima en particulier, dans le cadre de la Directive Cadre sur l'Eau (DCE). L'élaboration du plan de gestion des inondations dans le bassin du Lima est actuellement de la compétence de l'Administration de la Région Hydrographique du Nord (*Administração da Região Hidrográfica do Norte*, ARH-Norte). Ce plan de gestion en est au stade intermédiaire de sa préparation même si des conclusions ont dû être formulées dès septembre 2011. Quels sont les partenaires consultés pour réaliser ce travail, quelles sont les méthodes de travail choisies, quels sont les premiers résultats obtenus, quels sont les problèmes et les difficultés rencontrés par l'ARH-Norte dans l'élaboration de son plan de gestion de la ressource en eau? Telles sont les questions qui se posent. Les éclaircissements que nous apportons à propos de quelques consignes méthodologiques (cartographie, modélisation) de la Directive 2007/60/CE pour l'étude des inondations à Ponte de Lima nous permettent de montrer la complexité du plan de gestion et de sa mise en œuvre dans le cadre de la DCE.

1 Introduction

By analysing the large floods in the cross-border Lima catchment (NW Spain/Portugal), and in Ponte de Lima (Portugal) in particular, we aim to address some methodological aspects that would be necessary to take into account in the implementation of the Directive 2007/60/EC at the local level. Ponte de Lima is a city of the district of Viana do Castelo, located in the sub-region of Minho-Lima, NW of Portugal (Fig. 1A, 2), with approximately 2800 inhabitants. Considered by the Romans as the mythical Lethe, it is characterised by a mediaeval architecture and by its environment largely influenced by the Lima River. The Lima is an international river (total length: 108 km) rising in Spain (Galicia) in the *Serra de São Mamede* at about 975 m above sea level. From here it flows 41 km until it enters Portuguese territory by the valley situated between the mountains of Gerês and Peneda and then flows 67 km before reaching the Atlantic Ocean near Viana do Castelo (Fig. 1A). The Lima catchment represents a total drainage area of approximately 2496.4 km^2, from which 47.1 % are located in Portugal, and is associated with the Hydrographical Region 1 (HR1; Portuguese Legislative Decree No. 347/2007 of October 19), belonging to the jurisdiction of the North Hydrographical Region Administration (ARH do Norte, 2011a,b). The mean annual rainfall in the Portuguese part of the basin is 2164 mm, with 73 % of the precipitation occurring during the humid season, resulting in an average natural runoff of about 2.7 km^3/a. Two hydropower plants (Lindoso and Touvedo; total power: 656 MW; storage volume: $2.74 \cdot 10^8$ m^3) regulate the intra-annual river flow and have been in operation since 1992.

This paper offers the possibility to analyse how the flood risk is considered in the Lima catchment and in particular in the city of Ponte de Lima, faced with the challenge of implementing the European Water Framework Directive (WFD). In the Portuguese part of the catchment, the development of the plan for flood management is currently under the jurisdiction of the North Hydrographical Region Administration (ARH-North). The management plan is currently in the intermediate stages of its preparation. This research aims to answer several questions: Who are the partners consulted for this work, what are the working methods chosen, what are the initial results, what are the problems and difficulties encountered by the ARH-North in developing its management plan for water resources? Clarifications that we contribute about the methodologi-

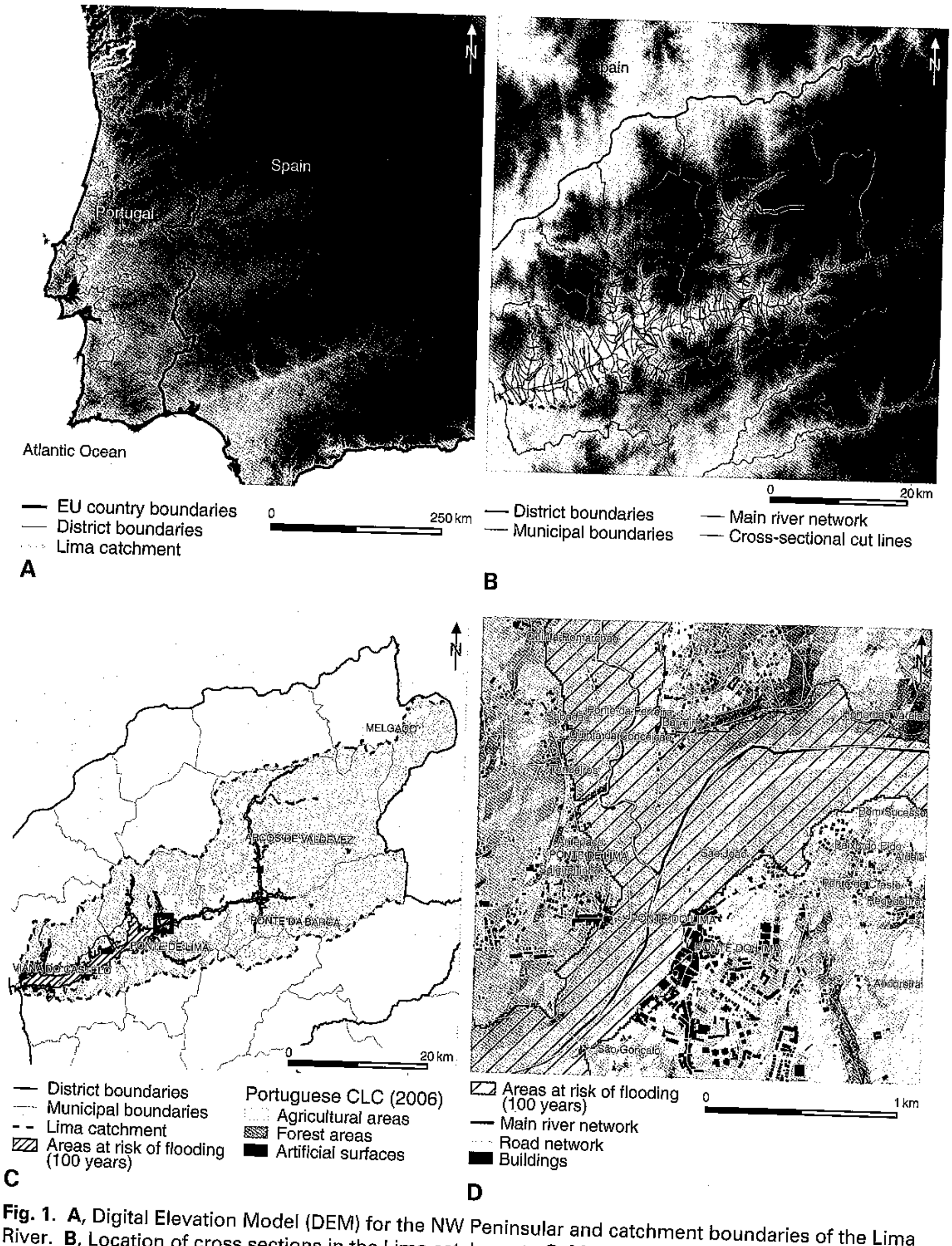

Fig. 1. **A**, Digital Elevation Model (DEM) for the NW Peninsular and catchment boundaries of the Lima River. **B**, Location of cross sections in the Lima catchment. **C**, Map of RI-100 years flood. **D**, Detailed flood map versus material and human stakes.

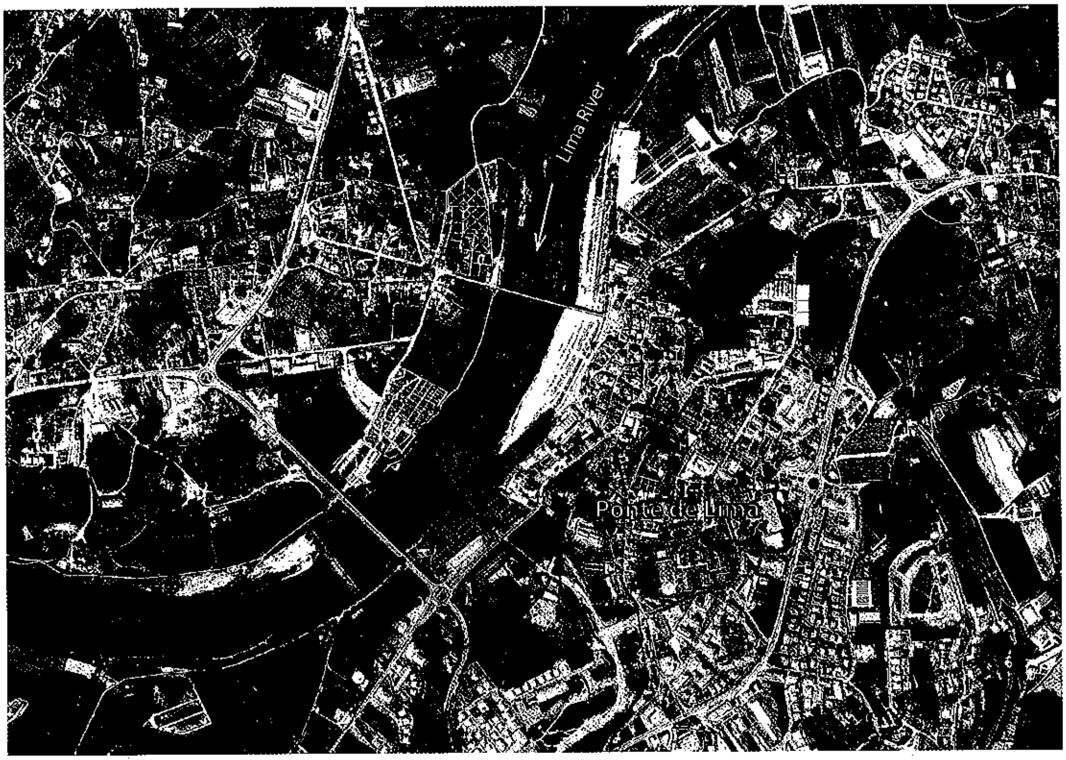

Fig. 2. Aerial photograph of Ponte de Lima and Lima River [from DGRF (Direcção-Geral dos Recursos Florestais), 2006].

cal guidelines of the Directive 2007/60/EC for the study of floods (modelling and mapping) in Ponte de Lima lead to the complexity of the management plan and its local implementation in the context of the WFD to be shown.

1.1 The starting point: Directive 2007/60/EC on the assessment and management of flood risks

The Directive 2007/60/EC of the European Parliament and of the Council of the European Union of 23 October 2007 states clearly the objective of conceiving a framework for the assessment, management, and mitigation of the risks that floods pose to human health, the environment, cultural heritage and economic activity and Member States shall ensure that flood risk management plans are completed and published by 22 December 2015. To achieve this goal the development of a preliminary flood-risk assessment, the spatial analysis and related outputs development (hazard and risk maps) focusing on zones potentially affected by flooding, a good institutional and technical coordination at the catchment scale, notably by flood-risk management plans and catchment management plans being prepared, are required, together with the implementation of transparent and agile public participation procedures within the preparation of these plans.

The details of the Directive 2007/60/EC can be found in the Official Journal of the European Union (L 288/27) published on 6 November 2007. All the sentences written both in italics and inverted commas in the second point of this paper were extracted from the text of the Official Journal. *"In order to have available an effective tool for information, as well as a valuable basis for priority setting and further technical, financial and political decisions regarding flood risk management, it is necessary to provide for the establishing of flood hazard maps and flood risk* *maps showing the potential adverse consequences associated with different flood scenarios"*. The Directive 2007/60/EC defines a 'flood' as the *"temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral watercourses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems"*. The WFD also argues that *"floods are natural phenomena which cannot be prevented"*.

On the basis of these definitions, a *"preliminary flood-risk assessment"* shall include several elements such as maps of the catchment district at the appropriate scale, and magnitude and/or frequency analysis of the past floods which had significant adverse impacts on human health, the environment, cultural heritage and economic activity. Numerous points must, therefore, be taken into account as far as the impact of climate change on floods, morphological, hydrological and hydraulic modifications of the floodplains, including floodplains as natural retention areas, effectiveness of existing anthropogenic flood-defence structures, and the geography both of population and areas of economic activity.

1.2 A flood-risk management plan for the Lima catchment: why, by whom, for whom, and when?

Both Spain and Portugal have started the transposition of the WFD contents in their national laws, in order to prevent the ecological deterioration and pollution of surface waters and the requalification of the related water bodies and their adjacent areas in order to reach a good ecological status, in accordance with the WFD (European Communities, 2001). It is stated that it is imperative to avoid the deterioration of water bodies, to achieve and maintain the good chemical and ecological status of the identified water bodies that have been significantly deteriorated, and to gradually reduce pollution and eliminate pollutant emissions, dumps, and hazardous substances.

In order to achieve these objectives, in Portugal, the environmental objectives set by the WFD and the National Water Law should be fulfilled through the implementation of programs and specific measures detailed in the River Basin Management Plan (RBMP) which represents a strategic document for catchment management, conditioning local activities and the pathways for environmental planning (EPCEU, 2000). The RBMP ensures the conformity between sectorial plans and local land management instruments, defined also by the legal obligations and, simultaneously, establishes a global strategy for local water resources management, planning and impact mitigation. The RBMP, by law, are considered as a land management constraint and are subject to an environmental assessment, with public participation and discussion. It is requested that the WFD environmental objectives are achieved in a balanced way taking into account, inter alia, the feasibility of the measures, which must be applied by scientific and technical standards, the effectiveness of these measures and the related institutional capacity as well as operational costs.

Furthermore, the choice of a specific water resources planning strategy, which must be in accordance with the WFD, requires the development of a plan at the catchment scale in each member state. In Portugal, the regional water administrative units do not coincide with the catchment limits, although water resource planning is made on a river basin basis. The river-basin association (named *"Região Hidrográfica"*, RH) is foreseen by the Portuguese National Water Plan (PNA), where eight RHs are proposed for continental Portugal: Minho and Lima are joined on a same RH (1), in continuation of the North I Spanish River-Basin District (RBD); Cávado, Ave and Leça as RH (2); Douro as an independent RH (3), in continuation of Douro Spanish RBD; Vouga, Mondego, Lis, and Ribeiras do Oeste as RH (4); Tejo joined to "Oeste river basins" in a same RH (5), in continuation of Tejo Spanish RBD; Sado and Mira as RH (6); Guadiana as an independent RH (7), in continuation of the two Guadiana Spanish RBDs, and Ribeiras do Algarve as RH (8); (AR, 2005; MAOTDR, 2006, 2007). Furthermore, continental Portugal is divided into five river-basin district administrations (called *"Administrações das Regiões Hidrográficas"*, ARH), which is consistent with the WFD, with ARH-North [RH (1) to (3)], ARH-Centre [RH (4)], ARH-Alentejo

[RH (6) and (7)], and ARH-Algarve [RH (8)]. *"All these ARH should be nationally coordinated by the Portuguese National Water Institute (INAG), empowered (and adapted accordingly) to be the true Portuguese National Water Authority, of which the ARH shall be decentralised services to ensure water resources management of the referred RHs"* (Maia, 2003).

In the Portuguese part of the Lima catchment the development of the flood-management plan is currently under the jurisdiction of the *"Administração da Região Hidrográfica do Norte"* (ARH-North, Administration of the northern Hydrographical Region), in the context of hydrological risk (flooding, drought). A critical risk corresponds to river flooding that primarily affects the downstream part of the valleys characterised by a broad, flat floodplain occupied mainly by human high density and urban areas. Historical chronicles report numerous recent floods in the Lima catchment, but paradoxically studies dealing with the flood risk are just beginning, this is particularly true for Ponte de Lima.

2 Methodological guidelines for flood analysis in the context of the WFD: contributions for local level assessments

The knowledge of flood regimes, flood areas and associated processes has always been an area of investigation in physical geography (Pedrosa & Costa, 1999; Saraiva, 1999). Unfortunately, in the Lima catchment, particularly on the Portuguese side, studies on flood regimes are still at an early stage, despite the recurrence of several floods in recent years that affected the villages and cities located in the valley area. Following the recommendations stated in the WFD, the methodological guidelines have to be developed in a three-stage approach: (i) *Preliminary flood-risk assessment* (i.e., spatial databases collection and cartographic representations, experience from past floods, predictions of future floods, identification of areas of significant flood risk; time schedule: 22 December 2011); (ii) *Flood mapping* (i.e., knowing areas at risk of flooding, different scenarios, flood-hazard maps, and flood-risk maps; time schedule: 22 December 2013); (iii) *Flood-risk management plans* (i.e., plans to reduce flood risks, covering all elements of the flood-risk management cycle; time schedule: 22 December 2015; MAOT, 2010). This paper proposes a methodological framework in order to contributes and implement these three stages in the Lima catchment, particularly in the urban area of Ponte de Lima, focusing on two particular points: (i) identification of areas of potential significant flood risk, and (ii) flood-hazard mapping.

2.1 Identification and assessment of significant flood-risk areas

According to the WFD, the identification and assessment of areas of significant flood risk is derived from several indicators:

(i) Historical archives and journalistic sources. In the case of the Lima valley many local newspapers, both recent and older (sometimes more than a century old), and several books report evidence of flood events that occurred in the Lima catchment. Other archives can and should be taken into account, including photographic records and the testimony (interviews, surveys) of local populations and even poetry inspired by local floods. Access, consultation, and analysis of all these documents were used to establish a flood chronology in the Lima valley, particularly at Ponte de Lima.

(ii) Benchmarks of floodwaters. Several plaques located on a very old tower of Ponte de Lima "Torre da Cadeia" (1511) mark the height reached by the major floods registered in Ponte de Lima (Fig. 3). It is also possible to quantify the height reached by the recent, large floods by measuring the water levels using a laser distance metre (Fig. 3).

(iii) Hydrometric records. If the series are long enough, they are undoubtedly the masterpiece both of description of the flood regimes and the hydrological variability. In the case of the Lima River, information for 10 hydrometric stations belonging to the Portuguese national water-monitoring network from which 5 are still in active duty is available. In the upstream part of the Lima catchment, water depths were measured with limnimetric scales but these latter are inactive today.

(iv) Rainfall records. Two main rainfall stations (Ponte da Barca and Ponte de Lima) are present in the Lima catchment. These stations provided rainfall data during the months for the time of which the floods of October 1987 and January 2010 occurred. Rainfall records allow linking the rainfall regime and the flood regime both at the seasonal and flood-event scales (Pedrosa & Costa, 1999).

Fig. 3. On the tower of the *"Passeio 25 de Abril"* Place, benchmarks of floodwaters indicating the occurrence of various floods (AD 1909, 1959, and 1987) in the city of Ponte de Lima (from Martins, 2009). Water heights have been measured with a laser distance metre.

(v) Civil Protection Information. Civil Protection assumes a multidisciplinary and multisectorial activity, which aims to prevent serious accidents and to limit their devastating effects (Câmara Municipal de Ponte de Lima, 2009). At the level of the municipalities, the implementation of municipal emergency plans is underway. These assume an important role in terms of civil protection, either by identifying risk factors and vulnerability areas, or by defining the organisation and institutional interoperability regarding the local civil protection infrastructure.

The main risks identified for the town of Ponte de Lima can be divided into natural (e.g., forest fires, floods, soil loss) and technological origin (e.g., urban fires, road and industrial accidents, transport of dangerous goods (Câmara Municipal de Ponte de Lima, 2009). Among these risks, the flood risk is the most important (Câmara Municipal de Ponte de Lima, 2009) due to its impact on local communities and economic activities, but also due to the changes it induces on the natural systems. This is why the evacuation plan (i.e., "catastrophe plan") was tested during a simulation named VALIMEX2000 that occurred on 6 December 2000. Implemented throughout the association of towns of the Lima valley (VALIMA), the catastrophe scenario was simulated with intense and extended rainfall accompanied by strong winds that typically lead to road destruction and power outage, as a result of strong gusty winds, landslides affecting the slopes, and flooding of the valley bottom. Several monitoring systems are used to predict both meteorological and hydrological risks, such as the System of Meteorological Prevention of the Institute of Meteorology (climate deterioration) or the System of Alertness and Alert of the Water Resources of the Water Institute (floods). The event reports (period 1973–2010) of the local fire fighters are also an important source of information, particularly with regard to the description of flood events.

2.2 Flood-hazard mapping

The development of a flood-hazard mapping involves a set of specific studies in the domains both of hydrology and geomorphology. Flood-hazard maps will cover the geographical areas which could be flooded, distinguishing (i) flood areas with a low probability (or extreme events scenarios), (ii) floods with a medium probability (likely recurrence interval $\leq 10^2$ years), and (iii) floods with a high probability. Identifying flood extent, water depths or water level appears as an appropriate method for flood-hazard mapping. Modelling procedures and techniques can serve to quantify water surface elevations and floodplain limits for a given flow rate.

2.2.1 Importance of hydraulic studies and models

Flood occurrence and its respective management include processes at variable spatial and temporal scales, multiple stakeholders, the associated loss values and possible conflicts of interest (Kenyon, 2007). With time, man has adapted itself to the floods and its cycles through the sustainable use of the land (Wheater & Evans, 2009), despite the increasing complexity of the socio-ecological systems and their inherent processes (Rahman, 2011). The environmental, economical and social dimension of the floods denotes the necessity of analysing the spatial and temporal dynamics of the associated risk and physical processes as well as the nature and extension of potential affected areas (EPCEU, 2007). The development and application of a spatially explicit model to evaluate the effects and extension of flood events is conditioned by the thematic, spatial and temporal dimensions of the studied processes. The current advances in the amount and quality of the available spatial databases (Devillers & Jeansoulin, 2010; Honrado et al., 2011) as well as the development of simulation, optimisation and decision support models from geographic information systems (Fotopoulos et al., 2010) came to be used as tools for water resource planning and management (Charneca, 2006; Alonso et al., 2011).

Within this framework this study aims at, for the Lima catchment (NW Portugal): (i) the development of a GIS project that incorporates reference and thematic geographic information organised in accordance with the annexes of the INSPIRE Directive (Infrastructure for Spatial Information in Europe). The INSPIRE Directive establish an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. It is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union and addresses 34 spatial data themes with key components specified through technical implementing rules); (ii) the development of a hydrologic model to evaluate flood risk and to produce maps of floodable areas; (iii) inferring the potential impacts on the exposed elements, environmental processes and associated ecosystem services; (iv) to elaborate proposals that contribute to the flood risk management plan and to the governance of flood risk at the catchment level.

The collected and organised geographic databases include thematic areas like physiography, lithology and geomorphology (DRAEDM, 1999), hydrography (Série M888, IGeoE), and land cover (SITGA, 2008) as well as municipal master land use and environmental management plans, natural resources, socio-economic and human elements. Beyond the available historical information about flood marks, climatic datasets, in particular the recorded rainfall data from the national meteorological network, were also collected. The digital terrain model (DTM), resulted from available altimetry information at the 1:10000 scale, including topographic actualisation and respective hydrological corrections supported by fieldwork or aerial photography interpretation (Cook & Venkatesh, 2009). The estimation of the peak flow was calculated using the unit hydrograph method within the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS, 2008), that structures the datasets in three critical units: the basin model, the meteorological model and the control specifications. The drainage surface modelling and the consequent establishment of the configuration of the free drainage surface resulted from the application of the software HEC-RAS in relation to geographic data processing using the software ArcGIS 9.3 and the respective HEC-GeoRAS extension (Knebl et al., 2005; HEC-GeoRAS, 2009; HEC-RAS, 2009; Fig. 4).

The application of the hydrological model mainly indicates the patterns and the risk of occurrence of flood along the flood valley in the catchment (Fig. 1B–D). As in others conditions and areas, this periodic occurrence of floods: (i) influences the nature and the distribution of the conditions and the natural heritage and thus, the functioning of habitats and ecological ecosystems, in several areas of the existing Natura 2000 network (PTCON040; PCM, 2008) with

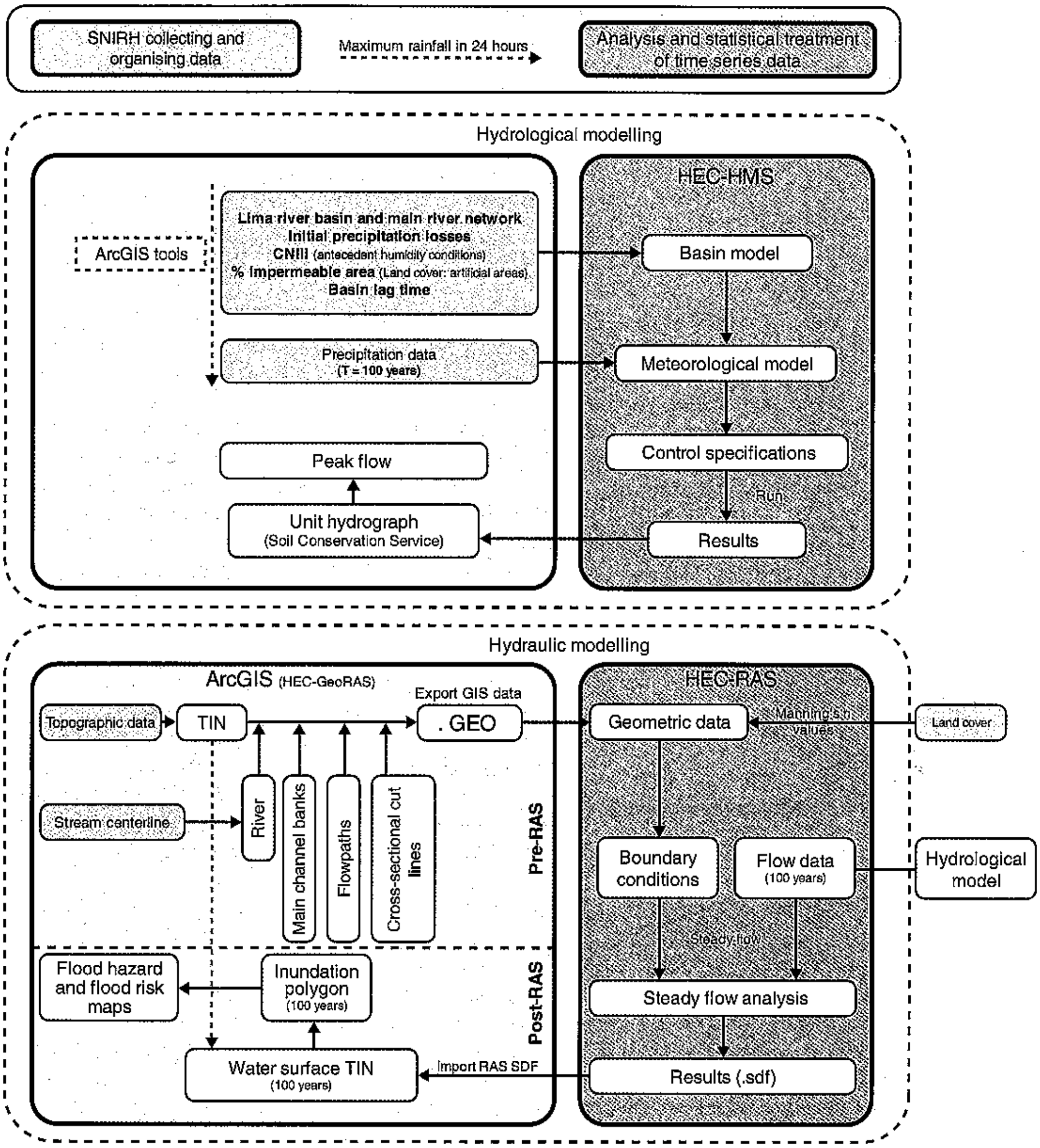

Fig. 4. Structure of the methodology used in flood-mapping and flood-risk assessment.

vegetal species and habitats life cycles and spatiotemporal patterns occurrence adapted to these processes of ecological disturbance, acting as chances for habitat recovery (Cox et al., 2006); (ii) directly affects the value and function of the human elements and activities displayed with economic losses in accordance with the level of vulnerability and local adaptation (Hansson et al., 2008); and (iii) evidences a potential impact on the physical and chemistry water quality (Lindenschmidt et al., 2009; Oeurng et al., 2010) as well as (micro)biological, by modifying the outflow conditions and favouring the dispersion of the effluents and residues of human activities (Posthumus et al., 2008), in particular at the industry, water treatment systems and water supply levels (Ten Veldhuis et al., 2010) in a direct relation to environmental and public health.

Table 1. Data introduced into the hydraulic modelling process, recorded under bridges and collected by a laser distance metre.

ID	Distance (in m)	Width (in m)	Elevation (in m)	Number of piers	Pier centerline spacing (in m)	Pier width (in m)
Rio Vez – 1	140	3	1	5/20	14/2	0.5
Rio Vez – 2	56	7	3.8	4	14	1.5
Rio Vez – 3	90	16	5.5	2	22.5	1
Rio Lima – 1	160	6	7.7	9	17.6	2
Rio Lima – 2	275	5.6	5.7	13	21.2	2
Rio Lima – 3	215	13	10.7	6	56	2
Rio Lima – 4	58.2	10	5.8	10	35	1.5

The process and the results of the study recognise: (i) the importance in detailing the spatial datasets used for the three-dimensional surfaces and conditions of outflow modelling; (ii) the need to validate and to calibrate the obtained flood volumes and gradually to transform the produced models into operational decision support information systems; and (iii) the articulation and relations needed between the national, regional and local public management and the social and economic stakeholders with practical proposals at the prevention (policies, landscape and land use management), alert (hydrological and meteorological), emergency management (forecast of scenes and its possible evolution, forecast of elements and infrastructures), and requalification/ reconstruction levels (to follow specific construction procedures and in appropriate places) as well as (iv) the critical importance to develop and validate flood risk spatial models at a detailed and local scale.

2.2.2 Population, activities and affected heritage

In Ponte de Lima, the only reference map of flooded areas is the zoning map of the *"Plano Director Municipal"* (Municipal Land Management Plan, 2005). The urban area affected by floods is mainly located on the right bank of the Lima River, along the historic centre of the city, and on the left bank, with numerous houses potentially inundated (Table 1). One important indicator of the human vulnerability (exposure degree) is the 'affected population'. The vulnerability of people living in the historic centre is linked to an aging population and an underprivileged social class. Anyway, it would be important to update the data on the local population, resident or not, from in-situ surveys.

As regards economic activities, the commercial sector associated with the restoration predominates. Almost all business premises have cellars, outbuildings, stores or balconies, which, during severe flood events, are the first to suffer the consequences of flooding. There are also services, particularly related to financial activities, public transport and fuel commerce that should be considered. Concerning the built heritage, the bridge of Ponte de Lima, classified as a national monument (Order 16/06/1910; GD 136 of 23/06/1910) suffered damage during the most violent floods (Table 1).

Compared to the natural heritage, it is possible to encounter ecological protected and classified areas, namely Natura 2000 areas that cover the riverbanks and part of the flood plain. In this sense, some sections of active channels, including riverbanks and bars related to riparian vegetation and watershed land use pattern needs detailed studies.

3 Conclusions: Key challenges for the years ahead

The traditional models of water-resource management of both Portugal and Spain will change and need to be adapted to modern developmental, environmental, legal, political and managerial models (Maia, 2000) by defining and implementing improved strategies and frameworks. Nowadays, Portugal applies the standards of the WFD by developing management plans (e.g., flood, drought, pollution) at regional and river basin scales; note that the flood-management plan is still being developed for the Lima catchment. While the deadlines (2015) set by the WFD will not be met, the supranational constraint imposed by the European Union has led to, at least for now, the renovation and evolution of the outdated Portuguese Water Law dating from 1919 to a more comprehensive legal framework published in 2005.

Regarding flood management, Directive 2007/60/EC aims to reduce the flood risk throughout the European Union. This is, undoubtedly, a directive that reveals a significant advance in flood assessment. This flood assessment requires the development of appropriate methods for flood-risk mapping, flood periodisation, plans of land use dynamics *versus* flood risk, characterisation of flood probability in relation to climate change and land use, prediction of the damages of future floods to human health, the environment, cultural heritage and economic activity. It is necessary to incorporate flood-risk management in the local or municipal procedures (Pottier et al., 2005; Carter et al., 2009), including suburban and rural areas (Kenyon et al., 2008; Morris et al., 2008). It is also important to consider the interest of local hydraulic structures, whether built or not in the framework of the re-naturalisation policy (Ledoux et al., 2005; Poulard et al., 2010) or the classification and assessment of water bodies as adaptive structural measures for flood risk management planning (McMinn et al., 2010). This progression must always promote information, participation and adaptation of the population (Ceccato et al., 2011). The implementation both of management plans and systems of governance of the flood risk (Schelfaut et al., 2011) should favour the necessary balance between institutional and social organisations, even at the local scale (Næss et al., 2005).

The difficulty of managing the Lima catchment derives from two main facts. First, it is difficult to promote a single management structure in a cross-border catchment, which is the case in the Lima catchment where there is no single body in charge of water management. Secondly, in Portugal, the spatial dimension of the water administrative units do not coincide with the river basin limits, although water resource planning is made on a river basin basis. In this context, the first version of the River Basin Plans (RBP) was completed in October 2000 for the four main international rivers and, in 2001, for the other 11 river basins (one international, the Lima; Maia, 2003)

Floods in Ponte de Lima are a phenomenon that has always marked and will continue to mark the social and economic dynamics in the historic centre of the city. Living with floods involves a new way to approach this type of phenomenon, requiring actors to assume and understand the risk (i.e., a new philosophy and conceptual approach to the risk), to know how to manage uncertainties, and to promote the integrated management ensuring its sustainability. This is a new vision involving a participative responsibility for all (i.e., the mayor, the administration, and the citizen) that has to be implemented at all the different decision/action levels in order to be successful.

In the city of Ponte de Lima, due to the current lack of flood risk studies and management strategies, it is necessary and urgent to develop an accurate, high-resolution flood-hazard mapping at the catchment scale. These maps have to take into account water-depth variability and the lateral channel mobility necessary for the good functioning of the Lima River *versus* the material and human stakes in the floodplain. On inundations, it remains to develop some methods for flood-hazard mapping integrating the "freedom space" and the "functional flooding area" of rivers (e.g., Arnaud-Fassetta & Fort, 2009) and/or flow modelling and hydraulic simulation through the use of the cellular automata (e.g., Menad et al., 2012) and agent-based models (Crooks et al., 2008; Dawson et al., 2011).

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