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Flood risk assessment and coping capacity of floods in central Vietnam

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ABSTRACT

In the perspective of improving and disseminating risk assessment methodologies and rise preparedness of people to flood hazard this paper presents flood hazard maps estimated in the Quang Ngai province, in central Vietnam, for different return periods in terms of depth, duration and velocity using the FLO-2D, hydrodynamic model with a 90 m × 90 m resolution grid. Then, based on the vulnerability functions determined from field surveys and the feedback to 400 questionnaires distributed to people regarding residential areas, paddy rice, road networks and the number of deaths and injuries, the total amount of tangible and intangible damage at each point in the study area is estimated and mapped, indicating risk levels and expected annual damage in case of flooding. The resulting damage functions are quite different from others available in the literature, as a result of the adaptive capacity and the resilience of the population to floods in the investigated area. Damage functions to buildings, agricultural areas, road infrastructures and people are normalised with respect to mean flooding depth and flooding hazard so that they can be generalized to areas with similar geographical conditions. In this way, a more comprehensive knowledge on the negative effects of floods is carried out, providing an important input to flood management plans in order to mitigate flood damage in tropical areas similar to the Quang Ngai province.

1. Introduction

The improvement of living standards and an increase in property value as well as less awareness and preparedness of people to floods has resulted in a greater vulnerability of society to flood hazards. More conscious land use planning, advanced forecasting and warning systems need to be enhanced. In addition, better preparation is needed among the people and the decision makers. Flooding is a very common environmental hazard, because of the widespread distribution of river floodplains and low-lying coasts and the importance they had on human settlement throughout the history of mankind (Smith and Petley, 2009). Flooding does not only affect normal everyday life but also has negative effects on the environment and on society as a whole, in terms of tangible and intangible losses and damage. Loss of life in floods occurs mostly due to drowning or to the spread of diseases. There are several studies indicating that the increase in life expectancy, the economy and the quality of the environment can be related to a growth in population and wealth in the floodplain areas (Barredo, 2009; Bouwer et al., 2010; Kreft, 2011; UNISDR, 2011; Barredo et al., 2012; Jongman et al., 2012). Improved flood risk management is essential in order to reduce flood losses and damage. It is important to invest in structural and non-structural measures for flood mitigation which is part of the investments allocated for socio-economic development (UNISDR, 2007; Giupponi et al., 2015).

The quantification and evaluation of flood damage is an important factor to consider in the decision making process about particular flood risk management measures. Quali-quantitative risk assessment is a combination of three main components including natural hazard (H), the value of the elements exposed to hazard (E) and the vulnerability (V) of the elements at risk (van Westen et al., 2010). Natural hazard (H) is defined as the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon (Varnes et al., 1984). Hazard assessment involves the analysis of the physical aspects of the phenomena through historic records or simulations of meteorological, hydrological and hydraulic data in order to estimate the probability of occurrence and the magnitude of the event in both spatial and temporal terms. Risk (R) is a combination of hazard and its consequences, or potential damage, and results as the expected number of fatalities, injuries, damage to property or disruption of economic activity due to a particular natural phenomenon. In the scientific framework we refer to, linked mainly to the physical sciences, risk is determined as the product of

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hazard, vulnerability and exposure: R = H × V × E (Varnes et al., 1984). Risk for direct losses or damage includes those losses or damages which are a direct result of the impact of the event. Risk for indirect losses or damages includes those losses not resulting from a direct impact, such as disruption of transport, business losses or clean up costs due to flooding. Tangible losses or damages are those which can be estimated in terms of monetary value. Intangible losses or damages are effects that cannot be calculated in terms of monetary values such as lives and injuries, cultural heritage, environmental quality, etc. (Dutta et al., 2003; Merz et al., 2010; Giupponi et al., 2013, 2015).

Risk assessment, including risk analysis and risk evaluation, is done in order to carry out a decision or recommendation for present risk control measures that should be justified or will be implemented, even though existing risk measures are acceptable and present risk control measures are satisfactory (van Westen et al., 2010; WMO/GWP, 2007). It is also important to guide people in selecting risk management strategies according to their capacity to reduce significant damage (Molinari et al., 2014). In order to estimate the expected economic flood impact, the governmental agencies, insurance companies and research institutions in many countries developed and used flood damage models. All flood risk methods are based on land use information, an estimation of specific values of elements at risk and damage functions, but results of flood damage model intercomparisons show high uncertainties (Apel et al., 2008, 2009) and a wide spread of damage estimates, up to one order of magnitude (Jongman et al., 2012). The depth–damage functions is the most common method for the estimation of direct flood damage and widely used in many countries (Jongman et al., 2012; Smith, 1994; Kelman and Spence, 2004; Meyer and Messner, 2005; Merz et al., 2010; Green et al., 2011). Different methods, softwares and decision support systems are adopted in different countries for flood risk assessment. We briefly mention, for example, the method adopted by the Ministry of Construction in Japan to estimate economic damage due to floods based on a standard procedure (Dutta et al., 2003). The Queensland Government (2002) published the Guidance on the Assessment of Tangible Flood Damages that focuses on how to estimate the potential physical damage to property and infrastructure due to flood inundation within an urban area. In Australia a systematic study is being completed to update standard criteria for assessing the flooding risk to people (Cox et al., 2010) and several assets as buildings, vehicles and infrastructures. In the UK on the national level the National Appraisal of Assets at Risk (NAAR) was carried out for England and Wales (DEFRA, 2001, 2004) to provide a unified approach for the evaluation of economic and social impacts of flooding (EA, 2004). Also in the Netherlands standard methods for flood damage evaluation are adopted (Kok et al., 2004).

The changes in the impact of extreme precipitation events resulting from projected climate change and increased vulnerability to the potential flood damage were examined in several studies. It is mentioned that the overall cost of flood damage, for instance in Europe, will more than double by the end of the 21st century (Döll et al., 2015) if the adaptation investments are not appropriately considered (Field et al., 2014). Also in Asia the expected increased frequency of floods, for instance, in the Lower Brahmaputra River basin has a number of policy level implications for policymakers and government agencies (Gain and Hoque, 2013; Gain et al., 2013, 2015) and Vo and Gourbesville (2015) project the 100-year return period inundation area, deeper than 2 m, to expand round 51% by the end of this century in the coastal plain of Vietnam.

The coastal areas in central Vietnam are becoming, indeed, more crucial towards the mitigation of the impact of climate change. The natural disasters are projected to occur more severely due to the combination of serious weather and hydrological conditions, including the impact of typhoons, the short time of concentration and high slope of the upstream rivers and the flat floodplain areas downstream. This leads to severe damages for regional socio-economic development annually. In addition, Vietnam is estimated as one of the countries which is most strongly affected by the consequences of climate change because of a very large population working in agriculture and inhabitants essentially concentrated in the coastal plain. The climate change and sea level rise scenarios for Vietnam are constructed by MONRE (2012) based on different greenhouse gas emission scenarios including: low emission scenario (B1), medium emission scenario (B2, A1B), and high emission scenario (A2, A1FI). The results show that by the middle and the end of this century annual rainfall will increase slightly; rising temperatures and potential evapotranspiration is projected to increase as well. The total annual runoff, as a result, is found to be not distinctly varied relative to the baseline period 1981–2000; however, the runoff will decrease in the dry season and increase in the rainy season (Nam et al., 2012). The projected changes in rainfall relative to the 1980–1999 baseline under the medium emission scenario (B2) is 1.8, 2.7, 3.8% for the same time horizons. The projected sea level rise (cm) relative to the 1980–1999 baseline under the medium emission scenario (B2) is expected to be 8 cm, 12 cm and 18 cm by 2020, 2030 and 2040, respectively.

In this paper a risk assessment methodology is implemented for the floodplain area of the Quang Ngai province (see Fig. 1) which is one of the most flood-prone areas of Vietnam as floods cause a heavy loss of lives and property, every year. Economic and human loss from flooding can push households into poverty that is difficult to overcome. Recently investments have been made in hazard and risk management, but the outcomes of management activities are not high yet. A flood hazard map is available for some scenarios but it is not well known by the public. The assessment or prediction of flood damage is therefore really important in order to improve flood preparedness and awareness activities but it is very seldom available. The preparedness activities are very limited, leading to a lengthy period for a complete socio-economic recovery. In order to reduce the negative effects of flood hazard, appropriate methods for flood hazard and flood risk assessment are needed. In this way, flood management activities will improve the capacity of people to "live with floods".

As requested, for instance, by the "European Flood Directive EC/2007/60" (European Parliament Council, 2007), flood risk maps are one of the key components of flood risk management plans, that provide the information needed to increase public awareness of the areas at risk, provide information as the input for spatial planning and support the processes of prioritizing, justifying and targeting investments in order to manage and reduce the risk to people, property and the environment.

The overall objective of this study is to focus on flood hazard and flood risk assessment and mapping by estimating appropriate methods and functions for estimating potential damage in areas, such as the Quang Ngai province, which have similar conditions, as all the coastal area at the bottom of the Annam mountain chain in Vietnam and, more generally, coastal floodplain zones of tropical areas exposed to floods and storms and are experiencing a fast socio-economic development, as for instance the Philippines and Taiwan. The specific objectives are: (1) to analyse the characteristics of floods corresponding to different return periods and develop hazard maps; (2) to assess the total potential damage to people, building structure, building contents, paddy rice, road networks, considered as receptors, and additional indirect costs due to flooding; (3) to estimate damage functions, also based on specific surveys, for a quick estimation of the total damage associated with different scenarios of flood hazard; and (4) to assess total risk and develop flood risk maps for the study area also normalising the results for applications to similar conditions.