RISK-BENEFIT ANALYSES TO BALANCE FLOOD RISK, LIVELIHOODS AND ECOSYSTEM SERVICES

A Dissertation

Submitted to the Faculty of the National Graduate Institute for Policy Studies (GRIPS)

in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY IN DISASTER MANAGEMENT

by

Andrea Mariel Juárez Lucas

August 2016

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Abstract

Traditional measures for flood risk reduction such as runoff and flood control structures, zoning and land use restrictions are often based on the principle of *keeping people away from floods*. Despite its effectiveness at reducing flood risk, the exclusion of direct human uses from flood-prone lands is not always possible. In many developing countries, for instance, local people may practice strategies to cope with floods and benefit from the use of frequently inundated areas. In such contexts, benefits provided by floods and use of flood-prone land are essential, particularly where livelihoods and ecosystem services are tied to natural hydrologic cycles. Measures aimed at managing flood risk, however, are usually based on the assessment of potential damages and often overlook the role of coping capacity and socio-ecological benefits from river-floodplain systems.

The original contribution of this study is a framework in which livelihood benefits of direct floodplain use are distinguished from those supplied through ecosystem services. Management of flood risk while procuring multiple benefits from flood-prone land may be realized through enhanced coping capacity. Decision-makers may thus apply this framework where flood risk, ecosystem, and livelihood objectives must be balanced. To support this conceptual approach, I present an integrated assessment of flood risk and probabilistic benefits in Candaba municipality, Philippines. I evaluate flood damages and the potential to accrue benefits from floodplain use by combining hydrological modelling, remote sensing techniques, and information on livelihoods and coping capacity collected from field surveys. Flood risk and probabilistic benefit trade-offs are analyzed according to current use of flood-prone land in the area (seasonal agriculture/wild fish capture). For this analysis, however, alternative scenarios of floodplain use are also considered on the basis of potential policies that may support, for instance, livelihood practices compatible with "low risk" direct human use (dry season agriculture/wild fisheries) or "flood storage/nature conservation" use (wild fisheries only).

Findings reveal that flood benefits related to ecosystem services and livelihoods from direct use of flood-prone land are vital to communities in Candaba. Though current "risky" use of flood-prone land is associated with potential damages to agriculture, for all investigated magnitudes of flood events with different frequencies, probabilistic benefits exceed risks by a large margin (US $ 58 million). In addition, probabilistic livelihood benefits associated to direct human uses (current "risky" and policy-driven "low risk" scenarios) far exceed benefits provided by the alternative "flood storage/conservation" scenario (difference of US $ 85-87 million). In Candaba, some communities cope with seasonal inundation, for instance, by adapting crop planting periods to the flood pulse or using land alternately for agriculture and wild catch fisheries during dry and wet seasons, respectively. The analysis of an additional scenario, which entails land use configurations associated to such practices, indicates that individual coping capacities may execute dual functions of reducing flood risk and facilitating greater benefit capture (US $ 125 million) in the area. Evidence from Candaba therefore suggests that acknowledging local capacity to live with and benefit from the use of flood-prone lands may lead to a better characterization of flood risk. Joint risk-benefit assessments may also provide essential information to support decision-making, which can result in more sustainable measures for integrated management of floods, livelihoods, and ecosystems.

Keywords: Risk-Benefit Assessment, livelihood benefits, ecosystem services, coping capacities, floodplain use, Philippines

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Chapter 1: Introduction

Over the last decades, floods around the world have been the most frequent natural disaster with the recorded number of events and devastating consequences showing an increasing trend (Douben 2006, Takeuchi 2001). The frequency and magnitude of extreme flood events in many regions, will likely continue to increase according to projected changes in climatic variability, population growth, and rapidly degrading river-floodplain systems (IPCC 2014, Tockner et al. 2008, Torti 2012). Exposure to flood hazard is often associated to substantial economic damage, human loss, and high incurred expenses for immediate response, relief, and recovery efforts (Ghatak, Kamal, and Mishra 2012, Mirza 2003). Structural measures such as flood-control dams and levees are often implemented as effective mechanisms to reduce potential flood risk. Though many developed countries are also reliant on governance schemes to manage flood risk, efforts targeting human behaviors or institutional systems are still less enforced in developing nations (Mirza, Warrick, and Ericksen 2003).

In less developed countries, the *business as usual* approach to flood management is still widely dominant. Thus, preferred measures by water managers and policy makers remain mainly structural. Mounting evidence indicates, however, that highly engineered river-floodplain systems may actually lead to catastrophic flood damages in the long term (Kundzewicz 1999). Exceedance of design capacities is an eventuality of all designed systems that becomes stark in the face of mounting climatic uncertainty and poor management practices that often characterize developing countries (Kundzewicz and Takeuchi 1999). When exceedance does occur, a society disconnected from expectations of naturally recurring floods and with low capacity to cope thus has few remaining defenses (Mirza 2003). Although these potential consequences are increasingly challenging the effectiveness of structural approaches to flood management, the disruption of natural hydrologic processes following their implementation is also widely acknowledged as an important shortcoming (Poff and Zimmerman 2010, Richter et al. 1997, Richter et al. 2003).

The chronic decrease in flood peaks, disappearance of natural extreme low flows, and changes in seasonality or predictability of the hydrologic cycle has protracted effects on the structure of both the physical river environment and the biological community of rivers and floodplains (Nilsson et al. 2007, Poff et al. 1997, Wohl et al. 2005). Evidence from river-floodplain systems indicates that elimination of natural processes has a major impact on the quantity and quality of benefits and services that are derived from these systems (Banerjee 2010, Dugan, Dey, and Sugunan 2006, Ringler and Cai 2006). Floods and human uses of flood-prone lands are not only associated to potential risk but are also considered beneficial opportunities to local people. For instance, the natural processes between rivers and their floodplains support multiple benefits and services such as water supplies, fertile soils for agriculture, wild harvest of food, recreation, and aquatic habitats that maintain biodiversity (Barbier, Acreman, and Knowler 1997, Brander, Florax, and Vermaat 2006, TEEB 2010). In many areas, these benefits and services are of important socio-economic value and often represent for rural communities the only viable source of livelihoods and sustenance (Cuny 1991, Few, Pham, and Bui 2004, Paul 1997, Paul and Routray 2010).

Developed countries are increasingly recognizing the value of the multiple benefits and ecosystem services that can be derived from river-floodplain systems. Paradigms for managing flood and ecosystems are thus shifting towards an integrated and socio-ecological approach. In these contexts, however, implemented joint flood risk-ecosystem practices are mainly driven by the challenges hard-engineering structures pose against flood risk uncertainty and ecological integrity. Most practices therefore aim to re-establish the natural processes between rivers and their floodplains. To reduce flood risk, these models often reallocate people and limit direct human uses of designated flood zones. Therefore, opportunities that can be derived from returning rivers to their natural and pristine state with limited human influence are often conceived as the potential benefits to societies. In addition, as management of flood risk is mostly based on the *precautionary principle,* prevented exposure to flood hazard is the preferred mechanism to build resilience instead of enhanced coping capacity.

In many developing countries, local communities have long adapted to regular exposure of inundation. Lifestyles, livelihoods and even their traditions are rooted to the expectation of seasonal floods. Although extreme flooding may lead to detrimental effects, local people may have different interpretations and perceptions of flood risk as opposed to those derived objectively from the product of probability and consequence. The trade-offs between potential flood risk and benefits from flood and use of flood-prone lands in such contexts may thus hold different values. In this case, one may argue whether the same principles driving joint flood risk-ecosystem practices in developed countries can lead to optimum outcomes in the context of developing countries. If not, which socio-ecological benefits and flood risk management strategies should be supported? And perhaps most relevant to decision and policy-makers, how can decisions be rationally based for implementing measures/policies that simultaneously target flood risks and potential benefits from flood-prone land use?

In order to inform and support decision-making processes that shape management of floods and river-floodplain systems, there is a need to re-evaluate the current frameworks and information tools that can further support sustainable practices suited to the challenges and opportunities of developing countries. This is the central theme of this study, in which I explore integration of flood risk-benefit analysis to assist evaluation of potential floodplain management policies and/or flood mitigation measures. Decision- and policy-makers could utilize such information to promote effective practices that could, for instance, aim at sustaining local livelihoods and natural hydrological processes while minimizing potential flood damage.

1.1 Study objectives

The overarching motivation of this research is to support efforts aimed at balancing flood risk, livelihoods, and ecosystem services in flood-prone lands to yield maximum benefits for the minimum risk. In order to partially contribute this overall goal, I specifically address the following research questions: (1) how do land use policies influence trade-offs between risks and benefits in flood-prone areas? And (2) what is the potential role of coping capacity in managing flood risk while supporting multiple benefits from flood-prone lands?

The general objectives of this study are therefore to (1) compare flood risk and potential benefits over varying probabilistic flood hazards associated with direct human uses versus flood storage/conservation use of flood-prone land, and (2) evaluate the effect of individual human behaviors (coping capacity) in determining potential flood risk and probabilistic benefits.

1.2 Outline of chapters

The chapters in this dissertation are organized as follows:

Chapter 2 presents background information on flood risk-ecosystem approaches for managing flood-prone land and their implementation in developed countries. The conceptual framework of this study is introduced, in which livelihood benefits from direct floodplain use are distinguished from ecosystem services to support management practices in developing countries. The concept of integrated assessment of flood risk and probabilistic benefits to inform decision-making is also presented, followed by a discussion on the role of coping capacity for managing flood risk while allowing for river-floodplain benefits.

Chapter 3 provides evidence from Candaba floodplain, Philippines of livelihood benefits and land adaptations local people practice to cope with regular inundation. An introduction of this area is followed by the analysis of identified coping strategies such as, adapting crop planting periods to the flood pulse or fishing instead of cultivating rice in the wet season. In addition, findings from the estimation of livelihood benefits from selected flood-prone areas and non-flooded villages in Candaba are presented.

In **Chapter 4**, livelihoods from wild fish capture activities in flood-prone lands of Candaba are further examined. Wild capture fisheries and the main types of equipment/techniques for capturing fish from seasonally inundated areas are described. I also present an analysis on the relation between wild fish capture productivity, flood pulse, and level of technology use based on empirical evidence reported by local fishermen. This analysis was used to derive linear models of wild fish catch productivity as a function of flood intensity, which were applied in the subsequent analysis of this study.

Chapter 5 presents findings from the integrated assessment of flood risk and probabilistic benefits associated to land use policies for Candaba area. Policies that support livelihood practices compatible with direct human use of flood-prone land (agriculture/wild fisheries) and nature conservation (wild fisheries only) are considered as potential scenarios. Flood risk-probabilistic benefit trade-offs are analyzed to identify optimal measures and discuss the value of this approach for decision-making. The role of individual coping capacity (adapting crop calendars or seasonal rice-fish practice) in minimizing flood damage while benefiting from flood-prone land use is also examined.

In **Chapter 6**, I present a synthesis of this study and a discussion on key findings and policy implications of this work**.** Summary remarks and conclusions are provided in **Chapter 7.**

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INTEGRATED FLOOD MANAGEMENT IN DEVLEOPING COUNTRIES: BALANCING FLOOD RISK, SUSTAINABLE LIVELIHOODS AND ECOSYSTEM SERVICES

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Chapter 2: Integrated Flood Management in developing countries: balancing flood risk, sustainable livelihoods and ecosystem services

2.1 Introduction

Human use of flood-prone land is often associated with the potential for flood damages and negative societal impacts. Flood management paradigms therefore frequently emphasize relationships between society and flood risks (Schanze 2006a). For instance, flood management decision making is often supported by risk assessment, which in practice often quantifies only the damaging effects of flooding (Meyer, Haase, and Scheuer 2009, Merz, Kreibich, et al. 2010). From a single-objective perspective, reducing human vulnerability by limiting exposure to flood hazards is often an effective strategy to reduce flood risk. Where reduced exposure is accomplished by *keeping people away from floods*, for example through land use designations and restricted floodplain uses, river processes driven by hydrologic variability remain intact, promoting river and floodplain integrity. Complimentary ecosystem benefits that follow from establishing natural hydrologic processes within rivers and floodplains create an ideal multi-objective partnership between efforts to manage flood risk and river ecosystems (Opperman et al. 2009). As climates become more variable and less predictable, this multi-objective partnership expands to enlist climate change adaptation among the suite of potential benefits (Palmer et al. 2009, Seavy et al. 2009). The win-win combination of ecosystem approaches for flood-prone land management has been well received and adopted by many flood adaptation and restoration practices in developed countries (Nienhuis and Leuven 2001, Moss 2007).

Another multi-objective approach to flood risk management, the Integrated Flood Management (IFM) concept promotes maximizing benefits from the use of frequently inundated areas while reducing potential damages from floods (APFM 2004). Conceptual ideas of river management by IFM represent a broader and more inclusive approach to managing floods, ecosystems, and sustainable livelihoods, as compared to single-objective flood control strategies (Grabs, Tyagi, and Hyodo 2007). Many ecosystem approaches for flood-prone land management promote opportunities related to natural hydrologic function, including regular floods, and societal benefits from flood-prone lands (Baron et al. 2002). Such ecosystem approaches implemented in developed countries are potentially useful models to support IFM in developing countries. Many example practices, however, often reinforce notions of safety and resource optimization based on the principle of *keeping people away from floods*. In practice, land use zoning or designation of flood-prone land for flood risk reduction and nature restoration/conservation often limits the accepted uses of flood-prone land to exclude many direct human values (Dufour and Piégay 2009). However, the exclusion of direct human uses from flood-prone lands is not always possible, or in some cases may not present the most optimal solution. This may be the case for developing and rural areas, or where livelihoods of local people are sustained from direct use of floodplain resources (Cuny 1991). Practices which optimize livelihood benefits of using flood-prone lands in combination with flood risk reduction and ecosystem services may provide unique opportunities and advantages for less developed nations. Despite the promising future of such multi-objective floodplain management approaches, the lack of practical tools and strategies may hamper their implementation. As trade-offs may exist, it is critical to address the distribution of benefits from direct human use versus exclusive conservation of flood-prone lands in order to achieve equitable outcomes. In this article, we examine the challenges and opportunities for ecosystem approaches to flood risk management in developing countries and propose a framework for balancing flood risk, sustainable livelihoods, and ecosystem services in flood-prone lands. We further propose that analysis of both risks and benefits associated with floods and use of flood-prone lands may serve as a useful tool to inform selection and implementation of potential flood risk and land management actions. This approach may elucidate appropriate flood-prone land management practices in developing countries and support opportunities for IFM.

2.2 Integrated Flood Management (IFM) and ecosystem approaches for flood-prone land management

IFM is a philosophy for integrated land and water resources development, aimed to maximize net benefits from the use of flood-prone areas while simultaneously reducing flood losses (APFM, 2004). The novelty of this concept is the goal of balancing development needs, environmental quality, and flood risks to support sustainable development (Grabs, Tyagi, and Hyodo 2007). Principal elements of IFM include managing flood risk and uncertainty, developing an appropriate mix of flood management strategies, and facilitating a participatory process (APFM 2004). One key aspect of IFM is the integration of land and water management. In practice, various ecosystem approaches for managing flood-prone land embody the IFM philosophy (see Table 2.1).

Strategies for adapting flood-prone land uses originate from different disciplines and frameworks such as Restoration Ecology, Flood Management, Integrated River Management, Ecosystem-based Adaptation (EbA) or Eco-based Disaster Risk Reduction (Eco-DRR). Though deriving from varied schools of thought and aimed at diverse objec-

Table 2.1. Ecosystem approaches for flood-prone land management to support IFM.

Approach	Definition
Integrated River Management	• Aims for the sustainable development and long-term stability of various elements of river systems, such as morphology, ecology, landscape, and human use (Wang, Lee, and Melching 2015). • Practices may include restoration of lateral and vertical connectivity of rivers, with appropriate integration and coordination of different interests, domains and functions (Verkerk and van Buuren 2013, Wang, Lee, and Melching 2015).
Ecosystem-based Adaptation (EbA)	• Considers integration of conservation, restoration and sustainable use of biodiversity and ecosystem services for human well-being and adaptation to climate change (Millennium Ecosystem Assessment 2005, Secretariat of the Convention on Biological Diversity 2009). • Main goal is to increase resilience and reduce vulnerability of people to climate change, promoting the use of traditional knowledge and local practices (Colls, Ash, and Ikkala 2009).
Ecosystem-based Disaster Risk Reduction (Eco-DRR)	• Defined as the sustainable management, conservation and restoration of ecosystems to reduce disaster risks and achieve resilient development (Estrella and Saalismaa 2013). • Highlights the interrelation between ecosystem management, disaster risk management, and climate change adaptation (Sudmeier-Rieux and Ash 2009). • Emphasizes the role of ecosystems for natural protection against hazards and for sustaining livelihood resilience (Estrella and Saalismaa 2013).
River restoration	• Defined as recovering the ecological integrity in a degraded watershed system by re-establishing the processes necessary to support the natural ecosystem within the watershed (Wohl et al. 2005). • Aims to recover spatial river processes for instance, the natural sinuosity of channelized rivers, lateral connection of rivers with their floodplains, longitudinal connectivity along the stream, and the vertical connections between river channels and underlying hyporheic zone (Kondolf et al. 2006). • Recovery of temporal river processes is mainly addressed through restoration of natural flow regimes and dam decommissioning (Richter and Thomas 2007).
Space or Room for the River	• Aims to create more space for rivers usually by increasing the river channel capacity or adapting floodplains to sustain flooding (Warner, Edelenbos, and van Buuren 2013). • Measures are driven by flood safety and restoration objectives, but often enlist climate change adaptation (Verkerk and van Buuren 2013). • Example practices mostly derive from application of comprehensive policies, multi-stakeholder involvement and sometimes include multiple benefits from flood-prone areas (Wiering and Arts 2006). • Different characteristics between practices, seem to be evident with regards to type of measure, scale of intervention, sector outreach, and the benefits often associated with the promotion of flood adapted areas (Verkerk and van Buuren 2013).

tives, these approaches often share a common strategy of restricting and adapting land uses in flood-prone areas and allowing rivers to temporally flood large areas (Clarke, Bruce-Burgess, and Wharton 2003, Klijn, van Buuren, and van Rooij 2004, van Eijk et al. 2013). Examples include restoration and/or legal designation of wetlands and floodplains to support natural flood attenuation (Hey and Philippi 1995, Galat et al. 1998, Wharton and Gilvear 2007, Ibe, Ahaotu, and Aju 2014), or the engineering of flexible embankments that allow adapted, multipurpose use of lands prone to seasonal flooding (Eakin and Appendini 2008, Edelenbos, Roth, and Winnubst 2013).

Interventions that include restoration of rivers, flows, and floodplains derive from geomorphic and ecological principles, and often seek to re-establish hydrological, ecological, and geomorphologic processes of rivers (Sear 1994, Poff et al. 1997, Ward et al. 2001). These practices are often based on recovering ecological integrity through the reconnection of rivers with floodplains (Buijse et al. 2002, Jungwirth, Muhar, and Schmutz 2002). In practice, use of restored floodplains is often restricted to the few categories of land use which are robust to periodic inundation, such as conservation, green space, and limited seasonal agriculture or pasture (Bernhardt et al. 2005, Purps, Damm, and Neuschulz 2005, Wohl et al. 2005, Moss 2007). As the reference state for most restoration projects is a natural and uncompromised river-floodplain system with limited human disturbance, designed uses of reconnected floodplains often exclude cultural and socio-economic values (Buijse et al. 2005) such as residential or commercial uses.

Space for the River or *Room for the River* practices largely originate from a flood management domain (van Stokkom, Smits, and Leuven 2005, Hartmann 2013, Potter 2013). These practices consist of floodplain restoration to increase retention capacity of rivers (Warner, Edelenbos, and van Buuren 2013). Similar to river restoration projects, *Room for the River* projects also promote ecological integrity and natural dynamic processes within designated river-floodplain areas (Hooijer et al. 2004, Warner and van Buuren 2011, Potter 2013). For example, interventions such as levee setbacks, ring polders, or river side channels (Nijland 2005) delineate zones within which natural flow patterns and processes are allowed. In some cases *Room for the River* projects such as in the Noordwaard and Overdiepse Polders, the Netherlands, include a compatible multifunctional use of flood-prone areas in which residences and agricultural activities are protected with the strategic location of polders or by placing homes and farm buildings on raised platforms (Edelenbos, Roth, and Winnubst 2013). In other areas, the multifunctional approach of *Room for the River* projects lists cultural use, preservation of heritage, and improved navigation as co-benefits (Corvers 2009, Zevenbergen et al. 2013). Often *Room for the River* measures are linked with transitions in policies, governance, planning, and decision-making (Wiering and Arts 2006, Rijke et al. 2012). For instance, Dutch water managers have adjusted their traditional roles to facilitate nature development and multidisciplinary cooperation in *Room for the River* projects (Roth and Warner 2007, Klijn et al. 2013).

Efforts that unfold from Integrated River Management, EbA and Eco-DRR approaches account for interactions between natural and human systems (Nakamura 2003, Renaud, Sudmeier-Rieux, and Estrella 2013, Wang, Lee, and Melching 2015). The main attribute connecting these approaches is the combination of multiple objectives, such as flood safety and sustainable use of land and water resources (Maltby and Blackwell 2005). Projects may consider not only ecological quality of river systems or flood safety, but also acknowledge the potential use of floodplains and local adaptation capacities (van Eijk et al. 2013, Verkerk and van Buuren 2013, Wang, Lee, and Melching 2015). In EbA and Eco-DRR projects, socio-economic and livelihood aspects are assumed to derive from the ecosystem services provided by functioning river-floodplain systems. Direct socio-economic benefits related to direct human use of flood-prone land may not feature prominently in projects implemented under such frameworks.

Considering the diversity of ecosystem approaches for flood-prone land management, these approaches may lead to a spectrum of possible flood-prone land conditions. Potential configurations may involve exclusive nature conservation of flood-prone lands, to multi-functional floodable areas where direct human uses are acceptable. Depending on the local and river basin contexts, these example practices therefore have great potential to serve as flood-prone land management models, which may be useful in supporting implementation of IFM.

2.3 Benefits from direct human use and exclusive conservation of flood-prone land

The varied land management models from joint flood risk-ecosystem approaches can produce a diverse array of potential benefits with respect to rivers and floodplains (Thorp et al. 2010). We distinguish benefits associated with direct human uses of floodplains from societal benefits that derive from designating floodplains exclusively for ecosystem conservation (Figure 2.1). For instance, a river restoration project may entail reoperation of a flood control dam to restore naturally-occurring floods, in combination with floodplain zoning and acquisition of flood-prone land for conservation purposes. The restoration of hydrologic processes and repurposing of flood-prone land to accommodate regular flooding produces benefits in both flood risk management and improved river ecosystem function. Although many direct human uses of the flood hazard area are prohibited in this case, the designation of floodplains for conservation provides ecological and societal benefits through provision of ecosystem services. In accordance with Hein et al. (2006), some of these benefits in practice may involve an *indirect use* and *non-use* value, such as maintenance of channel morphology and natural habitats, flood regulation, and clean water or a *direct use* value such as navigation or recreation (Holmes, Bergstrom, Huszar, Kask, and Orr III 2004, Bernhardt et al. 2005, Wohl et al. 2005, Verkerk and van Buuren 2013). This exclusive conservation model is in contrast to management models that allow humans to directly attain tangible benefits from direct use of floodplains, for instance, from agriculture, pasture, and housing.

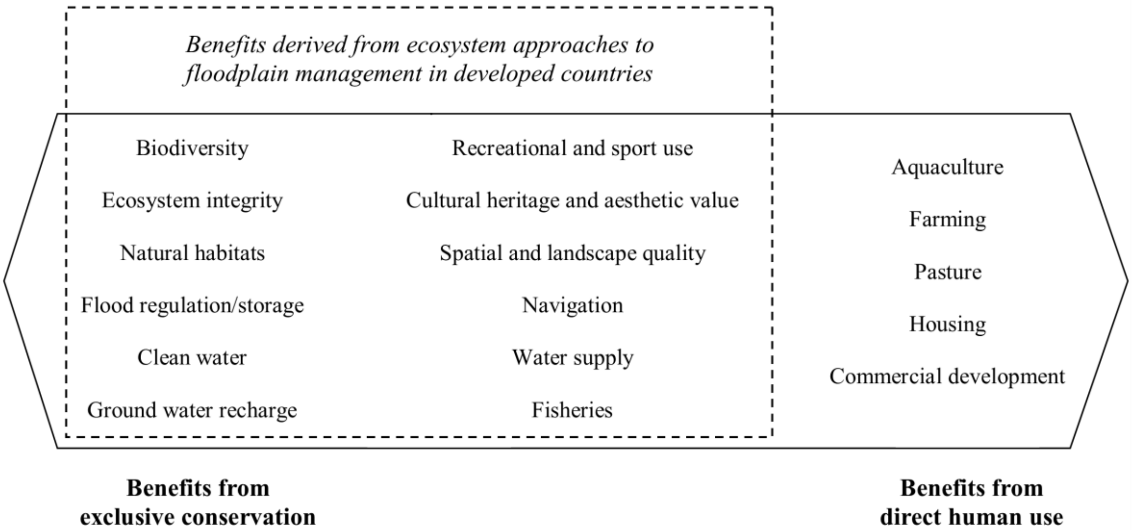

Figure 2.1 Continuum of potential benefits from flood-prone areas.

In developed countries, ecosystem approaches to floodplain management often support benefits and services related to *regulation*, *habitat* and *information (cultural)* functions of riverine systems (Figure 2.1). As floodplains are often designated exclusively for conservation and flood storage uses, these approaches often exclude many direct human uses of the land. Direct human use of flood-prone land is frequently associated with loss of lives and/or economic value, as people and assets are exposed to flooding. In consequence, while definition of IFM acknowledges the benefits associated with human use of flood-prone land, many approaches in practice tend to eliminate direct human use of floodplains in favor of benefits compatible to conservation and flood storage. The strategy of *keeping people away from floods* may therefore become implicit in measures aimed for risk reduction and ecosystem benefits. This may discount the full continuum of possible benefits from flood-prone areas. Where the exclusion of humans from floodplains is unrealistic, the lack of alternative models illustrating how direct human uses may be undertaken within the context of ecosystem approaches to flood risk management, may impede implementation of ecosystem approaches.

2.4 Flood-prone land management in developing countries

Trends in altered and degraded river systems and potential impacts of climate change (Tockner and Stanford 2002, Mirza 2003), may drive implementation of joint flood risk-ecosystem approaches in developing countries. The exclusion of direct human use of floodplains, however, may be a poor fit in the developing world. Rapid population growth and corresponding land pressure (Tockner et al. 2008) may challenge practices based on *keeping people away from floods* as people expand into marginal land such as floodplains. In Bangladesh, for example, increasing population density and high rates of rural-urban migration force landless families to settle in available lands, which are often disaster-prone areas alongside or within major rivers (Wisner et al. 2004, Webster et al. 2010). Even when human uses of flood-prone land are legally excluded, responsible institutions in many developing countries often fail to enforce these laws. For instance, China's flood management strategy designates a total of 98 flood retention zones for flood water storage (Cheng 2005). However, after years of encroachment and intensification of human activities, almost 2 million hectares are still used for agriculture and more than 17 million people live within these zones (Han and Kasperson 2011). People in developing countries may refuse to reallocate or settle back into flood-prone areas, partly due to weak governance, but also because many people living in such lands often must balance flood risk with other types of risk and social needs (Weng Chan 1995). For instance, poor people may be exposed to flood risks but, if excluded from the resources of flood-prone land, may face even greater livelihood risks (Arnall et al. 2013). People may, for example, have limited or no access to resources, monetary income, or water for domestic use and sanitation. The goods and services they might obtain from floods and use of flood-prone lands therefore represent their means of survival, making life in a hazardous area the best of poor choices. Evaluation of resettlement schemes for reducing flood risk in Malaysia, reveal that important challenges to reallocation are uncertainties of moving to new environments and strong values and attitudes to current ways of living in the communities (Weng Chan 1995). Evidence from two villages in Mozambique also highlights ability to secure a viable livelihood as a key determinant explaining whether resettled peoples remain in their new location or settle back in the floodplains (Arnall et al. 2013). In developing countries, policy-makers and managers may also prioritize development goals above conservation. For instance, a manager may veto joint conservation-flood risk schemes that limit human economic activities in favor of projects that enable economic growth following the Western model of development. In the Philippines for example, strategies in favor of aquaculture development, perceived low economic rent of mangroves, and lack of political will are listed among institutional factors that have compromised the sustainable development and conservation of mangrove ecosystems in the country (Primavera 2000).

In many countries, and particularly in delta nations such as Vietnam and Bangladesh, floods occur annually and direct exposure to seasonal flooding is expected and anticipated by local people. Many people derive direct benefits from *living with –and from floods* (Cuny 1991). Natural floods and floodplains have long provided multiple goods and services to communities, for instance, supplying soil moisture, nourishing fields with nutrients and sediment, and bringing fish into floodplain rearing habitat (Paul 1997). In many respects, floods are considered beneficial for agriculture and fisheries activities (Shankar, Halls, and Barr 2004). Housing is often adjusted to withstand some level of inundation (Cuny 1991), allowing people to live close to or on flood-prone land. Many people have therefore developed livelihoods and lifestyles which are tied to seasonal flood pulses (Paul and Routray 2010). In Vietnam, for example, *living with floods* includes seasonal planting of crops to avoid flood peaks or elevating paddy fields and building small-scale bordering embankments to protect crops (Tinh and Hang 2003). Common practices also include evacuation to high grounds during flood season and constructing elevated homes (Few, Pham, and Bui 2004). In such contexts, people able to cope with certain levels of inundation obtain direct socio-economic benefits of using flood-prone land.

Resources deriving from floodplains provide a considerable fraction of annual incomes and assets, and in some areas floods are important natural processes that support the base of rural economies and food security (Few 2003). For people living in these conditions *normal* floods are therefore not considered a disaster, but both the lack of flooding and extreme flood events are associated with negative consequences (Tinh and Hang 2003). Strategies that include relocation of people and designation of flood-prone land for conservation and flood risk reduction, are therefore not necessarily desirable or feasible in many developing countries. However, flood-prone land management models may contribute to maintain healthy ecosystems, while providing opportunities to sustain flood-adapted livelihoods and reducing potential flood risks. Hence, these practices may be useful in supporting and achieving main goals of IFM in developing countries. The interpretation of benefits in these contexts must, however, value benefits from both conservation and direct human use of flood prone land. This notion may suggest that flood-prone land adaptation and restoration efforts must include configurations that balance livelihoods, ecosystem services, and benefits while reducing hazard risks. The process towards implementation of adequate practices should therefore build from lining up and rightly acknowledging these elements and their interactions.

2.5 Balancing risks, livelihoods and ecosystem services in flood-prone lands

To support implementation of ecosystem-based approaches to managing flood-prone land in developing countries, there is a need for models and example practices that are suited to the context of developing nations or where human exclusion from floodplains is not possible. Such approaches require recognition of the opportunities and benefits that derive from direct use of flood-prone lands. We propose that livelihood benefits deriving from direct use of flood-prone land should be distinguished from those supplied through river- and floodplain-related ecosystem services. In order to evaluate the full scope of potential benefits, we propose a framework that emphasizes livelihood and socio-economic benefits, both from direct use of flood-prone land, as well as those related to ecosystem services derived from the preservation of natural hydrologic processes (Figure 2.2). Balanced consideration of ecosystem services and direct livelihood benefits may illuminate a wider range of adaptations and land use options that maximize the benefits of using flood-prone land, while promoting connection of rivers and floodplains and minimizing flood risk. In this way, alternatives to established models of exclusive ecosystem-flood storage uses are imaginable, encompassing strategies and adaptations that support many other potentially beneficial human uses of flood-prone lands. This framework may be used to explore and select management practices when a strong basis for securing livelihoods and favorable river environments is desired, for instance, through the optimization of both flood risks and benefits.

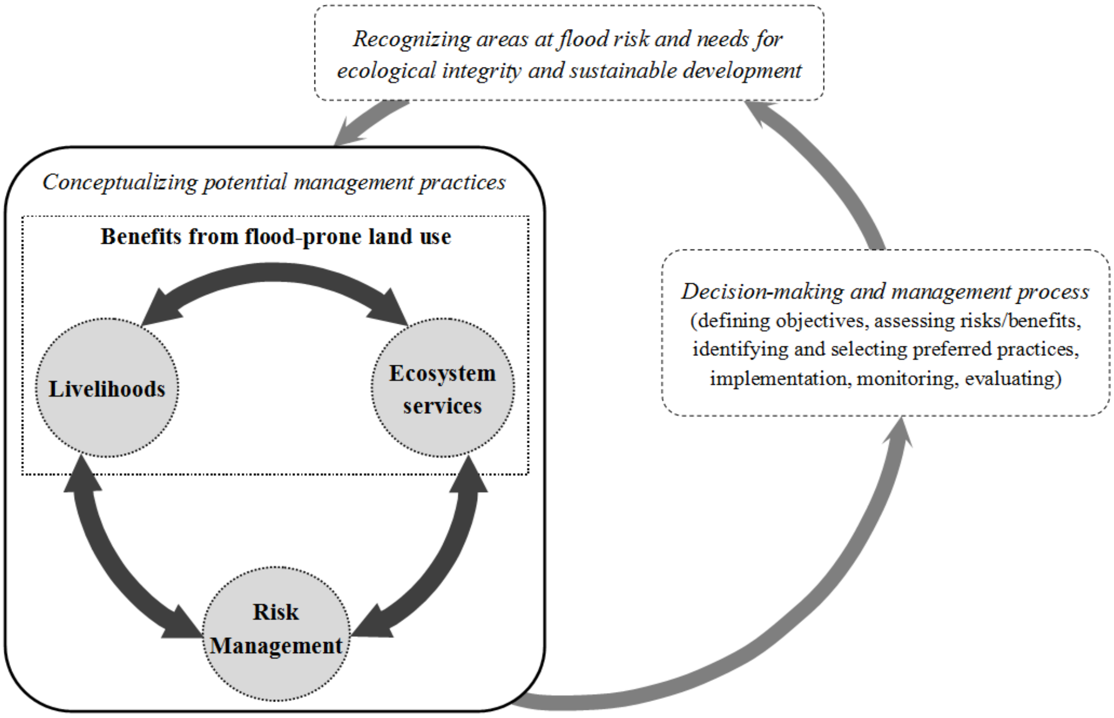

Figure 2.2 Conceptual framework for balancing flood risk, livelihoods, and ecosystem services in flood-prone lands.

2.5.1 Targeting coping capacity to mitigate risk

Our proposed framework balances livelihoods, ecosystem services and risk management. Translating this approach into practice, however, may require targeting risk from a broad perspective. Risk in flood management is defined as the probability that flood hazard will combine with vulnerability to produce negative consequences (Merz, Hall, et al. 2010). Vulnerability is often expressed as function of Exposure and Coping Capacity; thus, Risk may be expressed as in Eq. 2.1.

Risk = f (Hazard, Exposure, Vulnerability, Coping Capacity) (Eq. 2.1)

If, for example, there is no exposure to a hazard then the possible range of probabilistic hazards pose minimum or no risk. Similarly, if vulnerability is reduced (for instance, through enhanced coping capacity), exposure to hazards may lead to fewer negative consequences, which also reduces risk. Many models for managing flood-prone land in developed countries tend to limit hazard exposure as a mechanism to reduce flood risk. The potential to minimize flood risk by targeting and enabling coping capacities is frequently overlooked in favor of strategies that *keep floods away from people* or *keep people away from floods*. However, by targeting coping capacities rather than exposure as a strategy for risk reduction, it may be possible to simultaneously support flood risk reduction, livelihoods, and ecosystem services. Measures aimed to secure livelihoods while supporting other ecosystem services from natural river functions, most likely will involve land use scenarios under some level of exposure to flood hazard. Increasing coping capacities and supporting traditional knowledge are perhaps the keys to delivering multiple benefits from using flood-prone lands while minimizing flood risk (Figure 2.3).

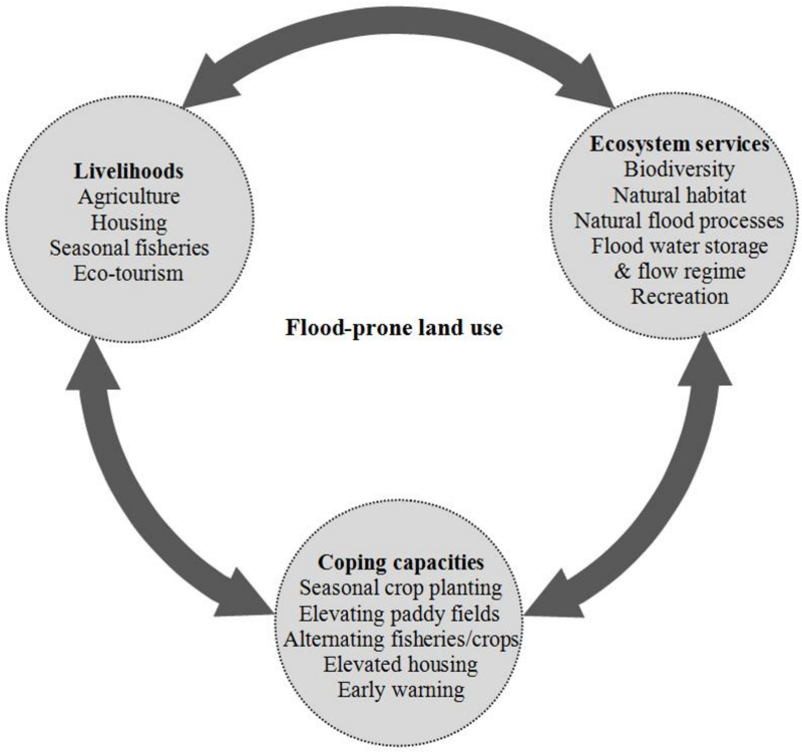

Figure 2.3 Enabling coping capacities to sustain livelihoods and ecosystem services and benefits in flood-prone lands.

Supporting ecosystem services such as natural flood processes while simultaneously securing livelihoods, for instance, through agricultural and fishery activities, may involve a scenario in which people are exposed to regular flooding. Enhancing coping capacities, for example, through seasonal adaptation of livelihoods such as alternating crops during the dry season with fishing during the wet season, may be an effective way to minimize potential losses and thus manage flood risk. Alternately, a scenario in which flood storage or natural flow regime services are promoted while allowing economic activities and residential use of flood-prone lands, may be an acceptable option if local capacities to save properties and assets are supported by early warning systems, flood risk maps, and risk education.

2.5.2 Supporting livelihoods, ecosystem services and other benefits

Depending on the approach behind floodplain use, trade-offs in resultant benefits may occur, such that certain values are favored relative to others. For instance, it is often assumed that benefits of restoration may be realized only when human disturbance is minimal or inexistent. Similarly, that human development can only be achieved if the environment is fully adapted and modified to fulfill societal needs. In other words, conservation and development goals are conflicting and therefore benefits to one sector may only accrue under conditions that limit provisioning of benefits to the other. In reference to floodplains, this assumption may apply in some cases, as projects promoting multi-functional use of floodplains still involve complex engineering works or alteration of natural processes. In the prior example of *Room for the River* in the Noordwaard polder, agricultural areas are converted into a multifunctional space with different flooding frequencies to restore flood and tidal dynamics and support nature development (Edelenbos, Roth, and Winnubst 2013). The final design includes the strategic location of high-diked polders to protect living and agricultural activities, however, the long-term effects on the delta Rhine features remain uncertain as sedimentation processes were largely overlooked (van Staveren et al. 2014).

Though inevitable trade-offs can result from securing livelihoods as well as supporting ecological integrity of river systems, these elements are not necessarily mutually exclusive. For instance, establishing or maintaining a natural regulation cycle in flood-prone lands, may provide different types of ecosystem services and goods (i.e. ecological, socio-cultural and economic). Livelihoods which are also tied to or dependent upon natural hydrologic regimes can be enhanced in a similar way. For instance, in the case of developing countries, this may apply for agriculture and fisheries-based livelihoods, and local tourism industries may also benefit from sustained natural environments. The key to crafting projects that provide benefits to multiple sectors (economic, ecosystem, flood risk reduction) may lie in articulating very clearly where risk and benefits occur in order to design strategies that derive maximum benefit for minimum risk.

2.6 Flood Risk-Benefit Assessment: delivering information for flood-prone land management

Risk assessment is an important tool to inform decision making and support implementation of flood management practices. Conceptualization of risk in flood management largely aligns with the scientific definition of risk, such that risk is often objectively quantified as the product of probability and consequence. The purpose of flood risk assessment is to determine potential consequences related to various magnitudes of flood hazard, such that measures to reduce damages and loss are designed, evaluated, and selected according to probability of occurrence. Current application of risk assessment, mostly focus on damages with respect to assets and lives (Merz, Kreibich, et al. 2010). Other societal and environmental consequences are frequently neglected, sometimes resulting in selection of countermeasures that manage only certain elements of flood risk (Meyer, Haase, and Scheuer 2009).

Despite wide acknowledgement of potential benefits that derive from direct use of flood-prone lands, techniques in flood risk assessments that explicitly include benefits are still limited (Meyer et al. 2013). Rather, risk assessments generally consider benefits in terms of loss avoidance of possible measures (Messner and Meyer 2006). We posit that coupled assessment of flood risks and probabilistic benefits can be an improved information tool to support balancing livelihoods, ecosystem services and flood risk management. For instance, if benefits from floods and use of flood-prone lands are properly integrated and evaluated next to risks of flooding, decisions to alter the magnitude of designed peak flows will be targeted to simultaneously reduce risk and align with local socio-economic preferences and environmental goals. In addition, the exchange of benefits against tolerable risks may reveal a wider spectrum of possible scenarios. For example, a naturally-restored floodplain where human use is limited may provide ecosystem benefits and very low flood risk; alternatively, a multifunctional floodplain may support similar ecosystem services as well as benefits from direct human use in exchange for tolerable levels of flood risk. The evaluation of acceptable risk and benefit trade-offs in decision-making can function as criteria for balancing various benefits while minimizing potential loss to support IFM. Targeted at the correct scale, the broader context provided by a Flood Risk-Benefit Assessment may represent local conditions and desired objectives, which may ultimately support more effective and socially compatible solutions.

We propose a step-wise approach to integrate benefits into risk assessments (Figure 2.4 (a)-(e)). Flood risk is assessed by combining a probability density function of flood hazard (f (x); Figure 2.4 (a)), with a damage function (D(x); Figure 2.4 (b)) to obtain a probabilistic damage function (Figure 2.4 (c)) as described in Eq. 2.2:

$$\mathrm{RI} = \int_0^\infty \mathrm{f}\,(x)\;\; D(x)dx \qquad \text{(Eq. 2.2)}$$

where f (x) is the probability density function of flood magnitudes x, and $D(x)$ is the relation between damages D and flood magnitudes x. The integration of f (x) and $D(x)$ for possible range of x results in the expected damage (RI). An analogous process may be applied to assess benefits, which may therefore include generation of functions $B(x)$ that relate benefits with flood magnitudes (Figure 2.4 (d)) to estimate the expected benefit (BE) from floods as indicated in Eq. 2.3 (Figure 2.4 (e)):

$$\text{BE} = \int_0^{\infty} \text{f}(x)\ B(x)dx \qquad \text{(Eq. 2.3)}$$

When balancing probabilistic damage and benefit functions in a common profile, the range of return periods associated with potential benefits and risks as well as maximum turning points, may be useful in supporting understanding and consensus among stakeholders. Such information can facilitate improved decision-making and ultimately development of socially-acceptable floodplain management.

2.7 Challenges and opportunities of Flood Risk-Benefit Assessment

Although Flood Risk-Benefit Assessments may be a promising concept, is worth recognizing potential challenges and limitations to application. As mentioned previously, risk in flood management is most often objectively quantified as the combination of hazard probability and resulting consequence. As such evidence is often used to support analyses of cost-effectiveness, risk as an objective measure appeals to governments and experts as a means to evaluate and compare countermeasures (Baan and Klijn 2004). It is worth noting, however, that risk may also be conceived as a collection of perceptions which influence how people perceive hazards (Raaijmakers, Krywkow, and van der Veen 2008). Aspects such as perceived preferences or possible gains are often decisive when humans judge hazards and determine acceptable levels of risk (Baan and Klijn 2004). Past experiences and emotion may also be influential to risk perception (Slovic et al. 2004, Raaijmakers, Krywkow, and van der Veen 2008).

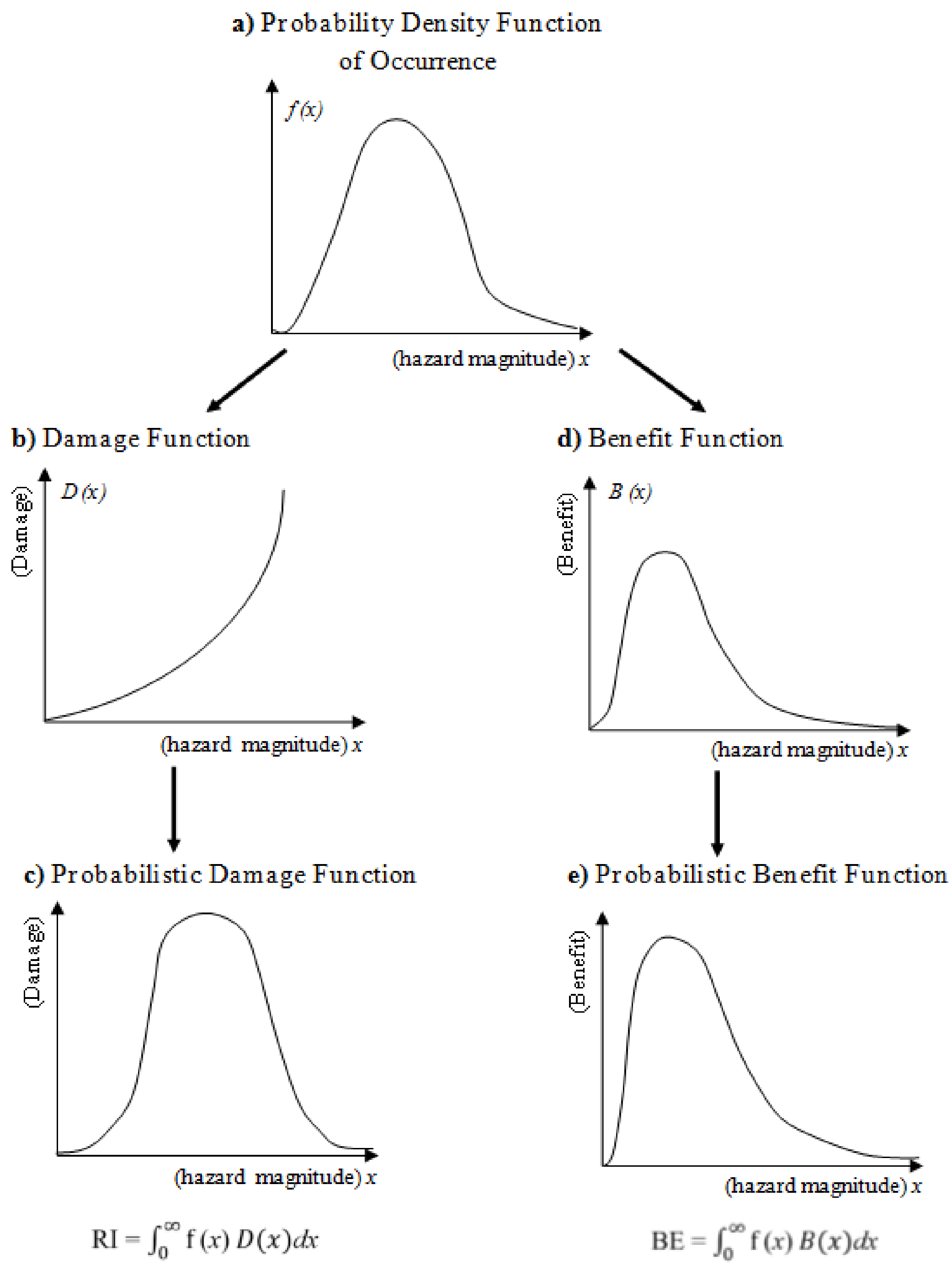

Figure 2.4 A step-wise conceptual approach to Flood Risk-Benefit Assessment.

Additionally, risk of a given hazard is rarely contemplated in a vacuum. Humans perceive and understand risk largely as a relative function, such that acceptable risk of flood is perhaps determined relative to risk of other hazards. Perceptions and views on risk can thus differ between government, managers, experts and community members (Baan and Klijn 2004) or vary at the individual and community level and amongst cultures. Risk assessment approaches focused on statistical risk alone can therefore lead to sub-optimal decision making if perceived or acceptable risk is significantly different from managers' assumption.

Both benefits and risks are related to hydrologic conditions that vary through time. This notion brings forward two different aspects of floods: the mid- to high-frequency events that secure many socio-economic benefits and perhaps low levels of damages, and low-frequency flood events that immediately result in catastrophic damages but eventually may provide lagged benefits such as soil fertilization. Risk-Benefit Assessments must therefore expand from current practices in flood management that focus on extreme events, to include low and high flows, seasonality, and perhaps various descriptors of flooding. Moreover, Risk-Benefit Assessments may involve exploring ways to relate potential benefits and damages to probabilistic flooding events. A combination of available methods to characterize flood hazard and value damages (Merz, Kreibich, et al. 2010, Meyer et al. 2013) and ecosystem services (Hein et al. 2006) may help overcome information gaps, but they require careful selection to accurately represent the context at stake.

Risk-benefit profiles may vary depending on the scale of analysis. As risk assessment may not necessarily preclude social disparity, attention to scale is necessary to ensure that benefits and risks are distributed equitably among sectors and communities. For example, if assessments are implemented at a provincial level, risks and benefits relevant to specific communities may not be reflected in identified risk-benefit priorities. Specific preferences may only become evident when assessments are performed at local scales. For example, the use of flood-prone areas for fisheries activities may be valued by specific groups at the community level, but at municipal or provincial levels such benefits may be perceived as marginal. It is therefore imperative that practitioners target the appropriate scale of analysis for a given objective, to ensure that the *preferred* risk-benefit profile accurately reflects stakeholder preferences. To capture more realistically desired and just outcomes, potential risks and benefits may be identified with a strong basis on local conditions and preferences, then nested within objectives at broader scales (for example, river basin, regional scales). Properly acknowledging that risks and benefits may trade off at different scales will allow managers to ensure that *preferred* risk-benefit levels are effective at all levels.

Flood Risk-Benefit Assessments should include multiple stakeholders' views and require interdisciplinary analysis. Integrating variable stakeholder preferences and finding a common currency for comparing benefits and risks can be challenging. The value perceived from certain benefits, such as biodiversity or wildlife habitat, is often an intrinsic interest and in many cases difficult to measure and capture in units that are comparable (de Groot, Wilson, and Boumans 2002) with flood damages. Traditional flood risk assessment also contends with this challenge in jointly assessing costs of property damage and human lives. When varied stakeholders' opinions are considered in multi-objective decision making where disparate pieces of information must be integrated, methods such as multicriteria analysis (MCA) may be applied (Meyer, Scheuer, and Haase 2009). Participatory approaches that support social learning processes can be effective mechanisms for achieving consensus and dealing constructively with trans-disciplinary domains and framing of issues (Pahl-Wostl et al. 2008). Such approaches might be useful when identifying *preferred* risk-benefits, as well as when defining units or weights for evaluation and decision-making. For instance, stakeholders may determine threshold values and weights to standardize multiple criteria in a comparable scale (Kiker et al. 2005). It is important to acknowledge, however, that such methods introduce subjectivity and depend on the positions, interests, and necessities of the actors involved (Hein et al. 2006). With the caveats of firm grounding in justice, appropriate scale of analysis, and adequate stakeholder representation, the integrated assessment of benefits and risks may be a valuable method to support participatory processes and more equitably address some of the complexities behind evaluation and selection of floodplain management practices.

2.8 Conclusion

Joint flood risk-ecosystem approaches for managing flood-prone land can lead to a spectrum of possible floodplain conditions and uses. However, many flood-prone land adaptations, such as *River restoration* and *Space for the River*, often emphasize recovering ecosystem integrity and reducing flood exposure to manage flood risk. In line with these principles, the ultimate design of example practices frequently consists of natural river-floodplain systems where human activity is limited. We find that such configurations favor societal benefits which are compatible with conservation and flood storage, such as maintenance of natural habitats, clean water, flood regulation, aesthetic value, and recreational use. In contrast, benefits from direct use of flood-prone lands, for instance for agriculture, pasture or housing, are frequently discounted.

In many developing countries *living with –and from floods* is the de facto management system, where people often base livelihood strategies on hydrologic cycles and direct use of flood-prone lands. Direct transfer of practices from developed countries that limit uses of flood-prone lands or constrict access to flood-adapted livelihoods may be unlikely to succeed in such contexts. Population pressures and poor governance systems that often characterize developing countries may also challenge the adequacy and effective compliance of such practices. Where exclusion of humans from floodplains is unrealistic, our proposed framework for balancing flood risk, ecosystems, and livelihoods can elucidate innovative management practices that allow benefit capture from a wide breadth of potential floodplain benefits. Distinguishing livelihood benefits of direct floodplain use from those that derive from flood- and floodplain-related ecosystem services may stimulate the exploration of floodplain conditions that support the full scope of livelihood and ecosystem benefits.

People living on and using flood-prone lands may be exposed to hazards; thus, enhancing coping capacities (for example, through early warning or seasonal fish-crop systems) must figure prominently into strategies for managing risk. In evaluating alternative measures following this approach, selection of preferred benefits may involve trade-offs within the range of potential benefits. Managers and decision-makers may also have to consider combinations of tolerable risk levels alongside benefits obtained in exchange. Flood Risk-Benefits Assessments can reveal information about return periods, flood magnitude range and turning points associated with levels of benefits and risks. This information has the potential to assist evaluation of floodplain conditions bearing different risk-benefit exchanges, which can lead to integrated socio-ecological solutions for implementing IFM. The appropriate integration of justice principles and consideration of scale and spatio-temporal variability may help overcome potential challenges to implementation.

BENEFITS OF FLOOD-PRONE LAND USE AND THE ROLE OF COPING CAPACITY, CANDABA FLOODPLAINS, PHILIPPINES

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Chapter 3: Benefits of flood-prone land use and the role of coping capacity, Candaba floodplains, Philippines

3.1 Introduction

Ecosystem-based approaches to flood management promote multiple benefits to socio-ecological systems in addition to flood risk reduction (Nakamura 2003, Estrella and Saalismaa 2013). Many ecosystem-based practices manage flood risk by lowering human exposure, following principles of *keeping people away from floods*. Such models often prioritize natural hydrologic regimes and flood retention within floodplains, and thus require designation of flood-compatible land uses in flood-prone land (Ibe, Ahaotu, and Aju 2014, Kiedrzyńska, Kiedrzyński, and Zalewski 2014). In addition to flood risk reduction, ecosystems services that follow from supporting river-floodplain integrity are recognized as important societal co-benefits (Baron et al. 2002, Thorp et al. 2010). Floodplain ecosystem services may derive from the direct use, indirect use, or non-use of flood-prone lands (Barbier 1993). Benefits obtained through direct use of flood-prone land may include agricultural production and soil moisture supply, wild harvest of food or medicinals, and recreation. Benefits of indirect use include nutrient cycling, hazard mitigation, groundwater recharge, and water purification. Non-use benefits may include preservation of critical aquatic habitats and biodiversity (Barbier, Acreman, and Knowler 1997, Brander, Florax, and Vermaat 2006, TEEB 2010).

Ecosystem-based strategies that favor specific categories of ecosystem services over others may carry trade-offs with respect to the full range of potential floodplain benefits (Iacob et al. 2014). In developed countries, for instance, joint flood risk-ecosystem initiatives often enhance benefits that are compatible with conservation and flood storage

(Juarez-Lucas and Kibler 2016). Ecosystem services from *non-use* values (e.g. natural habitats, biodiversity), *indirect use* (e.g. flood regulation, clean water), or limited *direct use* of flood-prone lands (e.g. navigation, recreation) are often supported (Bernhardt et al. 2005, Holmes, Bergstrom, Huszar, Kask, and Orr 2004, Verkerk and van Buuren 2013, Wohl et al. 2005). Many direct uses of flood-prone lands are thus restricted, precluding realization of benefits such as farming, aquaculture, and housing. In developing countries, benefits deriving from direct human use of flood-prone lands are often indispensable in securing local livelihoods and supporting human welfare (Cuny 1991, Few 2003). Population pressures and weak governance systems that often characterize developing countries may challenge the adequacy and effective compliance of ecosystem-based strategies that limit direct uses of land for human sustenance (Juarez-Lucas and Kibler 2016). Thus, direct transfer of ecosystem-based practices that restrict access to flood-prone lands may be unlikely to succeed in the context of many developing countries. Alternatively, ecosystem-based approaches that balance flood exposure with enhanced coping capacity may hold promise in reducing flood risk while supporting ecosystems and livelihoods.

Flood-prone ecosystems exhibit shifting, multi-functional landscapes that provide a temporally-variable mix of possible land uses and benefits. For instance, in delta regions such as Vietnam and Bangladesh, low laying areas are often cultivated during the dry season, while in the wet period seasonally inundated lands turn into temporal open-freshwater systems (Dey et al. 2005). Local communities have traditionally benefitted from utilizing these lands to sustain a seasonal rice-fish practice, supporting livelihoods through the direct use of flood-prone ecosystems (Dugan, Dey, and Sugunan 2006).

People in such systems therefore implicitly value direct-use benefits of crop production and/or habitation, but also depend upon the processes that maintain wild fisheries, water supplies, and fertile soils, or support spiritual-religious practices (Banerjee 2010, Ringler and Cai 2006). The potential trade-offs that may occur with alteration of such processes in these areas are becoming clearer with the development of knowledge around rivers as socio-ecological systems (Auerbach et al. 2014). For instance, in Bangladesh, trade-offs between crop production and availability of wild fish protein occurred following intensification of rice cultivation with the construction of dikes and development of flow control programs (Mirza and Ericksen 1996, Shankar, Halls, and Barr 2004).

Where human livelihoods depend upon direct access to flood-prone lands, broad consideration of ecosystem services and livelihood opportunities from floodplain use is essential for effective and sustainable flood risk-ecosystem management. However, the complex suite of potential benefits deriving from the flood pulse and human use of flood-prone land are poorly described, especially relative to the extensive literature on flood risk and damages (Apel et al. 2009, Dutta, Herath, and Musiake 2003, Jonkman et al. 2008, Merz, Kreibich, et al. 2010, Messner and Meyer 2006). Furthermore, the role of coping capacity as a mechanism for managing flood risk is rarely quantified. As such, important livelihood benefits are often discounted in decision making regarding flood risk management and potentially effective flood risk reduction strategies may be overlooked. The objectives of this work are therefore to (1) evaluate the benefits of using flood-prone land in Candaba, Philippines for agriculture and wild fish collection, (2) compare benefits of using flood-prone and non-flood-prone lands, and (3) explore the mechanisms by which human coping capacity may influence net benefits of flood prone land use.

3.2 Methods

3.2.1 Study site: Candaba municipality

Many river systems in the Philippines are prone to high frequency of flood-related hazards, however, in different areas of the country communities have adopted strategies to cope with recurrent and increasing flooding (Gaillard et al. 2008, Uy, Takeuchi, and Shaw 2011). Candaba municipality is a flood-prone area located in Pampanga province, approximately 85 km north-west of Metro Manila on the island of Luzon, Philippines (Figure 3.1; Appendix 1). Candaba lies within the Pampanga River basin on an alluvial floodplain where the Malibay, San Miguel, Garlang, and Maasim Rivers drain into the main Pampanga River. Topography in the area is generally flat with depressions. In the dry season, Candaba is a mosaic of crop plantations, grasslands, aquaculture ponds and residential areas. However, during the wet season (May-Nov), much of the land is inundated, forming a complex of variably-saturated wetlands, shallow swamps and deeper freshwater ponds (Protected Areas and Wildlife Bureau 2013).

Mean annual rainfall in Pampanga river basin is 2,155 mm (Japan International Cooperation Agency 2011a) and river flows generate through rainfall-runoff processes that vary through distinctive wet and dry seasons. Rainfall driving high river flows is recurrent from June to August as result of the Southwest Monsoon combined with the South Pacific trade winds. Heavy precipitation augmented by an irregular pattern of typhoons may extend the rainy period to the end of October (Guanzon and Basa 1977). The dry season extends from December to April while November and May are often considered transition months (Guanzon and Basa 1977; Philippine Atmospheric Geophysical and Astronomical Services Administration 2015).

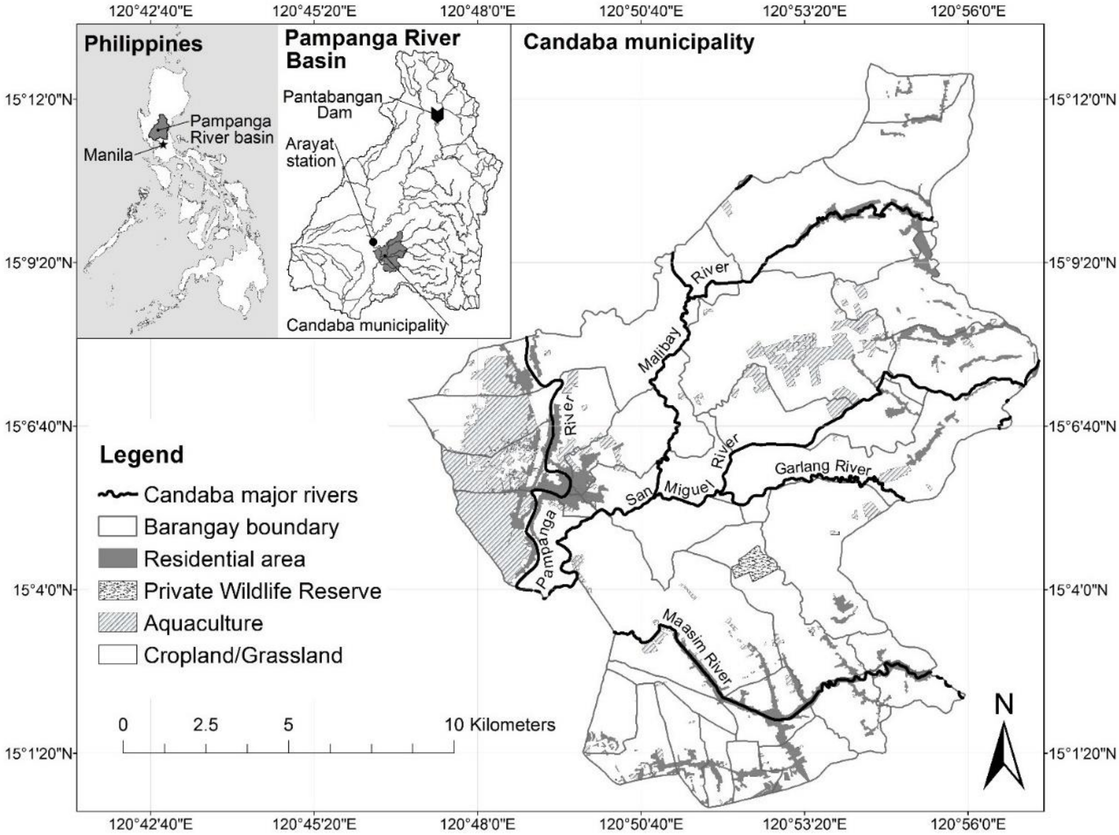


Figure 3.1 Location of Candaba municipality and main land uses.

Candaba contains approximately 20,211 households with a mean size of five members (Municipal Disaster Plan 2014). Mean annual per household income is US $ 1,845, making Candaba one of the poorest local government units in Pampanga province. Sixty-seven percent of the total population is rural. Residences are often located adjacent to municipal roads and concentrated in the west, northeast and southern portions of the municipality. Houses are often one or two-story buildings constructed of light materials, such as used lumber and galvanized iron. However, the use of concrete and construction of houses on top of silts is common in some villages.

At municipal level, agriculture and fisheries are the main sources of income for 70% and 13% of the total households, respectively (Municipal Disaster Plan 2014). Some Candaba residents, for instance, capture wild fish from open inundated areas (Melendres 2014) and/or cultivate fish in aquaculture ponds. In the dry season, most of the land drains completely and is cultivated into rice, vegetable and watermelon plantations (Protected Areas and Wildlife Bureau 2013).

In combination with a natural hydrologic regime that includes recurrent and predictable long-term inundation, the land of Candaba holds an additional and important ecological value. This seasonal wetland has historically been a staging area for over 10,000 winter waterfowl (Alonzo-Pasicolan 1987, Davies et al. 1990, Lambert 1993) and habitat to many other endemic species (Garcia 2010, Melendres 2014, Paz-Alberto et al. 2009). Over the years, populations of birds have rapidly declined largely due to hunting activities for food and recreational purposes (Department of Environment and Natural Resources 2005; BirdLife International 2015). It has been suggested that the decline in bird utilization is also tied to hydrologic alteration, perhaps related to artificial drainage to support agriculture (Department of Environment and Natural Resources 2005). However, following preservation efforts bird hunting is now prohibited in the area, and a private wildlife reserve of 72 hectares (Figure 3.1) was established to support suitable habitats for migratory birds and recreational activities.

The natural hydrology of Candaba therefore provides many vital ecosystem services, both locally and to the wider region, including flood retention within lower Pampanga River basin, irrigation water storage (especially as soil moisture), sustenance of livelihoods through wild fisheries and flood-recession agriculture, pest control, and habitat to support biodiversity (Society for the Conservation of Philippine Wetlands 2015). Following two to three days of heavy rainfall, much of Candaba may remain inundated for one week, while in extreme conditions, low lying lands may be flooded for 2-3 weeks (Municipal Disaster Plan 2014). From a disaster management perspective, such exposure to seasonal flooding is often associated with risk of potential human losses and damages to crops, public works, residences, and other productive assets. However, perceived risk and acceptable level of flood risk may vary across the local population of Candaba, as some communities and households adopt behaviors that allow citizens to adapt to the local conditions (Local Disaster Risk Reduction Management Plan 2007). Community members exposed to regular flooding may, for instance, practice alternative livelihood strategies or land use adaptations to minimize potential flood losses and obtain benefits from direct use of flood-prone lands. The evaluation of benefits from natural hydrology and direct use of flood-prone lands is thus crucial to support decision-making and future implementation of sustainable flood management practices that maximize benefits to livelihoods and ecosystem services.

3.2.2 Village selection

Much of our analysis takes place at the scale of a *barangay*, a native Filipino term for village, which represents the smallest administrative division in the Philippines. Candaba municipality is comprised of 33 barangays, which, according to geography, are exposed to varying degrees of seasonal inundation. In order to compare natural resource-based livelihoods and behaviors in flood-prone and non-flood-prone areas of Candaba, we selected a subset of barangays for detailed analysis, choosing barangays with very high and very low levels of regular flood exposure. We modelled rainfall-runoff processes and characterized inundation (see Section 3.2.3) through the 2010 wet season (Figure 3.2). We characterized flood exposure in all 33 barangays, according to mean percentage of barangay inundated and mean flood depth at the time of peak flooding (Figure 3.3 and 3.4). Because our objective is to explore livelihood benefits or losses associated with natural hydrology, we selected barangays where livelihoods are dominantly accrued through natural resources and potentially influenced by hydrology.

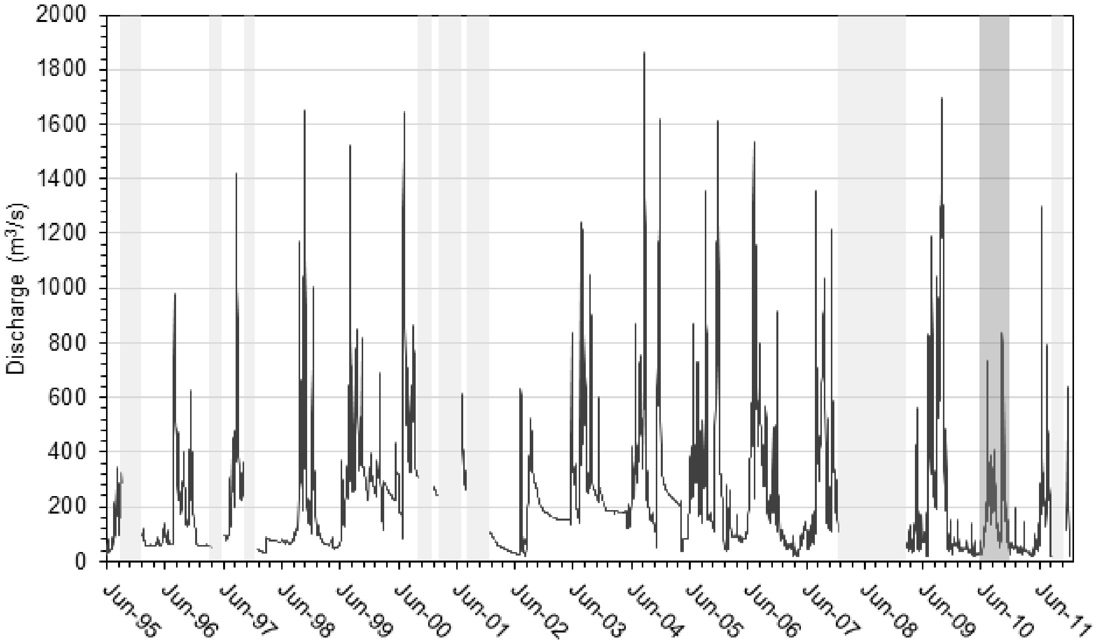


Figure 3.2 Daily mean discharge at Arayat Station, 1995-2011. The wet season of 2010 is indicated; light colored boxes indicate data gaps.

3.2.3 Hydrologic simulation of runoff and inundation

We characterized depth, duration, and spatial extent of inundation in Candaba during the 2010-2011 water year using the Rainfall-Runoff-Inundation (RRI) hydrologic model (Sayama et al. 2012). The RRI is a two-dimensional model that deals with runoff and inundation simultaneously with diffusive wave approximations. The model assumes onedimensional diffusive wave river routing, while lateral flows are simulated as two-dimensional diffusion (Sayama et al. 2010).

We simulated runoff and inundation processes at the scale of Pampanga River basin. We applied observed precipitation from 17 gauges across Pampanga basin, collected from the Philippine Atmospheric, Geophysical & Astronomical Services Administration (PAGASA). We estimated evapotranspiration utilizing the Harmon method (Japan International Cooperation Agency 2011b), with air temperature records provided by PAGASA. Within RRI, channel dimensions are estimated from empirical relationships of hydraulic geometry to basin area (Leopold and Maddock 1953). We used these approximations to characterize dimensions of low-order tributaries. However, we specified geometry of main river channels with surveyed river cross sections (Japan International Cooperation Agency 2012).

For the purpose of runoff modeling, we reclassified the Global Land Cover Characterization (GLCC-V2) data from the USGS (available at http://edc2.usgs.gov/glcc/glcc.php) into the following classes: (1) cropland and pasture, (2) forest, and (3) water bodies. We used the 15-arc second (approx. 450 meter resolution) USGS HydroSHEDS Digital Elevation Model (DEM) (available at http://hydrosheds.cr.usgs.gov/dataavail.php), resampled into a 500-meter grid. We compared river routing generated from DEM processing to satellite images and high-resolution maps provided by the municipality. In a low-relief floodplain area where topography was represented incorrectly, we corrected routed river networks to correspond with true river networks, as observed in the field.

Our model included a boundary condition of regulated discharge in the mainstream Pampanga River at the location of Pantabangan Dam (Figure 3.1), upstream of Candaba. Pantabangan Dam is principally managed to serve irrigation water to agricultural lands. However, this dam is also designed for hydropower generation and reservoir operations may support flood control in the basin (Peras et al. 2009). We set a boundary condition in the model to account for the effect of regulated discharge, using outflow records from the National Irrigation Authority (NIA).

We applied a rating curve provided by PAGASA to obtain discharge data from water level records at Arayat station for the period 2009-2010. We used rainfall and discharge data from 2009 for model calibration, and from 2010 to validate our parameter setup. To validate inundation given by the model we compared modelled inundation extent with detected inundation from satellite images. We selected MOD09A1 Terra products (available at http://e4ftl01.cr.usgs.gov/MOLT/) with less than 40% cloud coverage and applied the Land Surface Water Index (LSWI) (Boschetti et al. 2014) for flood detection. We used a composite of 22 MODIS images from 2009 and a composite of 15 images for 2010. Following computation of the spectral index, we established a threshold of 0.25 to separate water bodies from other land-cover features based on the spectral characteristics of the satellite data. This threshold consistently identified inundated areas when applied to imagery from different seasons and years. Beyond this threshold, detected inundation included forest lands where, given the location and topography, inundation is unlikely. We consulted local risk managers with flood experience in the area to validate inundation maps obtained from simulations and satellite images.

We then compared maximum inundation extent simulated by RRI with inundation from reclassified grids in composite images. We applied two categorical verification statistics, the Critical Success Index (CSI) and Probability of Detection (POD) (Khan et al. 2011), to estimate the correspondence between inundation area by RRI and MODIS.

3.2.4 Identifying livelihoods and seasonal land use

We collected records of agricultural and fisheries activities during the wet season of 2010 and dry season of 2011, reported at barangay level from Candaba municipality and the Provincial Agriculturalist Office in Pampanga. This benchmark data set includes information on yields, farm gate prices and calendar of activities related to agriculture and fishing. We supplemented collected records with information gathered in the field, through focus groups, semi-structured interviews, and surveys to households and fishermen (Table 3.1; Appendix 2) in six barangays of Candaba municipality. Focus groups and semi-structured interviews were conducted targeting key informants to collect base-line information on local livelihoods, land uses, coping capacities to regular inundation, and floods exceeding tolerance levels at municipal and barangay scales. We queried information on socio-economic level, residential use and flood experiences through household surveys, which we used to complement characterization of Candaba area. The survey aimed at fishermen (n = 70; 90% confidence level; random sampling) was designed to collect information on wild fish capture activities (e.g. technologies, catch effort, yields at different inundation depths, costs, fish types, market prices) and thus support quantification of livelihood benefits from the use of flood-prone lands.

Table 3.1. Data collection methods during field surveys.

Method	Sample
Focus groups	n = 8 municipal officers
	n = 6 San Agustin community members
Semi-structured interviews	n = 8 barangay leaders
Household and fishermen survey	n = 31 households
	n = 40 San Agustin fishermen
	n = 30 Paralaya fishermen

To evaluate flood-adapted capacities in selected flood-prone barangays, we examined the degree of seasonal coupling between livelihoods and land use. We compared seasonal inundation and land use with the behavior of individuals, for instance, in their seasonal differentiation of livelihoods and the timing of transition from wet to dry seasonal activities. We then compared seasonal agricultural and fisheries yields associated to land uses and livelihood strategies to determine the value of benefits from direct land use in flood-prone and non-flooded barangays (see Section 3.2.5). Due to extended inundation during the wet season, land cover in parts of Candaba vary seasonally. However, available land use maps convey only dry season use designations. To create dynamic land cover maps, we analyzed land cover from 2010-2011 using four Landsat-L4-5TM images (available at: http://glovis.usgs.gov/). We applied the ISO Cluster Unsupervised algorithm to classify imagery into 30 spectral classes. Spectral classes were then grouped into informational land use types and validated using the most recently available municipal land cover map as reference information. Our analysis of data from 2010 provides a conservative estimate of land that is flooded every year. As the peak flood event of 2010 is moderate compared to other years (Figure 3.2), inundation extent driven by the 2010 rainfall provides a fair approximation of areas in Candaba that are inundated almost every year.

3.2.5 Valuation of benefits from direct land use

We employ direct market pricing methods (Adekola et al. 2008, Barbier 1993) to assess livelihood benefits in selected barangays. We evaluate benefits of direct use of lands for farming as income value (PHP-Philippine Pesos-/ha) derived from wet and/or dry season agriculture, estimated from reported rice-crop yields (kg/ha) and farm gate prices (PHP/kg) disaggregated at barangay level:

$$NIV_a = CY_a \times P_a \qquad \text{(Eq. 3.1)}$$

where NIV_a is the income value per unit area from seasonal agriculture a (e.g. rice-crop cultivation), CY_a is seasonal crop yield per unit area, and P_a is seasonal farm gate price (value of product excluding transport and marketing costs) per unit quantity of crop product.

To evaluate the benefits of wild capture fishing during the wet season, we estimate the income (PHP/fisherman) derived from wild fish capture in flood-prone lands as follows:

$$NIV_f = \left(FY_f \times E_f \times P_f\right) - FC_f \qquad \text{(Eq. 3.2)}$$

where NIV_f is the net income value per fisherman from wild fish capture f, FY_f is wild fish capture yield per fisherman (kg/day), E_f is catch effort per fisherman during the wet season measured in number of days, P_f sales price per unit quantity of fish product (PHP/kg), and FC_f are seasonal costs (PHP/fisherman). In San Agustin and Paralaya, we collected information regarding seasonal yields of wild fish capture at different inundation depths directly from barangay residents. Seasonal yields in this case are related only to activities that involve use of water crafts to capture wild fish. However, information of yields was collected and evaluated based on whether reported fish capture is associated with use of motorized or non-motorized crafts. In addition, seasonal yields include total capture of different types of fish during the wet season, such as tilapia, catfish and mudfish. In our analysis we derived wild fish capture yields from the hydrological simulation of 2010. We used the mean depth during maximum inundation and associated this value to the corresponding surveyed inundation depth interval. The mean of reported wild fish capture yields from such interval was then used for the benefit estimation. We further assessed livelihood benefits from fishing activities in PHP/ha by considering the total number of fishermen and total area at each barangay.

3.3 Results

3.3.1 Characterization of inundation in Candaba

Simulated discharges are consistent in timing and volume with observed flows at Arayat station during the onset of the wet season (September) and typhoon period (October to November) in 2010 (Nash-Sutcliffe Efficiency (NSE) = 0.52 and r^2 = 0.57). Satellite-detected and RRI-simulated inundation also show reasonable agreement of maximum inundation extent during the same period (Figure 3.3, CSI = 0.56 and POD = 0.67 for 2010). Based on the maximum inundation extent during 2010, the model indicates that 92% (162 km^2) of Candaba municipality was inundated with maximum depths varying up to 2.25 m. According to the simulation, the central to western region of the municipality was inundated to the greatest depth, with inundation extending to the northeast.

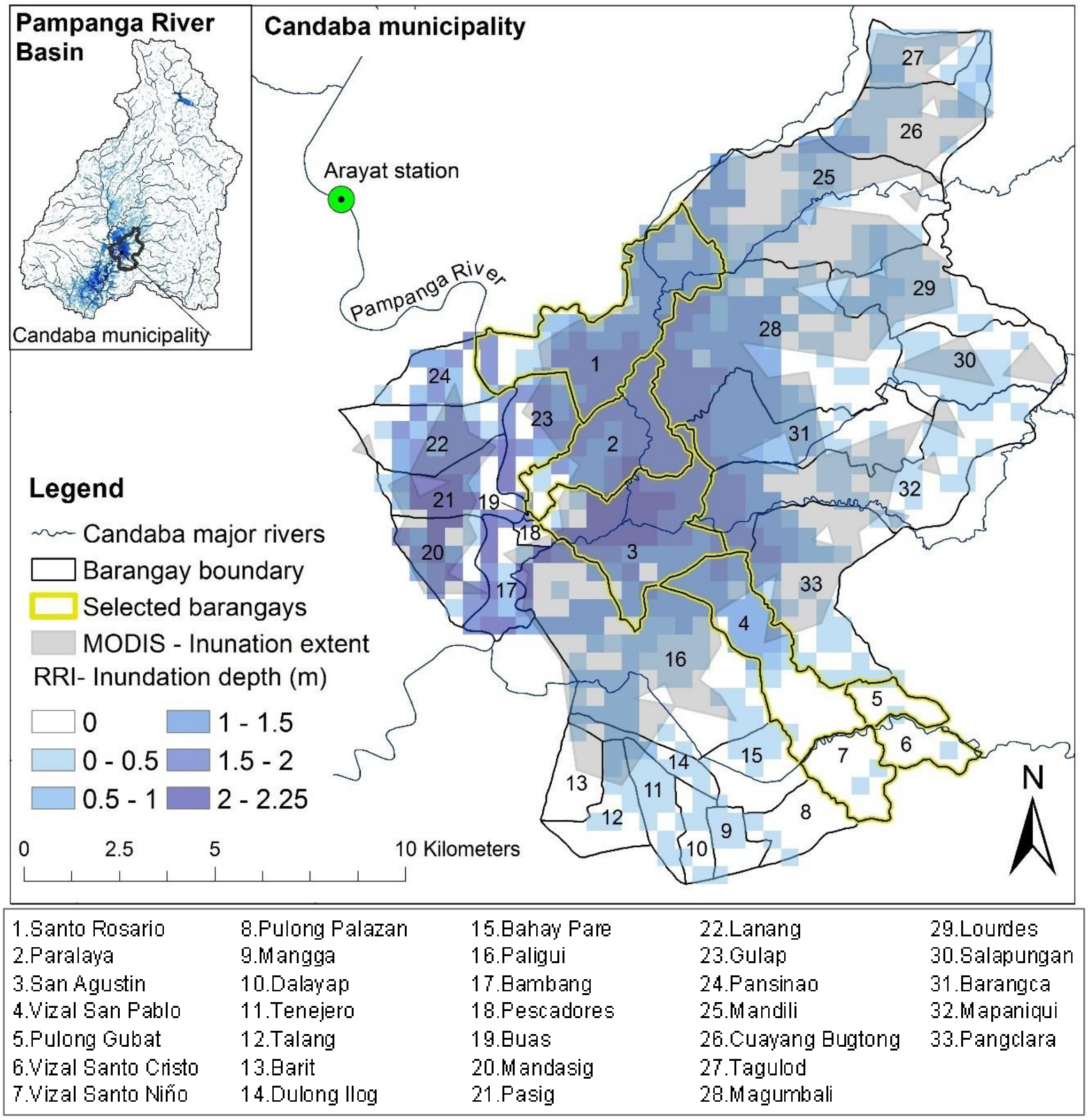


Figure 3.3 Maximum simulated inundation depth and extent, and observed (remotely-sensed) extent in Candaba municipality, 2010, relative to all barangays.

The correlation between mean inundation depth and percentage of inundated area (Figure 3.4) illustrates the degree of inundation per barangay during maximum inundation. From our results, our selected barangays with high flood exposure (Santa Rosario, Paralaya, and San Agustin) can be distinguished from selected non-flooded barangays (Pulong Gubat, Vizal Santo Cristo, and Vizal Santo Niño). In addition to these six barangays, we also selected Vizal San Pablo for analysis. The location of a local wildlife preserve in this barangay represents a natural resources-based livelihood that is unique from the farming and fishing livelihoods found elsewhere.

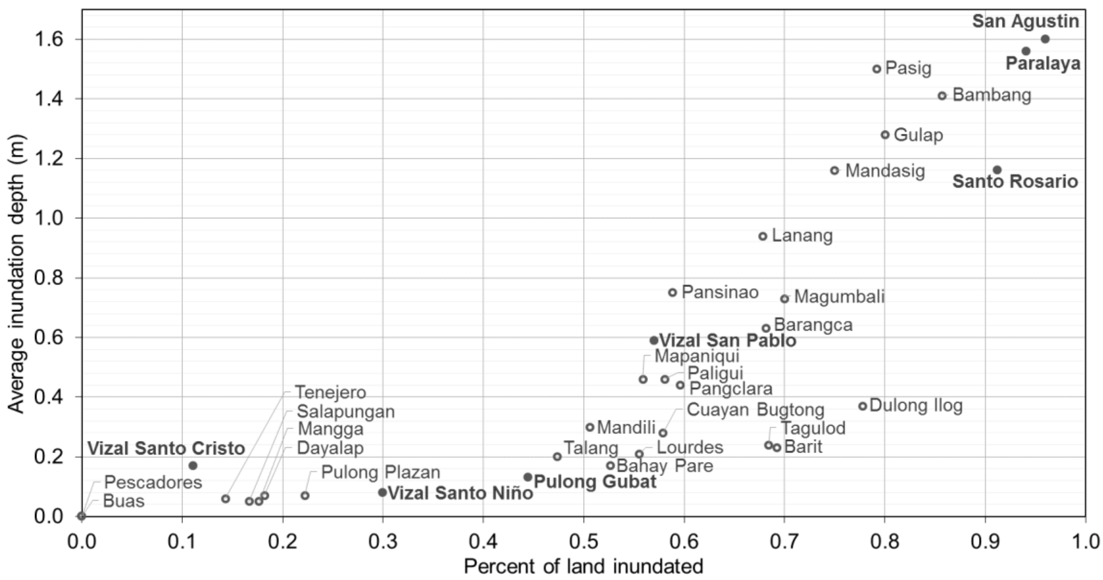


Figure 3.4 Percent of land inundated and mean inundation depth during maximum inundation, 2010. Markers denote each barangay in Candaba; selected barangays are highlighted in bold

Closer examination of the spatio-temporal patterns of inundation in selected flood-prone barangays (Figure 3.5) indicates two periods of inundation. The first, extending from July to September, is typical of monsoonal precipitation, while the second, which corresponds to the maximum inundation associated with typhoons, occurs between October and November. Among selected barangays, San Agustin and Paralaya experience the highest inundation depth and extent in 2010, while inundation conditions in Santo Rosario and Vizal San Pablo are relatively less predominant.

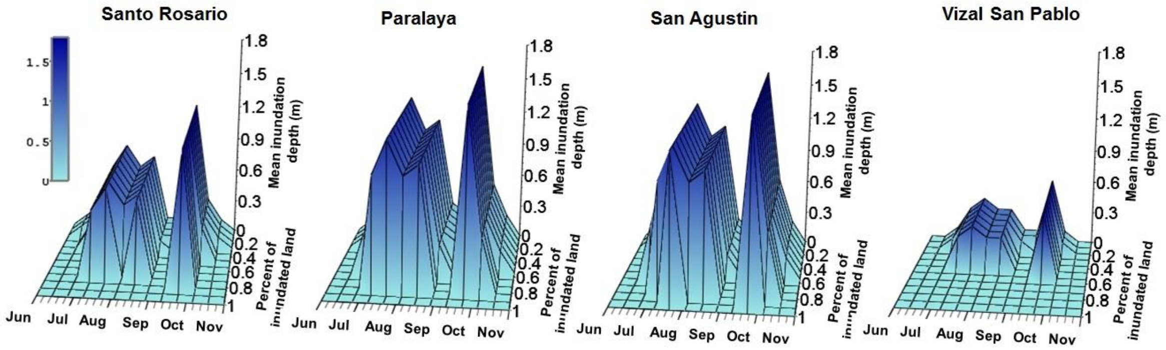
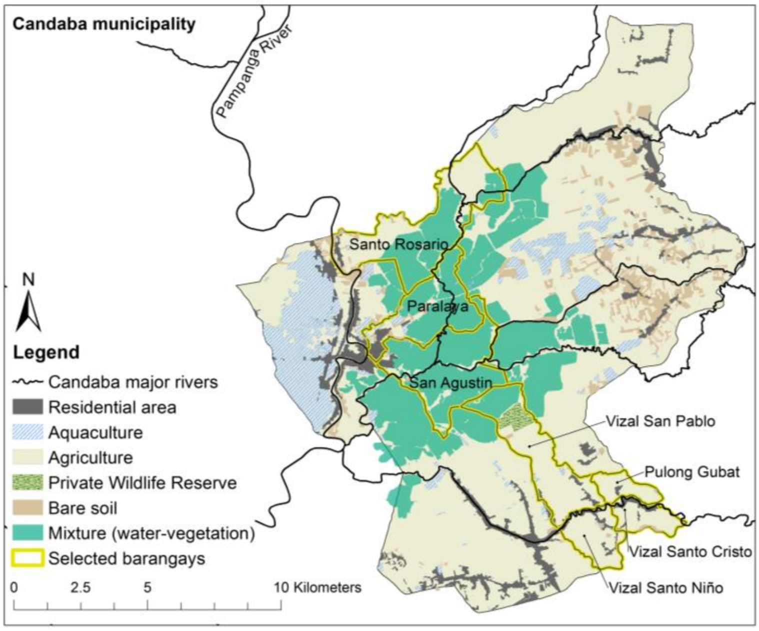


Figure 3.5 Three axis figure of mean depth, and spatially-variable inundation extent in flood-prone selected barangays, 2010.

In the case of San Agustin and Paralaya, simulated flood extent during maximum inundation covers approximately 95% of the area in each barangay and mean inundation depth is more than 1.50 meters (Figures 3.4 and 3.5). During the same period, 91% of barangay Santo Rosario is inundated with a mean depth of 1.16 m. In Vizal San Pablo, 57% of the land is inundated with a mean depth of 0.59 m, however, according to the model in some areas, inundation reaches up to 1.55 m in depth. Prior, in the modelling stage, maximum simulated inundation depth, extent, and flood durations related to various flood magnitudes were confirmed by local managers providing additional validation of the modeled simulation.

Processed land cover from satellite imaginary (2010-2011) indicates that agriculture is the main dry season land use in all selected barangays (Figure 3.6(a)-(b)). In non-flooded barangays, there is no significant land use change between the dry and wet seasons. However, agricultural land in San Agustin and Paralaya is replaced by mixed water-vegetation during the wet season, and agricultural land decreases in Santo Rosario and Vizal San Pablo by 43% and 18%, respectively.

(a)



(b)

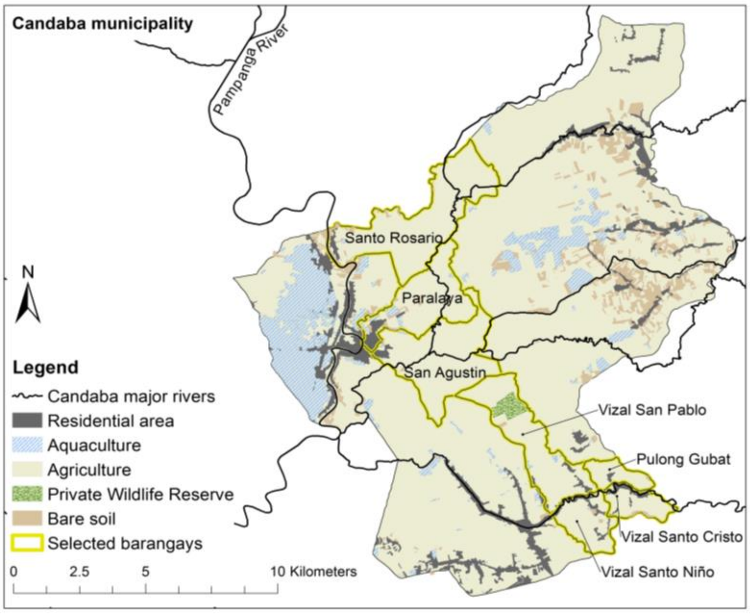


Figure 3.6 (a) Land cover map during wet season, 2010; (b) Land cover map during dry season, 2011.

3.3.2 Livelihoods in selected villages

Livelihoods of local people in Candaba municipality are mainly accrued from agriculture and fisheries. In 2010, agricultural land in Candaba was allocated to rice (14,279 ha), corn (188 ha), and watermelon (214 ha). On a much smaller scale, some farmers benefit from mango plantations or produce vegetables. Permanent aquaculture ponds occupy 556 ha of the land, however, during flood season around 837 ha of seasonal open waters are utilized as open grounds for fishing. Within the seven barangays selected for analysis, main livelihoods are rice cultivation and, in flood-prone barangays, wild capture fishing.

Agricultural records from 2010-2011 indicate that all farmers in selected barangays cultivated a dry-season rice crop (Table 3.2, Figure 3.7). Differences between barangays that sustain high levels of inundation (flood-prone barangays) and those that do not (non-flooded barangays) are evident. For instance, farmers in flood-prone barangays tended to plant dry season rice earlier, in November, while farmers in drier barangays tend to plant later, in December. Additionally, during the wet season, we observe different cultivation behaviors in dry and flood-prone barangays. While 100% of farmers in drier barangays cultivated rice from July to October, most farmers in wetter barangays either shifted their planting period to earlier in the season, or did not plant a second crop. Many dry-season farmers in flood-prone barangays choose not to farm during the wet season (Table 3.2).

Table 3.2. Land use and livelihoods in selected barangays.

Barangay	Area (ha)	Total households[a]	Land use[b] (ha) Aquaculture ponds	Agriculture	Inundated land[c]	Number of farmers[d] and Fishermen[e]
1. Santo Rosario (flood-prone)	1,237	214	3	*Dry season:* 1,168 *Wet season:* 635	1,064	*Dry season:* 230 farmers *Wet season:* 83 farmers
2. Paralaya (flood-prone)	746	1,164	41	*Dry season:* 622 *Wet season:* 0	679	*Dry season:* 288 farmers *Wet season:* 0 farmers 582 fishermen
3. San Agustin (flood-prone)	1,041	794	9	*Dry season:* 985 *Wet season:* 0	958	*Dry season:* 447 farmers *Wet season:* 0 farmers 715 fishermen
4. Vizal San Pablo (moderately flood-prone)	834	505	10	*Dry season:* 708 *Wet season:* 557	400	*Dry season:* 301 farmers *Wet season:* 277 farmers
5. Pulong Gubat (dry)	188	424	0.3	*Dry season:* 176 *Wet season:* 176	0	*Dry season:* 134 farmers *Wet season:* 134 farmers
6. Vizal Santo Cristo (dry)	251	420	0	*Dry season:* 194 *Wet season:* 194	0	*Dry season:* 98 farmers *Wet season:* 98 farmers
7. Vizal Santo Niño (dry)	373	564	1	*Dry season:* 321 *Wet season:* 321	0	*Dry season:* 223 farmers *Wet season:* 223 farmers

[a] 2012 Household census, Municipality of Candaba
[b] Land use is based on the analysis of Landsat-TM images of 2010-2011 described in Section 2.4
[c] Maximum inundated land is based on rainfall-runoff simulation for 2010
[d] 2010-2011 Agriculture and Fisheries Benchmark Data, Pampanga Provincial Agriculturalist Office
[e] Collected information from field surveys

For instance, in Santo Rosario and Vizal San Pablo, 36% and 92% of the total farmers in each village cultivated rice during the wet season, respectively. In Santo Rosario, where 91% of land was inundated to over 1.16 m depth during the maximum seasonal flood, all farmers who do plant a wet-season rice crop planted rice in April or May, 2-3 months earlier than farmers in drier barangays. In San Agustin and Paralaya, barangays where 96 and 94% of land was inundated, no farmers planted a wet-season rice crop.

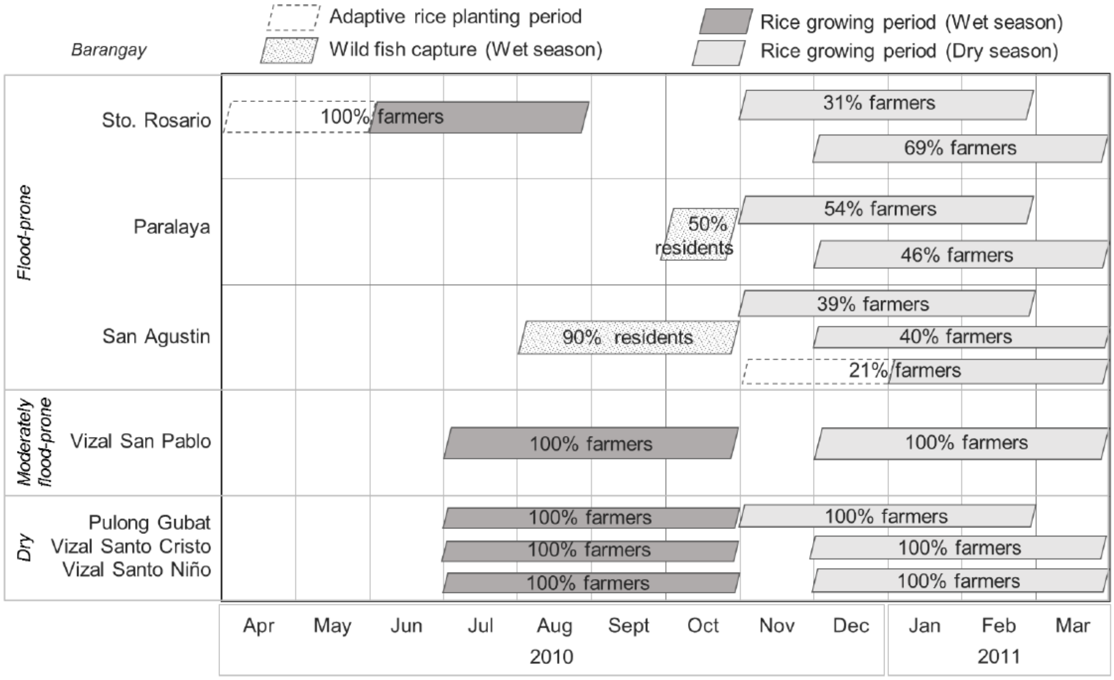


Figure 3.7 Main livelihood activities in selected barangays, 2010-2011.

Responses to household surveys indicate that 90% of the population in San Agustin and 50% of people in Paralaya practice wild fish capture during the wet season. Wild fish capture in Paralaya is usually conducted during the onset of the typhoon season (October), while in San Agustin local people capture fish from August through October. Fishing occurs in open-inundated areas, which are often agricultural lands converted into grasslands or fodder after harvesting in the dry season. Fishermen in Paralaya capture fish utilizing non-motorized water crafts, whereas many fishermen in San Agustin utilize motorized crafts. Given similar equipment and catch effort, we find that mean yields from wild fish capture at 1-2 m inundation depth (Table 3.3) are comparable in Paralaya (38 kg per fisherman month) and in San Agustin (40 kg per fisherman month). In San Agustin, however, reported yields from the use of better equipment (mean 84 kg per fisherman month), combined with a prolonged catch effort (three months versus the one month reported in Paralaya) indicate potential for higher benefit capture from fishing in open inundated lands.

Table 3.3. Wild capture fish yields from field interviews.

Barangay	Per fisherman yield from wild fish capture (1-2 m water level)			Total fishermen
	Equipment	Mean (kg/month)	Range (kg/month)	
San Agustin	Motorized craft	84	67 - 100	500
	Non-motorized craft	40	35 - 45	215
Paralaya	Non-motorized craft	38	23 - 53	582

3.3.3 Benefits from direct use of flood-prone land

During the 2010-2011 dry and wet seasons (Figure 3.8), accumulated mean benefits from farming and fishing in flood-prone barangays is approximately US $ 2,266/ha (±16%). This is lower than the livelihood benefits accrued in non-flooded barangays (US $ 2,746/ha ±18%). In the dry season, mean livelihood benefits do not differ among flood-prone (US $ 1,571/ha ±11%) and non-flooded barangays (US $ 1,531/ha ±13%). However, mean benefit capture during the wet season is considerably greater in drier barangays (US $ 1,215/ha ±26%) than in flood-prone villages (US $ 695/ha ±27%).

In non-flooded barangays, farmers cultivate two crops of rice annually. While there is little variation in rice cultivation benefits among non-flooded barangays (Figure 3.8) during the wet season (US $ 1,215/ha ±26%), we find that farmers in Pulong Gubat accrue greater benefits in the dry season (US $ 1,711/ha ±13%) as compared to farmers in Vizal Santo Cristo and Vizal Santo Niño (US $ 1,440/ha ±13%). As result, livelihood benefits during the 2010-2011 dry and wet seasons are slightly larger in Pulong Gubat (US $ 2,926/ha ±18%) than in other selected non-flooded villages (US $ 2,656/ha ±18%).

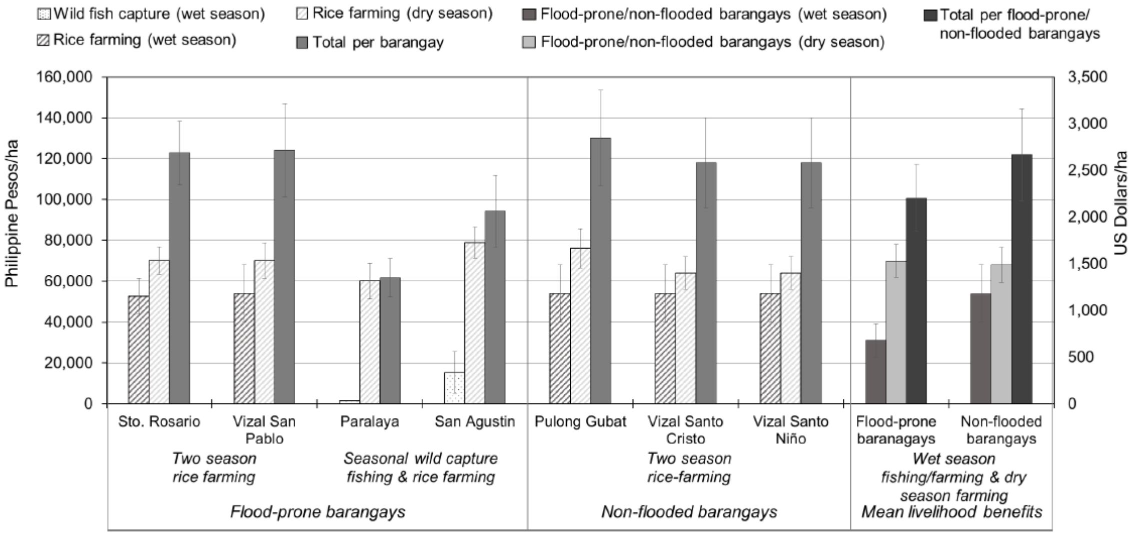


Figure 3.8 Livelihood benefits from farming and fishing in selected barangays, 2010-2011. Error bars indicate the range of rice-crop benefits according to price variability and range of fisheries benefit from differences in equipment (motorized versus non-motorized watercrafts)

In flood-prone barangays, we find much greater variability in benefits of farming among selected barangays. For instance, farmers in San Agustin accrue the greatest dry-season agricultural benefits (US $ 1,776/ha ±10%), outpacing all other barangays, wet or dry. By contrast, farmers in Paralaya, a barangay with an inundation signature very similar to San Agustin, derive the lowest benefits from dry season farming (US $ 1,352/ha ±15%) as compared to all other barangays. In the wet season, the farmers that do cultivate rice in the more moderately inundated barangays of Vizal San Pablo and Santo Rosario accrue US $ 1,215/ha ±26% and US $ 1,186/ha ±17%, respectively, which is similar to agricultural incomes earned per hectare in dry barangays during the wet season. Through wet season fish capture, fishermen in San Agustin and Paralaya derive total US $ 345/ha ±66% and US $ 36/ha in benefits, respectively. Total livelihood benefits in barangays that cultivate two rice crops per year are greater than in barangays that cultivate one dry season rice crop. For instance, annual benefits in Vizal San Pablo (US $ 2,793/ha ±18%) and Santo Rosario (US $ 2,763/ha ±13%) are comparable to annual benefits in dry barangays. By comparison, annual benefits in San Agustin (US $ 2,120/ha ±19%) and Paralaya (US $ 1,388/ha ±15%) from combined farming and fishing are lower.

3.4 Discussion

Much of Candaba municipality is prone to inundation during the wet season, even during relatively dry years. Although simulations indicate that more than 90% of Candaba municipality was flooded at the time of maximum inundation in 2010, the magnitude of the peak flood event of 2010 was moderate relative to other years (Figure 3.2). Thus, our analysis of land inundated in 2010 should reflect an extent that is equaled or exceeded most water years. We are confident in model efficiency at representing peak inundation extent in 2010 despite differences between modeled and observed volumetric discharge at the Arayat gauging station. Such discrepancies are perhaps due to alterations of natural flows by upstream dam operations and water withdrawals. Records from NIA indicate sizable water releases in 2010 from Pantabangan Dam (1,919 million m^3) compared to mean annual outflows from 2005-2009 (1,776 million m^3). Total irrigated area reported for the Upper Pampanga River Integrated Irrigation Systems was also larger in 2010 (182,973 ha) than mean serviced area from 2005-2009 (164,045 ha). Although the model accounts for regulation at Pantabangan Dam, it is unable to capture all human dynamics influencing distribution of water in the basin, for instance at other dams or locations of water withdrawal. Despite some discrepancy in simulated and observed discharges, particularly during the dry season, magnitude and timing of the simulated peak discharge agree with observation from Arayat station. Furthermore, and perhaps more significantly, we observe that simulated flood extent is consistent with remotely-sensed inundation, particularly where inundation is moderate to severe. Discrepancies in extent of shallow inundation are likely the result of error in the digital elevation model and sensitivity of the spectral index to soil and vegetation water content in mixed land cover conditions. However, consultations with local managers and answers of surveys support and validate the peak inundation extent and range of depths simulated. Though we apply a 500 m DEM, improvements to this model through stream burning and manual corrections using high resolution river networks allowed for improved accuracy in spatial representation of simulated floods. Furthermore, responses to interviews on expected levels of inundation are consistent with respect to magnitudes from modelled floods.

In 2010, the barangays of San Agustin and Paralaya experienced greater depth, extent, and duration of inundation as compared to other areas in Candaba. Responses to interviews indicate that both villages are accustomed to experience inundation every year. Pronounced inundation in both villages is mainly driven by the combined effect of geomorphic depressions and convergence of tributary rivers. In these flood-prone areas, land ownership is fixed according to tenure agreements that apply during the dry season. During the wet season, however, inundation extends as an open inland water system, often with no visible individual land holdings. Inundation waters are common property and thus all members have open-access, for instance, to fish resources in all areas of the communities. In non-flooded barangays we observe that most of the land remained dry during the wet season of 2010, with simulations indicating minimum inundation depths (<0.2 m) in limited areas at the time of peak inundation. According to the Municipal

Disaster Plan, this area of Candaba would experience low to moderate inundation following even extreme events. In these drier areas, land tenure is fixed during the wet and dry seasons.

We find that residents living in parts of Candaba subject to different flood hazards implement different livelihood strategies. For instance, although farmers in every barangay cultivate rice, the number and timing of cultivations varies between flood-prone and dry barangays. In flood-prone barangays, we find that some farmers shift their planting schedule, sowing their dry-season rice as early as November. Accordingly, these farmers report bringing in their dry season harvest up to one month earlier. This shifted cultivation period could reflect that some farmers in flood-prone areas wish to take advantage of soil moisture from inundation, lessening their dependence on irrigation. The staggered planting schedule reported, with some portion of farmers planting early and some planting later, likely reflects the spatio-temporal patterns of flood recession in each barangay.

We find that residents of flood-prone barangays employ varied strategies to secure livelihoods. For instance, wet season farmers in Santa Rosario cultivate much earlier than wet season farmers in non-flood-prone barangays, some bringing in their harvest as early as April (as opposed to July in non-flood-prone barangays). Early planting may offer farmers the chance to bring in their harvest before peak seasonal flooding. However, wet season farmers in Vizal San Pablo, a barangay that is only partially flooded each year, take a different strategy. Instead of shifting the timing of cultivation, only a portion of the farmers in Vizal San Pablo cultivate a wet season rice crop. Likely these farmers cultivate land that is less prone to inundation. In the same barangay, owners of regularly-flooded land have established a private wildlife reserve. Direct use of flood-prone lands supports livelihood opportunities related to tourism and nature-oriented recreational activities. Other community members that become actively involved, for instance, as tourist guides, also benefit. Farmers in the highly flood-prone villages of San Agustin and Paralaya do not plant a second rice crop during the wet season, because they expect seasonal inundation of high depth and long duration. Dry-season farmers and many other people from the communities of San Agustin and Paralaya become fishermen during the wet season. Responses to interviews indicate that community members not involved in wild fish capture or any other direct use of flood-prone lands depend on income from household members working in Manila or other barangays as a main source of income during the wet season. Local people in Candaba also indicate that normal flood pulses in low-laying areas are expected to occur at least twice a year. Duration of expected inundation may extend up to four consecutive weeks with minimum and maximum flood depths of 0.5 to 3 meters, respectively. Beyond such levels of inundation, people in the area may sustain damages to agriculture and residential housing (Shrestha et al. 2015), flood conditions are reported dangerous for capturing wild fish by local fishermen, and residents may evacuate to municipal shelters, such as during the 2009, 2011 and 2015 floods. Though information collected on normal flood conditions in Candaba is mainly qualitative and relative to tolerance levels indicated by interviewed residents, we find that perceptions may vary significantly between activities and households even within a single village. For example in San Agustin, while some residents built or have remodeled their houses to reduce damages from flood exposure, not every household is able to afford such options. In this case, people living in two-story residences or elevated houses with stilts indicate potential damages to household assets and buildings at flood depths above 2.8

meters. However, floods exceeding 0.5 meters depth are considered risky, for instance, to owners of one-store wooded residences (Shrestha et al. 2015).

As opposed to the varied livelihood and cultivation strategies documented in the wet barangays, we note that livelihoods in dry barangays tend to be more homogenous. Every farmer cultivates two crops of rice per year and timing of sowing and harvest are uniform as compared to flood-prone barangays. In these drier areas, livelihoods of local people are not shaped by regular inundation, as we observe in the flood-prone barangays. Although we hypothesize that inundation is a key factor influencing land uses and livelihood practices, other factors may also condition the behavior of local people. For instance, planting may be determined by the availability and access to irrigation water. In selected non-flooded barangays and in Vizal San Pablo, irrigation water is provided by NIA through irrigation canals during the wet and dry seasons. However, in Santo Rosario, the source of irrigation during both seasons is provided by Communal Irrigation Systems (CIS) (Japan International Cooperation Agency 2011c). Similarly in Paralaya and San Agustin, benchmark data from the Provincial Agriculturalist Office in Pampanga indicate that irrigation water in the dry season is served by CIS and irrigation facilities consist of shallow tube wells and open surface pumps. This suggests that seasonal operation and management of irrigation water in flood-prone villages is different and perhaps more localized, implying different possibilities for irrigation associations to support seasonal demands of beneficiaries. Interviewed community members also indicated that farmers in flood-prone villages utilize receding floods as initial soil moisture supply to establish dry season crops.

Our findings demonstrate that many local livelihoods in Candaba derive from the direct use of flood-prone lands. Annual net benefits accrued from direct use of flood-prone lands likely reflect a significant value to the local people who receive them. We find that in 2010, mean livelihood benefits in flood-prone villages are comparable to mean annual benefits in non-flooded barangays. In the dry season, benefits per hectare from rice cultivation are actually greatest in the severely flood-prone village of San Agustin. During the wet season, livelihoods in flood-prone villages such as wild capture fisheries are supported and maintained by seasonal flooding. Although the material benefits of the capture fishery are marginal to those obtained from rice cultivation, such fisheries ensure a source of both food subsistence and income during the wet season. Especially for the rural poor, wild capture fisheries may represent one of few means of livelihood and a primary source of animal protein (Thompson et al. 2002). Analyses on the consumption of aquatic organisms and nutrition in communities located upstream of Candaba reveal that fresh fish constitute up to 30% of protein intake for rice-fish farmers. The food diet of rice-fish farmers is also found more or less adequate compared to sole rice farmers in terms of recommended dietary allowances. In addition, open-water capture was indicated the most important source of fish for local people, supported by findings suggesting that cultured fish in controlled conditions are not preferred species for household consumption in these areas (Horstkotte-Wesseler 1999). As such, is possible that nutritional benefits from wild fish capture in Candaba area support overall local livelihoods through income generation and potentially saved expenditures on basic protein food supply. The wild floodplain fishery in Candaba may thus hold greater value beyond the direct market value reported in this study.

The reduction or complete elimination of aquatic habitat in flood-prone areas of Candaba may result in a corresponding reduction of fish biomass production. This effect may consequently diminish wild fish capture yields of fisherman and availability of fresh fish in rural areas. With a decline in open-water fishery resources local people may thus experience an important loss of a valuable resource. In this context, the potential implementation of flood risk management practices that, for instance, limit human uses of flood-prone land (e.g. reallocation of people, land use zoning) or eliminate natural hydrologic processes (e.g. levees), can lead to restricted access or lost provision of essential ecosystem services and livelihoods (Mirza and Ericksen 1996, Orr et al. 2012). Flood risk management that acknowledges and accommodates such ecosystem services and livelihood benefits may maximize socio-ecological benefits rather than simply minimize risk (Juarez-Lucas and Kibler 2016). Efforts that increase the capacity of citizens and communities to cope with flood hazards rather than seeking to minimize exposure may be a promising path in this direction.

Data from Candaba suggest the influence of coping capacity in determining benefits of flood-prone lands. The potential benefits to be accrued through use of flood-prone lands may be higher or lower depending on human behavior and decision making. For instance, by adapting crop calendars to plant and harvest earlier in the wet season, farmers in Santa Rosario are able to bring in two harvests per year and derive an annual income similar to drier barangays, despite experiencing severe inundation. The role of coping capacity may be demonstrated in the two most flood-prone barangays of San Agustin and Paralaya. Despite that people in both San Agustin and Paralaya adopt similar livelihood strategies of fishing in the wet season and cultivating rice in the dry season, people in San Agustin accrue greater livelihood benefits in both seasons. Although they face similar flood exposure in terms of timing, duration, and depth, farmers and fishermen in San Agustin are able to harvest more fish and more rice than their peers in Paralaya. We posit that this observed difference may by partially due to a difference in the capacity of people in San Agustin and Paralaya to cope with the regular flood exposure. For instance, farmers in both San Agustin and Paralaya are unable to cultivate rice in the wet season due to severe and prolonged inundation; however, residents of San Agustin are more adept at utilizing the wild capture fishery as supplemental income. More people fish in San Agustin, and they report greater catch effort as compared to fishermen in Paralaya. Additionally, many fishermen in San Agustin have invested in motorized watercraft, which increases yield considerably. The difference in dry-season rice yield between San Agustin and Paralaya is also stark. Paralaya farmers report the lowest dry-season yields of all studied barangays, while San Agustin farmers report the highest yields, bringing in over 30% more than Paralaya. As these two barangays have similar exposure to flooding, the observed differences in agricultural benefits cannot be attributed to hydrology, and are perhaps related to other influencing factors such as socio-economic status and access to human/social capital across households. Such pressures and constraints may be drivers of low coping capacity and correspondingly low incomes in Paralaya. Though we do not examine directly the impact of supplied fertilization from flood pulses in agricultural productivity (Banerjee 2010, Few 2003, Shankar, Halls, and Barr 2004), reported rice yields during 2010-2011 may illustrate some indication of this phenomena. For instance, reported rice yields per hectare are in fact greater in flood-prone areas than in dry lands. Furthermore, farmers in dry villages of Candaba report higher farm gate values likely to compensate for increased expenses from their seasonal rice planting activities. This may suggest that residents from dry villages sustain more investments in operations or inputs such as fertilizers and irrigation water to secure competitive yields and profitable incomes. Therefore, the overall net available income of farmers that sustain agricultural activities only and cultivate areas less exposed to seasonal inundation in Candaba is perhaps effectively less as result of additional expenditures to derive productive harvests and supplement their protein diet.

Finally, our results evidence the importance of probabilistic comparison of both flood damages and benefits. Had we analyzed data from a year marked by catastrophic flooding, annual net benefits may have been lower than what we find during the moderate flood year of 2010, as flood damages may have reduced agricultural yields. This underscores that flood and floodplain management decisions cannot be based upon a single year of catastrophic flooding, nor any other one year. Rather, a probabilistic accounting of combined magnitude and frequency of hydrologic events and relative damages and benefits is the appropriate tool upon which such decisions could be rationally based.

3.5 Conclusion

Flood management strategies which aim to manage risk through reduced exposure to floods often overlook the role of local capacity to cope with and benefit from regular flooding. In this study we evaluate local strategies of living with and benefiting from the use of flood-prone land in Candaba Municipality, Philippines. We find that in the wet and dry seasons of 2010-2011, total livelihood benefits in selected flood-prone villages (US $ 2,266/ha) are comparable to livelihood benefits in villages that sustained limited or no inundation (US $ 2,746/ha). Seasonal variability in benefit capture among non-flooded villages is fairly uniform as compared to flood-prone villages, where differences are more distinctive. We find that residents of flood-prone villages implement variable coping strategies in response to flooding, allowing some to attain incomes similar to drier villages. Some flood-prone villages adjust rice cultivation periods to be more synchronous with seasonal inundation. This allows some farmers in flood-prone barangays to sustain two rice crops per year, providing incomes similar to dry barangays. In the severely flood-prone barangays of San Agustin and Paralaya, residents cultivate rice in the dry season only, and practice wild capture fishing during the wet season. Although they face similar flood exposure in terms of timing, duration, and depth, farmers and fishermen in San Agustin are able to harvest more fish and more rice than fishermen in Paralaya. The lower capacity of Paralaya residents to cope with seasonal inundation may in part explain the observed income differences.

In Candaba floodplains, livelihood benefits are derived from the use of flood-prone land and provisioning services. Neglecting benefits from direct floodplain use that can simultaneously support natural hydrologic processes may thus significantly affect the socio-economic role in this area. Coping capacities and benefits from flood-prone lands must, therefore, figure more prominently in decision-making and implementation of flood risk management practices in order to support and deliver more sustainable and effective measures. Targeting coping capacities may enhance resilience to seasonal flooding and socio-ecological values.

Chapter 4: Seasonal inland fisheries yield on flood-prone lands: the influence of flood characteristics, equipment, and catch effort

4.1 Introduction

Local communities in many developing countries have traditionally utilized river-floodplain systems to sustain primary production activities such as wild capture fisheries (Banerjee 2010, Ringler and Cai 2006). Inland fisheries are strongly related to flood sequence, which constitutes vital aquatic habitat for many species (Welcomme 1979, 1995). For instance, inundated floodplains are nutrient-rich environments and play an important role as nurseries for many fish species, as well as provide food and shelter for adult fish (Bayley 1988, Junk, Bayley, and Sparks 1989, Welcomme 1985). Many riverine fish species have adapted to the river-floodplain connectivity and their life cycles are tuned to natural flow regimes (Finger and Stewart 1987, Poff et al. 1997, Ross and Baker 1983). The seasonal variation of inundation determines the availability and spatio-temporal heterogeneity of aquatic habitat, which greatly influences the productivity of freshwater fisheries (Bayley 1988, Dudley 1972, Halls 1998, Power et al. 1995, Welcomme 1985, Welcomme and Hagborg 1977). The annual cycle of flood and recession -also known as the *flood pulse*- is thus considered a key driving mechanism that regulates the existence, productivity and interaction of biota in river-floodplain systems (Junk, Bayley, and Sparks 1989).

The relation between fish productivity and flood intensity suggests that corresponding variations of fish catch occur in response to annual fluctuations in rainfall and pulsing of river flows (Dudley 1972, Halls 1998, Halls, Hoggarth, and Debnath 1998, Welcomme 1985). Though productivity of river-floodplain fisheries is driven by many geomorphology and eco-hydrologic processes (Junk, Bayley, and Sparks 1989, Vannote et al. 1980), fish capture productivity is also influenced by human behaviors and societal factors such as catch effort and the level of technology use (De Graaf 2003). Fish is an important source of protein and income in Candaba floodplains, Philippines, however, limited studies are available on the ecological dynamics and socio-economic value of this resource (Bernal et al. 2015, Garcia 2010, Melendres 2014). Many residents of Candaba, for instance, procure seasonal livelihoods and food sustenance from wild fish capture as coping strategies to sustain livelihoods in areas severely exposed to regular inundation (see Chapter 3: section 3.3.2). The assessment of wild capture fisheries in Candaba with respect to floodplain inundation is thus essential to support sustainable practices as well as inform decision-making aimed at integrated management of ecosystems and flood risk. The objectives of this study are therefore to (1) characterize wild capture fisheries in open flooded areas during the wet season in Candaba, (2) evaluate the effect of flood pulse, technology use and effort in wild fish capture productivity of two villages and (3) propose models of fish catch productivity as a function of flood intensity, which can be useful to support integrated assessments of potential benefits from the use of flood-prone lands.

4.2 Methods

4.2.1 Study site: wild capture fisheries in Candaba municipality

Candaba municipality located in Pampanga province, Central Luzon, Philippines, is a complex flood-prone area with a multi-functional and seasonally-variable landscape (see Chapter 3: Figure 3.1; Appendix 1). During the dry season (December-May), the area is primarily used for rice and watermelon cultivation and thus land use is largely dominated by agricultural systems (Protected Areas and Wildlife Bureau 2013). In the wet season, however, significant area of the municipality retains seasonal floods from the Pampanga and tributary rivers, which turns the landscape into an open freshwater system. Like many productive floodplains in other regions (Junk and Wantzen 2006), flood-prone lands in Candaba support seasonal fisheries that coincide with the arrival of monsoon floodwaters (Garcia 2010). In the area, seasonal inundation extends as an open inland water system, where inundation waters become fishing grounds and local people have open-access to wild fish resources (see Chapter 3: section 3.4). Wild fish capture activities in this case are supported and maintained by the seasonal migration of fish into flood-prone lands (Garcia 2010).

Productivity of freshwater fish in Candaba area depend on the annual flood cycle. Spawning takes place during early monsoon season and while some fish species nurture in the rivers others rear in the floodplains (Bernal et al. 2015, Delmendo 1977). Lateral migration of fish to the floodplains occurs with the early floods as water level in the rivers rises. Larvae, juveniles and adults can grow rapidly in seasonally inundated areas (Bernal et al. 2015, Delmendo 1977) and when waters recede, fish may migrate back to the rivers or concentrate in channels and floodplain depressions (Delmendo 1977, Melendres 2014). Monitoring efforts in Candaba reveal that fish composition is largely dominated by introduced species such as *Barbonymus gonionotus* (java barb), *Cyprinus carpio* (common carp), *Oreochromis niloticus* (tilapia), and *Pterygloplichthys disjunctivus* (catfish), although examples of important native species are *Leipotherapon plumbeus* (tiger perch), *Anabas testudineus* (climbing perch), and *Arius dispar* (local catfish) (Bernal et al. 2015, Garcia 2010).

Residents of Candaba utilize different types of equipment and techniques to capture wild fish from seasonally inundated land. For instance, local people commonly employ gear such as fishnets and screens, and many utilize boats to store and transport captured fish across inundation waters (Melendres 2014).

4.2.2 Characterization of wild fish capture activities in flood-prone lands of Candaba

We conducted focus groups and semi-structured interviews targeting key informants to collect baseline information on local livelihoods and flood experiences in Candaba municipality (see Chapter 3: Section 3.2.4; Appendix 2). Although residents from different villages in Candaba engage in fishery activities, most community members of Paralaya and San Agustin (Figure 4.1) practice wild capture fishing in seasonally inundated land. Therefore, we conducted interviews in these two villages (n = 70; 90% confidence level; random sampling) to collect information on fishery activities that are supported and maintained by the annual flood pulse.

The survey was designed to query local fishermen on their fishing efforts, use of equipment and gear to capture wild fish, and associated fishing costs. We collected information on the relationship between fish catch and flood intensity, dominant species per catch, fish value (*i.e.* household consumption, intermediary or direct sale), and sales price of the main types of captured fish in the area.

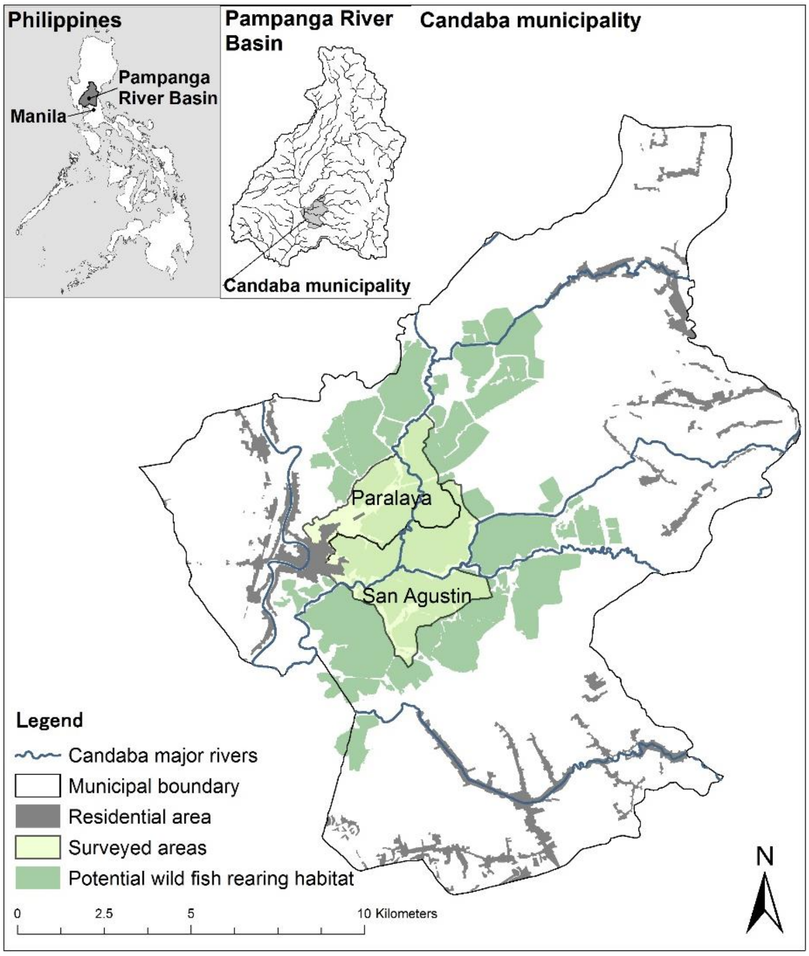


Figure 4.1 Potential wild fish rearing habitat and surveyed villages, Candaba municipality.

4.2.3 Evaluation of wild fish capture effort and flood pulse

We use yields (kg of fish caught per day) reported by local fisherman as an indication of the wild fish catch of individual fishermen [catch per unit effort (CPUE)] from flood-prone areas in Candaba. We analyze mean CPUE associated to different equipment and gear use to identify differences in wild fish catch according to level of technology use. Since we collected fish capture yields at varying inundation depths, we also compare mean CPUE and inundation severity to assess the effect of flood pulse. Evidence from temperate and tropical river-floodplain systems indicate that in most cases, relationships between fish catch and flood intensity follow general linear models:

$$c_x = a + b(Fl_x) \qquad \text{(Eq. 4.1)}$$

where, c_x is fish catch in any year with flood intensity of x, Fl is some index of flood intensity x (Welcomme, 1985 and 1995) and a and b are constant parameters. To develop wild fish catch productivity models for Candaba, we consider the relation between CPUE and inundation depth. We estimate the Total wild fish catch (C) at specific inundation depths using reported information on the number of fisherman and the mean CPUE as follows:

$$C_l = \sum_{i,l=1}^{n} f_{il} \times CPUE_{il} \qquad \text{(Eq. 4.2)}$$

where, C_l is total wild fish catch (kg/day) at inundation depth l, f is the total number of fishermen, $CPUE$ is the mean reported wild capture fish yield (kg/day) per fisherman, and i is an index for type of fishing technology. For this estimation we consider the use of motorized and non-motorized boats as the main types of technology. We thus aggregate mean CPUE from different reported types of gear that are employed in combination with either motorized or non-motorized boats. To derive wild fish capture and flood intensity relations, we plot the estimated C_l against the corresponding inundation depth. From the resultant relationship we estimate potential fish benefits in the area as response to variability of inundation and level of technology use.

4.3 Results

4.3.1 Wild fish capture in surveyed villages of Candaba

Responses to interviews indicate that in Paralaya and San Agustin, 50% and 90% community members, respectively, pursue fishing activities during the wet season (Figure 4.2; Table 4.1). Wild fish capture in Paralaya is usually conducted for two weeks during the onset of the typhoon season (October), although 30% of the fishermen may extend their activities three to four weeks. In San Agustin, some capture wild fish from August through October, however, approximately 48% fishermen may also start fishing as early as May. While the majority of fishermen in this village indicated that they capture wild fish for three to four weeks every month in the wet season, only 38% fishermen indicate to capture wild fish for a period of one to two weeks per month.

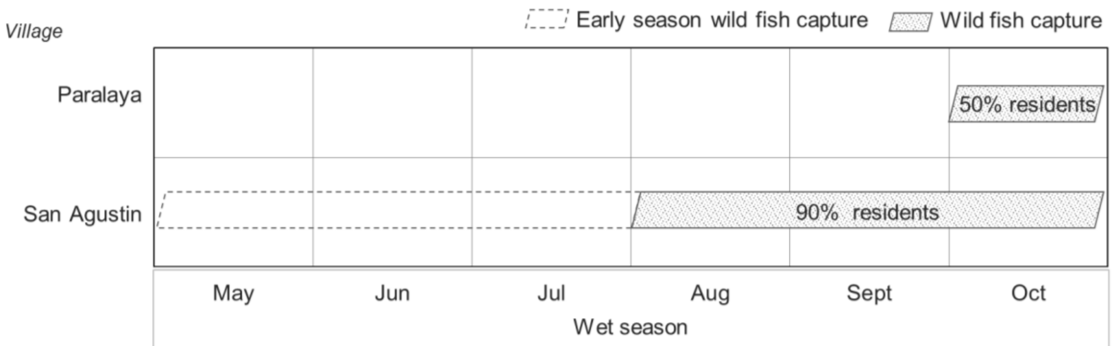


Figure 4.2 Wet season calendar of wild capture activities in surveyed villages of Candaba.

Responses to interviews (Table 4.1) also indicate that more than 70% of the fishermen in Paralaya conduct agricultural activities during the dry season, while 23% engage in other livelihood activities, such as construction work. In San Agustin, 50% fishermen may continue to pursue fishery activities through early in the dry season, 20% establish agricultural crops, and 30% derive an income from selling dry fish.

Table 4.1. Fishermen and seasonal wild fish capture activities in surveyed villages of Candaba.

Village	Number of fishermen	Wet season wild fish capture (number of fishermen)		Dry season wild fish capture (number of fishermen)
		7-14 days/month	14-30 days/month	
Paralaya	582	407	175	*
San Agustin	715	272	443	366

*None reported

4.3.2 Technology use and wild fish capture yields in surveyed villages of Candaba

In the wet season, the majority of fishermen in Paralaya (93%) use non-motorized boats, whereas only 4% utilize motorized boats to conduct wild fish capture activities. The remaining fishermen use no boat. However, in San Agustin 28% of fishermen use non-motorized boats and 63% use motorized boats (Table 4.2). According to the interviews in Paralaya and San Agustin, more than 90% and 35% fishermen, respectively, utilize screens to capture wild fish in open-inundated lands. In San Agustin, however, approximately 65% fishermen use other gear such as fishnets, fish cages, electrified sticks, and hooks attached to lines to capture wild fish.

Table 4.2. Fishing equipment and gear of fishermen in surveyed villages of Candaba.

Fishing technology	Paralaya Percentage of fishermen	San Agustin Percentage of fishermen
Equipment:		
Motorized boat	4	63
Non-motorized boat	93	28
No use of boat	3	9
Gear:		
Screen	94	35
Fishnet “lambat”	3	30
Small fishnet	*	18
Fish cage	*	5
Electrified stick with net	3	5
Line with hook(s)	*	7

*None reported

Reported CPUE at varying inundation depths (Table 4.3; Figures 4.3 (a) and (b)) indicate that mean CPUE at village level in San Agustin ranges from 5.0 to 11.5 kg/day. This is greater than mean CPUE in Paralaya (1.2 - 6.0 kg/day). Results also show that mean fish catch yields from the use of motorized boats in Paralaya (3.0 - 15 kg/day) and in San Agustin (6.5 - 25.3 kg/day) are larger than mean CPUE from non-motorized boats in both villages, 0.8 - 4.0 and 5.1 - 8.8 kg/day, respectively.

Table 4.3. Mean wild fish capture yields per fisherman (CPUE) in surveyed villages of Candaba.

Village	Fishing equipment	Fishing gear	CPUE at varying inundation depths (kg/day)				
			0.5 m	1 m	2 m	3 m	4 m
Paralaya	Non-motorized boat	Screen	0.8	0.9	1.7	3.5	3.6
		Electrified stick with net	1.0	1.7	2.3	5.0	3.3
		Fishnet “lambat”	0.7	1.0	1.0	3.3	5.0
	Motorized boat	Screen	3.0	3.0	7.5	10.0	15.0
	No use of boat	Screen	0.7	0.7	0.7	1.3	3.3
		Mean CPUE	*1.2*	*1.5*	*2.6*	*4.6*	*6.0*
San Agustin	Non-motorized boat	Small fishnet; fishnet “lambat”	7.5	5.0	3.9	1.6	2.5
		Line with hook(s)	5.0	10.0	2.0	0.0	0.0
		Electrified stick with net	2.8	4.4	7.5	20.0	0.0
		Screen	5.0	2.5	2.5	15.0	15.0
	Motorized boat	Small fishnet; fishnet “lambat”	9.6	7.0	6.3	15.9	20.0
		Screen	7.6	6.5	9.0	34.5	49.4
		Fish cage	2.3	3.8	7.5	5.0	6.5
	No use of boat	Small fishnet; fishnet “lambat”	4.3	4.0	4.4	3.0	6.3
		Line with hook(s)	4.0	6.0	0.0	3.0	0.0
		Mean CPUE	*5.0*	*5.9*	*5.8*	*12.1*	*11.5*

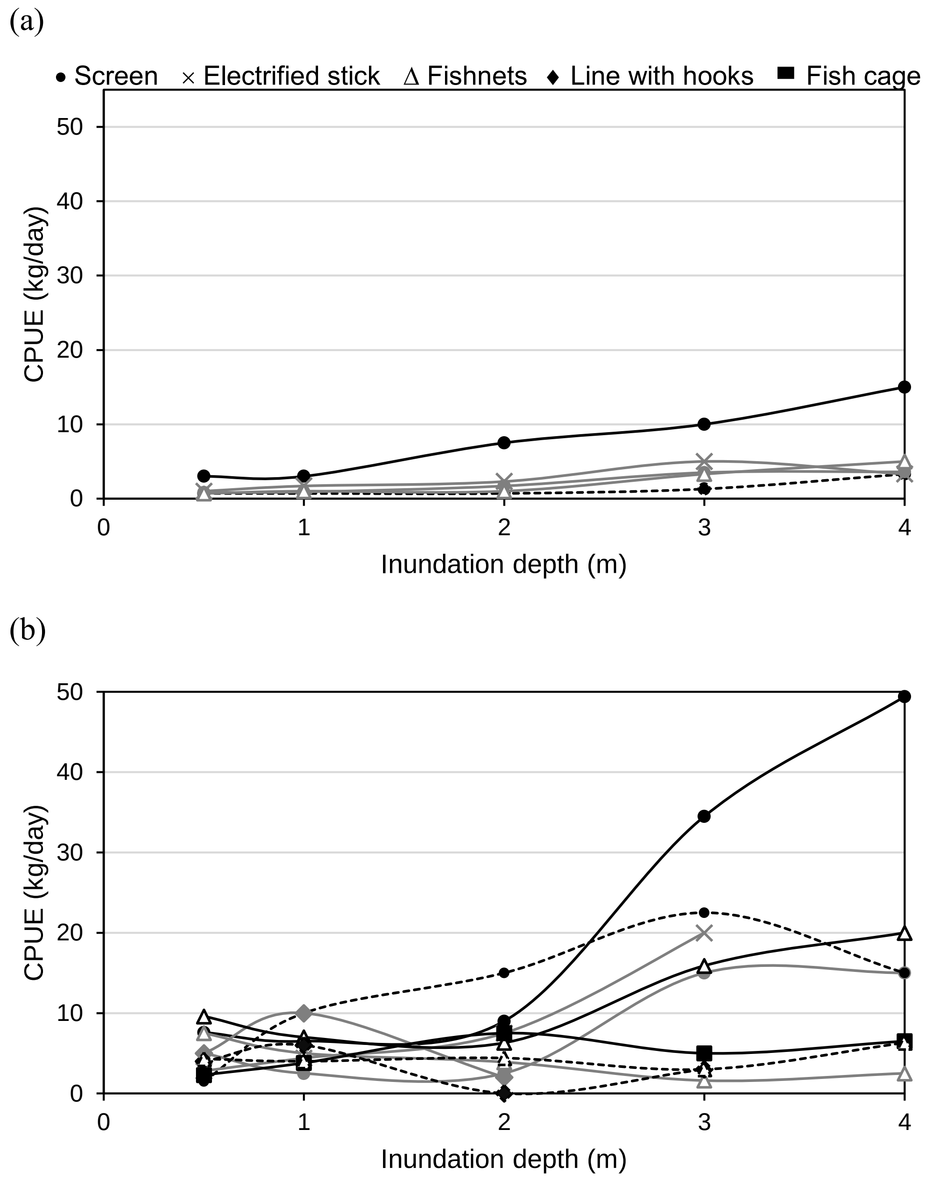


Figure 4.3 Mean wild fish capture yields per fisherman (CPUE) at varying inundation depths in surveyed villages of Candaba: (a) Paralaya and (b) San Agustin. Black lines denote use of motorized boats, gray lines indicate non-motorized boats, and dashed lines indicate no use of boat

In Paralaya, the majority of fishermen use non-motorized boats with electrified sticks, screens, or fishnets to capture wild fish. Mean CPUE of non-motorized boats and electrified sticks is largest (1.0 - 5.0 kg/day) at 0.5-3 m inundation depth. However, the combined use of non-motorized boats and fishnets indicates greatest mean CPUE (5.0 kg/day) at 4 m inundation depth. In this village, the single use of screens to capture wild fish or the use of screens with motorized boats is less representative. However, results show that mean CPUE from all reported equipment and gear types increases with inundation severity. Except for the use of electrified stick and non-motorized boats in which fish catch yields decrease at 4 meters inundation depth.

Fishermen in San Agustin employ a wider variety of gear combined with non-motorized and motorized boats, or just utilize fishing gear without boats to capture wild fish. For instance, residents indicated that they use non-motorized boats with fishnets, lines with hooks, electrified sticks, and screens. In this case, results show that mean CPUE from the use of fishnets decrease with inundation. However, at 0.5 m inundation depth, mean fish yields (7.5 kg/day) from fishnets are larger than mean yields from other gear (4.3 kg/day). In contrast, mean CPUE from the use of lines with hooks (5.0 – 10.0 kg/day) and electrified sticks (2.8 – 20.0 kg/day) increase with inundation depths up to 1 and 3 m, respectively. Mean fish yields from the use of line with hooks and electrified sticks at such inundation levels are grater (10.0 and 20.0 kg/day, respectively) than mean yields from other types of gears (4.0 and 8.3 kg/day, respectively). Mean CPUE from the use of screens with non-motorized boats also increases with inundation depth (5.0 - 15.0 kg/day). Such equipment and gear type show highest fish capture yields at 4 m inundation depth.

In San Agustin, most fishermen utilize motorized boats combined with fishnets, screens or fish cages. We find that mean CPUE from the use of motorized boats with any gear type generally increase with inundation depth. Mean CPUE from fish cages is lower across varying inundation depths (0.5 – 4 m), except at 2 m, which mean capture yields are greater (7.5 kg/day) than mean yields from fishnets (6.3 kg/day). In this case, mean CPUE from the use of fishnets are greatest (9.6 -7.0 kg/day) at 0.5 – 1 m inundation depth, however, mean fish catch yields from screens are largest (7.0 – 49.4 kg/day) at 2 – 4 m of inundation. Reported fish catch yields of fishermen who employ a single type of gear to capture fish in San Agustin show that mean CPUE from the use of screens are greatest (1.5 – 15.0 kg/day) at 1 - 4 m inundation depth, while mean fish yields from the use of fishnets (4.3 kg/day) are largest at 0.5 m of inundation.

In addition, although the use of non-motorized boats and fishnets shows that mean CPUE at 0.5-2 m inundation depth is higher in San Agustin (7.5 – 3.9 kg/day), mean fish catch at 3-4 m depth in this village is lower (1.6 -2.5 kg/day) than reported yields at the same inundation depths in Paralaya (0.7 - 1.0 and 3.3 - 5.0 kg/day).

4.3.3 Total wild capture and flood intensity

Results indicate that total wild fish capture yields from the use of motorized and non-motorized boats vary with flood intensity (Figure 4.4). Total fish productivity from the use of both motorized and non-motorized boats increases with inundation depth. We also find a significant correlation between total fish yields and severity of inundation from use of motorized and non-motorized boats, $R^2 = 0.87$ and 0.90, respectively.

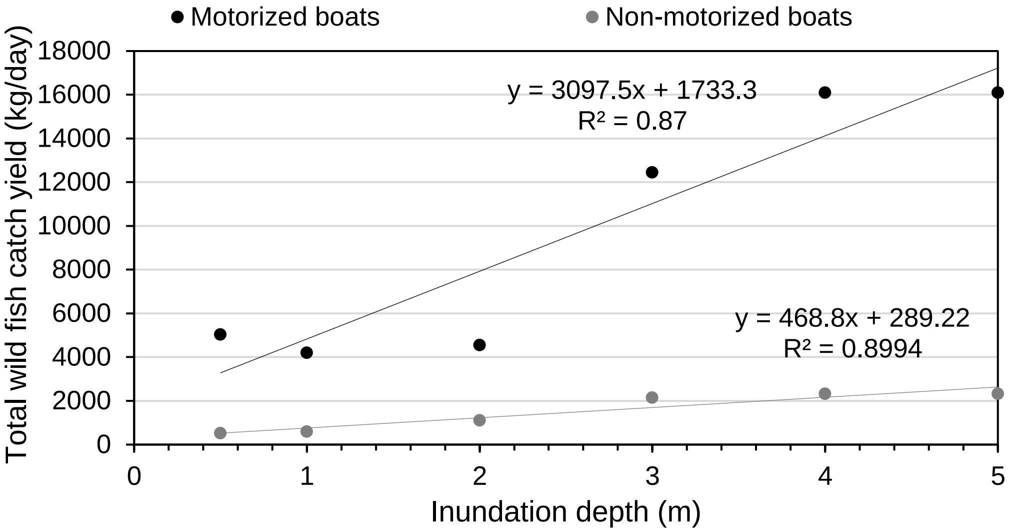


Figure 4.4 Total wild fish catch related to varying inundation depth, Candaba area.

4.3.4 Costs, main types of fish and value of wild fish capture activities

Responses to interviews by local fishermen indicate that mean costs (Table 4.4) of fishing gear combined with use of motorized boats (US $ 129.19) are higher than with non-motorized boats (US $ 31.90). In Paralaya and San Agustin the main types of fish captured from open-inundated areas are tilapia, catfish, and mudfish (Table 4.5). In addition, local residents indicated that wild fish resources are mostly sold to local markets or intermediaries (70-83%) while the rest is used for household consumption (Table 4.6.).

Table 4.4. Fishing gear and equipment costs associated to wild fish capture activities in surveyed villages of Candaba.

Village	Costs from motorized boats (US $/fisherman)	Costs from non-motorized boats (US $/fisherman)
Paralaya	135.04	34.54
San Agustin	123.34	29.26

Table 4.5. Main types of captured fish from flood-prone areas in surveyed villages of Candaba.

Village	Main types of fish (Percentage per day)
Paralaya	61 % tilapia
	17 % catfish
	15 % mudfish
	8 % other (gourami)
San Agustin	57 % tilapia
	22 % catfish
	11 % mudfish
	11 % other (common carp, gourami)

Table 4.6. Main types of sales/consumption of wild fish resources in surveyed villages of Candaba.

Village	Main types of fish (Percentage per day)
Paralaya	10 % household consumption
	70 % sale to intermediary
	20 % direct market sale
San Agustin	12 % household consumption
	5 % sale to intermediary
	83 % direct market sale

4.4 Discussion

We find that most residents of Candaba who practice wild fish capture do so at the end of the wet season, when flood-adapted fish stocks are expected to have accumulated biomass and reached state of maturity. Local people in Paralaya and San Agustin are exposed to high depths and long duration of seasonal inundation, making wild fish capture a feasible activity to ensure livelihoods and subsistence resources in the wet season. During the dry season, however, most residents in both villages switch to agricultural practices and benefit from the use of fertile soils and receding flood waters as initial input of soil moisture (see Chapter 3: section 3.4). Responses to interviews indicate that many fishermen in San Agustin (50%) may conduct wild fish capture activities throughout the wet and beginning of the dry season. When inundation subsides early in the dry season, land owners have exclusive rights to harvest wild fish within the confines of levees constructed around their land holdings. This fishing technique is locally known as *salandra* and is operated by fitting screens or nets across water gates to catch wild fish carried by draining waters (Delmendo, 1977; Garcia, 2010; Melendres, 2014). Screens are usually made of bamboo sticks or nets fixed with poles, which are placed at suitable points along the waterways. In Candaba area, a similar technique known as *bokatot* is also employed during the dry season and consists of fixing fyke nets in the middle of flowing tributaries to capture wild fish (Garcia, 2010). Responses to interviews indicate that in addition, fisheries activities during drier months are conducted using fishnets and electrified sticks with nets to capture cultured fish from aquaculture ponds and/or wild fish directly from tributary rivers.

During the onset of the dry season when flood waters recede, fish usually migrate back to the rivers or concentrate in channels and depressions to find cover from predators, which makes fish easier to catch. More than 90% of fishermen in Paralaya indicate that they fit screens across waterways to capture wild fish during receding floods. In addition, fishermen in Paralaya report conducting wild fish capture activities during October for a period of one to two weeks, which often coincides with the timing of flood recession. In contrast, fishermen in San Agustin employ varied gear and fishing techniques to capture wild fish during the wet season. Fishermen in this village reported capturing wild fish for a longer period (August-October) and during three to four weeks per month.

In San Agustin, while only 35% fishermen utilize screens to capture wild fish, 65% employ other gear such as fishnets, fish cages, electrified sticks with fishnets, and lines attached to hooks to capture wild fish directly from open-inundated lands. In the wet season, the majority of fishermen in Paralaya (93%) use non-motorized boats to pursue fisheries activities. In San Agustin, however, 28% of the fishermen use non-motorized boats and 63% use motorized boats. In this area, boats locally known as *bancas* are also used to move across inundated areas while operating fishing gear and transporting captured fish. We find that mean wild fish capture yields associated to the use of motorized boats are greater than those of non-motorized boats in both villages. Responses to interviews indicate that motorized boats allow fishermen to navigate longer distances, withstand stronger currents, and fish for longer periods in a day. Therefore, fishermen have better possibilities to access remote sites or search for hot spots and highly productive fishing grounds in the area. In addition, the use of motorized boats in combination with certain types of gears, such as fishnets, may also influence the efficiency by which wild fish is captured. For instance, residents of Candaba reported that they operate motorized boats to create slight disturbances in flood waters while dragging fishnets, which often drives fish more effectively into the nets.

As the majority of fishermen in Paralaya utilize non-motorized boats, we find that community members in this village have less potential to capture wild fish than fishermen in San Agustin. Furthermore, we find that most residents in Paralaya employ opportunistic and low-investment approaches to capture wild fish, such as placing screens across waterways. Only a few fishermen in this village reported the use of non-motorized boats with electrified sticks or fishnets to capture wild fish directly from fish rearing pools throughout the floodplains. In this village, differences in wild fish catch yields between types of gear are probably driven by the potential access to fish according to the fishing method and the operating mechanism and effectiveness of each type of gear at different levels of inundation. However, we find that in general for all types of gears and equipment, mean wild fish capture yields increase with inundation.

We find that in San Agustin, fishermen who employ non-motorized boats and fishnets capture higher wild fish yields at lower inundation depths. Similarly, the use of non-motorized boats with lines attached to hooks is associated with greater yields at lower inundation levels. In such cases, fishermen are likely capturing wild fish in open-inundated areas during the early stages of inundation. Local residents indicated that during periods of intense flooding the use of non-motorized boats is usually avoided for safety reasons. These findings therefore suggest that fishermen with non-motorized boats in San Agustin probably prefer not to capture wild fish during risky periods of inundation, in contrast to residents of Paralaya.

In San Agustin, we also find that fishermen report the use of motorized boats and fish cages to derive wild fish capture resources. Although fish cages are not commonly employed in Candaba, the method consists of a floating fish enclosure made of synthetic net wire, bamboo screens or other materials, which are tied to poles often anchored in flood-prone areas. These structures are usually used to contain and culture fish in open-inundated lands, taking advantage of seasonal floods and wild fish as main input resources. In this village, differences in mean wild fish capture yields are probably the result of variability in accessed fishing grounds, operation and effectiveness of employed fishing gear, and human behaviors with respect to the perception of risk for conducting fisheries activities during intense periods of inundation. However, we find that wild fish capture yields from the most commonly utilized gears and equipment in this area generally increase with inundation.

We find that total wild fish capture yields from the use of motorized and non-motorized boats vary with flood intensity, indicating a significant correlation with inundation depth (R^2 = 0.87 and 0.90, respectively). These findings may suggest that fish productivity in the area is not only the result of equipment, technology or human preferences but is also related to flood pulse. The existence of flood pulse has been demonstrated and reported for a number of tropical floodplains in many developing countries (Welcomme, 1975; Shepherd, 1976). Previous studies have assessed the complexity embedded in river-floodplain fisheries and indicated the necessity for long-term data to formulate and support management options (de Graff, 2003). Although our assessment of fish catch productivity and flood intensity in floodplains of Candaba is grounded on empirical evidence, our findings suggest a cogent indication of this phenomenon. As such, the relations between wild fish catch yields at varying inundation depths can be used as potential models to evaluate wild fish productivity as a function of inundation severity. These functions can support estimation of potential benefits according to inundation conditions, which can lead to informed decision-making for the integrated management of river-floodplain systems in Candaba area.

4.5 Conclusion

The assessment of benefits derived from river-floodplain systems is essential to support integrated management of freshwater ecosystems and also flood risk. In many developing countries, inland fisheries are important livelihood resources. These systems are supported and maintained by seasonal pulsing of river flows, however, human behaviors and societal conditions also determine their level of productivity. The characterization and understanding of underlying processes of many of these river-floodplain systems is still poorly described. Often efforts require significant resources and extensive monitoring systems, which can be challenging to carry out. In this study, we evaluate the effect of flood pulse, technology use, and effort in wild fish capture productivity of two villages of Candaba floodplains, Philippines. We present an approach to derive models of fish catch productivity as a function of flood intensity using empirical evidence based on the experience of local fishermen. We find that local fishermen in Candaba utilize motor and non-motorized boats in combination with types of gears such as screens, fishnets, electrified sticks, or lines attached to hooks to capture wild fish from seasonally and open-inundated areas. In the village of Paralaya, fishermen pursue wild fish capture activities during the onset of the wet season and the majority (93%) employ non-motorized boats. In contrast, fishermen from the village of San Agustin conduct wild fish capture activities throughout the wet season (August-October) and most residents (63%) employ motorized boats. Mean wild fish catch yields from the use of motorized boats in Paralaya (3.0 - 15 kg/day) and in San Agustin (6.5 - 25.3 kg/day) are larger than mean yields from non-motorized boats in both villages (0.8 - 4.0 and 5.1 - 8.8 kg/day, respectively). Although fishermen in these areas employ different types of gears, more than 90% and 35% fishermen in Paralaya and San Agustin, respectively, utilize screens as fishing methods to capture wild fish in flood-prone lands. Differences in mean wild fish capture yields among types of gears in both villages are probably due to the variability in accessed fishing grounds, operation and effectiveness of employed fishing gear, and human behaviors with respect to the perception of risk for conducting fishery activities during intense periods of inundation. However, we find that wild fish capture yields from most commonly utilized types of gears and equipment generally increase with inundation depth. Our findings suggest that Total fish capture productivity in the area according to the use of motorized and non-motorized boats is significantly related to intensity of inundation (R^2 = 0.87 and 0.90, respectively). Such findings indicate that wild fish capture yields in Candaba area are influenced by varying flood pulses. The relationships between total wild fish catch yields and inundation depths can therefore be used as potential models to evaluate wild fish productivity as a function of inundation severity. These functions may support evaluation of potential fish benefits according to inundation conditions, which can lead to more sustainable and integrated management practices of river-floodplain systems in Candaba area.

Chapter 5: Flood risk and probabilistic benefit assessment to support management of flood-prone lands: evidence from Candaba floodplains, Philippines

5.1 Introduction

Floods and human use of flood-prone lands are often associated with negative economic and societal impacts. Flood management frameworks therefore frequently target the relationship between society and flood risks (Schanze 2006b). For instance, decision-making in flood management is often supported by risk assessments, which in practice are mostly used for identifying thresholds to prevent flooding or quantify potential damages to design according to risk reduction measures (Merz, Kreibich, et al. 2010, Meyer, Haase, and Scheuer 2009). In this context, *risk* is objectively defined as the probability that flood hazard will combine with vulnerability to produce negative consequences. In turn, *vulnerability* is often expressed as a function of exposure and coping capacity (Merz, Kreibich, et al. 2010). In developed countries, many models for managing flood-prone land limit exposure to hazard as a mechanism to reduce flood risk. Implemented practices are often based on the principles of "keeping people away from floods" while simultaneously promoting river-floodplain integrity. Joint flood risk-ecosystem initiatives in such cases favor benefits that are mostly compatible with designated flood storage and conservation uses of flood-prone land (Juarez-Lucas and Kibler 2016). As such, management practices may frequently overlook the potential to minimize flood risk by targeting and enabling capacities to cope with and benefit from direct use of flood-prone land.

In developing countries, many flood-prone systems have seasonally-variable configurations of land use from which local people secure a wide range of socio-ecological benefits (Cuny 1991, Few 2003). For instance, in delta regions such as Vietnam and Bangladesh, local communities have traditionally benefited from sustaining a combination of dry season agriculture and wet season fisheries, thus deriving livelihoods through the direct use of flood-prone ecosystems (Dugan, Dey, and Sugunan 2006, Dugan et al. 2010). Similarly, local people in floodplains of Candaba, Philippines, practice livelihood strategies and land use adaptations in response to flooding in order to accrue benefits and provisioning services from the direct use of flood-prone lands (Juarez-Lucas et al. 2016 *in review*).

Though integrated approaches to flood management recognize the importance of benefits from direct uses of flood-prone lands (Grabs, Tyagi, and Hyodo 2007), techniques in flood risk assessments that explicitly include benefits from the use of flood-prone lands are still limited (Meyer et al. 2013). The coupled assessment of flood risks and probabilistic benefits (potential benefits over varying probabilistic flood hazards) can be an improved information tool to support decision-making and implementation of more sustainable and effective flood management practices. For instance, if benefits and coping capacities are evaluated alongside evaluation of flood risk, decisions to alter the magnitude of design peak flows and/or land use configurations can be rationally based to simultaneously reduce risk and balance livelihoods and ecosystem services (Juarez-Lucas and Kibler 2016). The objectives of this work are therefore to (1) assess flood risk and probabilistic benefits associated with different scenarios of flood-prone land use in the case of Candaba, Philippines, (2) compare flood risk and probabilistic benefits of livelihood practices compatible with direct human use and flood storage/conservation of flood-prone land, and (3) evaluate the role of individual coping capacity in determining potential benefits and damages. Development of the proposed risk-benefit analysis may support practices and floodplain landuses that yield maximum probabilistic benefits for the minimum risk.

5.1 Methods

5.2.1 Characterization of flood hazard at different return intervals

We derive probabilistic floods (events with a given probability to occur in any one year) from the frequency curve of observed rainfall and simulation of rainfall-runoff and inundation processes at the scale of Pampanga River basin. Severe flooding in Pampanga River and Candaba municipality is often associated with typhoons that occur late in the wet season (September-November), and which typically apply precipitation over a 2-day period. The frequency analysis is therefore based on the annual maximum series of 48 hour accumulated rainfall (mean of 12 precipitation gauging stations) from 25 years of record (1980-1982, 1992-1993, 1995-2007, and 2009-2015). We obtain probability curves by fitting the Gumbel and Generalized Extreme Value (GEV) distribution models to the rainfall data. The parameters of each distribution were estimated using the sample L moments approach and the empirical exceedance probability was determined with the Gringorten method for Gumbel distribution and Cunnane's plotting position method for GEV. To evaluate the goodness of fit between probability functions and observed data we employ the Probability Plot Correlation Coefficient test (Filliben 1975, Vogel 1986).

We evaluate floods in the area based on potential conditions of severe inundation. The September 2011 flood associated with Typhoon Pedring is one of the biggest recorded events in Pampanga River basin. For instance, over US $ 30 million worth of total damages and more than 400 thousand affected people were reported in Pampanga Province alone (Office of Civil Defense 2011; Philippine, Atmospheric Geophysical and Astronomical Services Administration 2012). We thus selected the rainfall pattern of the 2011 Typhoon Pedring event (Appendix 3), and apply the Gumbel probability function to develop design hyetographs of 1.33-, 2-, 2.5-, 5-, 10-, 25-, 50-, and 100-year return periods. The rainfall magnitudes corresponding to the 1.33- and 2-year return intervals represent the 25^{th} and 50^{th} percentiles of the 25 years of 48-hour rainfall. We evaluate a wide range of flood events to capture both the normal and extreme flooding conditions according to interview responses by local people in Candaba (see Chapter 3: section 3.4). To obtain design hyetographs we multiplied the selected rainfall pattern by the corresponding rainfall magnitude according to the frequency curve.

We apply the Rainfall-Runoff-Inundation (RRI) model (Sayama et al. 2012) to compute depth, duration, and spatial extent of inundation for each return period of rainfall, using an hourly time step and a simulation period of 30 days. To simulate run-off and inundation, we use the USGS HydroSHEDS Digital Elevation Model (DEM) and the Global Land Cover Characterization (GLCC-V2) data at a 15-arc second grid resolution (see Chapter 3: section 3.2.3 for full details on the simulation conditions). We apply the RRI model, which was previously calibrated and validated for the 2009 and 2010 water years, respectively (Chapter 3; section 3.3.1).

We model inundation typical of typhoons, which often occur at the end of the wet season. We target this period mainly because wild fish capture activities are practiced by the majority of local people in Candaba late in the wet season. Although community members of San Agustin may capture wild fish through the entire season, these activities are mostly conducted during the month of October (see Chapter 3: section 3.3.2). Damages to rice agriculture are also often reported during typhoon months. We thus initialize the model to typical late-wet season conditions, using river and hillslope water depths from the end of the 2010 monsoon. We then calculate the maximum simulated inundation depth and duration from each return period, in addition to the daily maximum inundation depth at each grid. The monsoon season of 2010 was selected for this analysis as we observe that peak discharge during this period is moderate relative to other water years. We thus evaluate different return intervals following a monsoon period that is likely to be equaled or exceeded most water years. Coupled extreme monsoon and typhoon periods may result in more pronounced levels of inundation. As such, probabilistic benefits and flood risk may show different behaviors. In this study, however, we do not expand to include the analysis of benefits and damages with intra-seasonal variability.

5.2.2 Estimating benefit of direct flood-prone land use

We define benefits as the income obtained from the use of flood-prone land for agriculture and/or fishery activities that directly supports local livelihoods in Candaba. To assess potential net benefits, we propose benefit functions given by relationships of wild fish capture or rice-agriculture yields with respect to inundation severity. We develop wild fish benefit functions based on the principles and relations between fish productivity as response to fluctuations in rainfall and flood intensity (Dudley 1972, Halls 1998, Halls, Hoggarth, and Debnath 1998, Welcomme 1985). Wild fish production is dependent upon floodplain availability for habitat and nurseries (Welcomme and Hagborg 1977) among other ecological factors (Welcomme 1985). However, fish catch is the result of combined social and ecological conditions that may influence the level of productivity. In our models, we therefore capture explicitly the relation of inundation depth and technology use on wild fish catch. We do not model, for instance, fish stock dynamics or the extent to which fish growth may affect seasonal production outcomes. Our objective is not to capture the entire complexity of fishery systems and human effects. However, our model is useful for evaluating annual fish catch benefits, which is our primary goal. Taking into account that depth of inundation correlates to total habitat area and habitat complexity, and that we account for different levels of technology use to capture fish, our models therefore provide reasonable approximations for our analysis.

Benefit curves of wild fish capture (Figure 5.1 (a)) are derived from reported yields (kilograms of fish caught per day) by local fishermen at varying inundation depths (meters). We found that fishermen in Candaba use both motorized and non-motorized boats, and that reported yields varied with the type of equipment used. We therefore present two benefit functions relating wild fish capture yields with inundation depth- one from the use of motorized boats and one from non-motorized boats. We thus obtain benefit functions of wild fish capture that are associated to high and low level of technology use (see Chapter 4: section 4.2.3). To derive rice benefit curves of sustained yields at different levels of inundation, we estimate attainable crop production as the complementary percentage of yields lost due to floods as reported by Shrestha et al. (2015). The relation of rice yields at varying depths and durations of inundation (Figure 5.1 (b)) therefore indicates attainable crop production from total potential harvest at the mature growth stage.

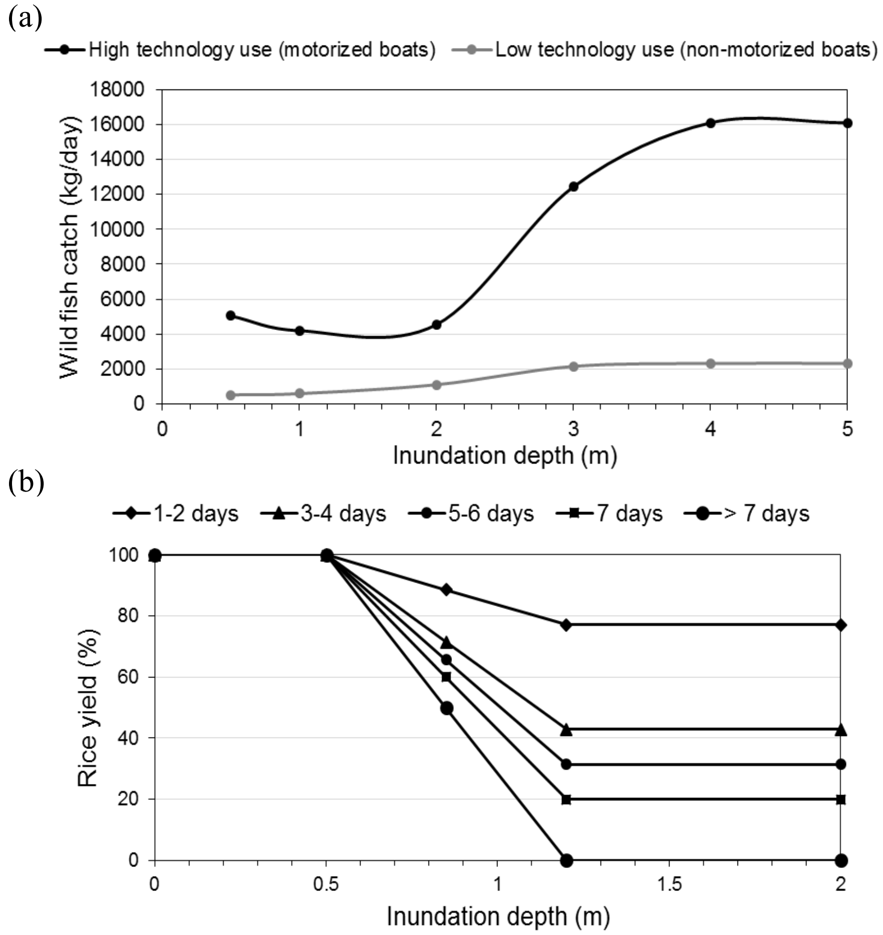


Figure 5.1. (a) Benefit functions to estimate wild fish catch in flood-prone lands; (b) Benefit function to estimate rice-yields from inundated areas. Adapted from Shrestha et al. (2015)

We combine fish benefit functions with model outputs of 24-hour maximum inundation depth to obtain wild fish catch yields at daily time intervals per grid. Potential benefits from wild fish capture activities in each grid are calculated as follows:

$$b_{ftn} = (q_{ftn} \times p_{ftn}) - c_{ftn} \qquad \text{(Eq. 5.1.)}$$

where, b_{ftn} is the net benefit per grid n at daily time step t from wild fish capture f, q is wild fish capture yield (kg/day), p mean fish price (US \$/kg) and c mean costs (US \$/day).

Total benefits from wild fish capture (B_f) activities (Eq. 5.2) are estimated by aggregating the net fish-benefits temporally and spatially according to the simulated time period and scenario of flood-prone land use (see Section 5.2.5).

$$B_f = \sum_{t,n=1}^{T,N} b_{ftn} \qquad \text{(Eq. 5.2)}$$

We apply the high- technology fish benefit function to estimate q_{ftn}. To estimate net benefits from wild fish capture activities, we thus consider mean reported costs associated to the use of motorized (high technology) boats. Fish yields, price of fish, and equipment costs were collected from interviews with local fishermen of Candaba (see Chapter 4: section 4.2.2 for details of field survey activities).

To estimate potential benefits from rice agriculture, we obtain the percentage of attainable yields from the rice benefit curves and the simulated maximum depths and durations of inundation. We obtain rice benefits per grid from the product of percent yields gained, mean rice crop yields, and farm gate prices as follows:

$$b_{rn} = y_{rn} \times g_{rn} \times p_{rn} \qquad \text{(Eq. 5.3)}$$

where, b_{rn} is the benefit per grid n from rice agriculture r, y is the mean rice yield (kg), g the percentage of yield gain, and P the mean farm gate price of rice (US $/kg). We base mean rice yields and farm gate prices on village-level data reported during the 2010 wet season by the Provincial Agriculturalist Office of Pampanga.

Total benefits associated with cultivating rice (B_r) in flood-prone land are determined by spatial aggregation of rice benefits (Eq. 5.4) across areas identified as agricultural land during the wet season (see Section 5.2.5).

$$B_r = \sum_{n=1}^{N} b_{rn} \quad \text{(Eq. 5.4)}$$

It is important to note that our rice benefit curves reflect the ability to accrue crop yields from the total expected harvest. As such, estimates of rice agriculture denote net benefits with respect to the total potential or ideal gains. In addition, the functions we propose do not indicate, for instance, relations of crop yields with respect to supplied moisture and fertilization following flood events (*i.e.* benefits from supporting and regulating services).

5.2.3 Flood damage estimation

We assess flood damages associated with rice losses due to inundation. We estimate rice damage at each return interval by considering yield loss as a function of flood depth, duration, and plant growing stage (Shrestha et al. 2015; Figure 5.2). In Candaba municipality, farmers may plant rice at different times during the wet season. Thus, we use reported crop calendars from the 2010 wet season and rice production period (Bureau of Agricultural Statistics 2013) to determine the growing stage of rice during typhoon season. We apply damage functions to estimate the percentage of rice loss according to the simulated maximum duration and maximum depth of inundation at each grid. We estimate rice damage as follows:

$$d_{rn} = y_{rn} \times l_{rn} \times p_{rn} \quad \text{(Eq. 5.5)}$$

where, d_r is damage per grid n from rice agriculture r, y is the mean rice yield (kg), l the percentage of yield loss, and p the mean farm gate price of rice (US \$/kg).

The aggregated rice damage from areas identified as agricultural land during the wet season (see Section 5.2.5) is used to obtain total rice-production damage (D_r) as follows:

$$D_r = \sum_{n=1}^{N} d_{rn} \qquad \text{(Eq. 5.6)}$$

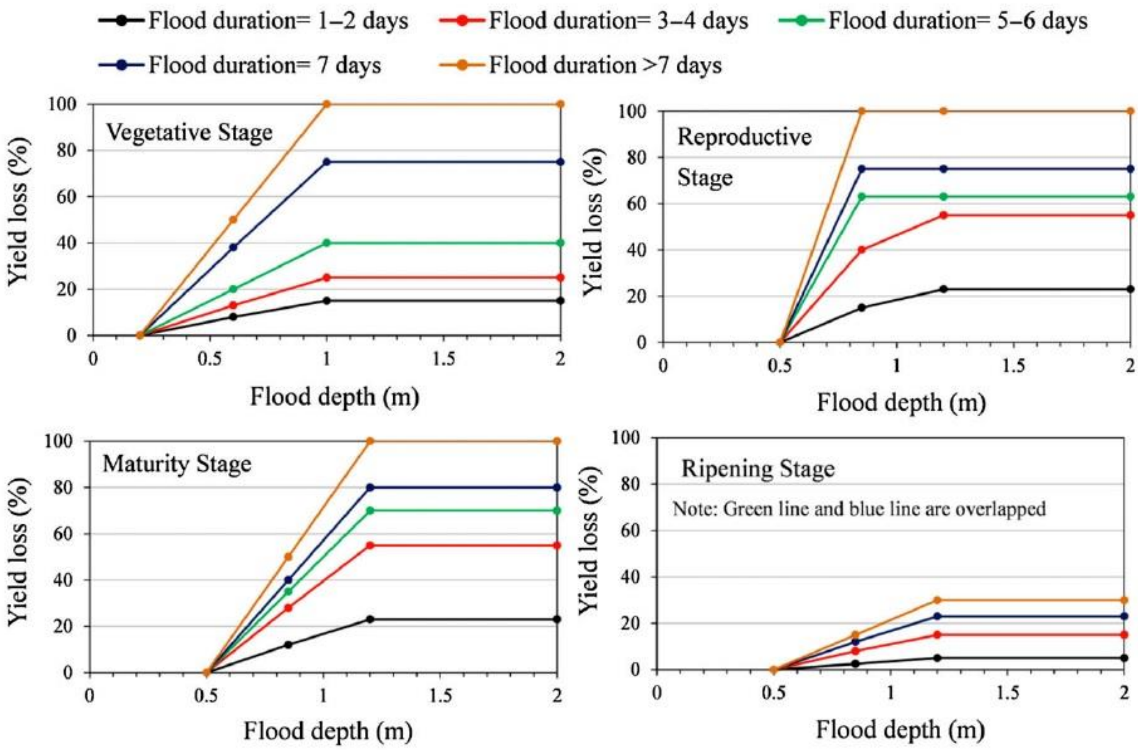


Figure 5.2. Damage functions to estimate rice yield loss due to inundation. Source Shrestha et al. (2015)

5.2.4 Assessment of flood risk and probabilistic livelihood benefits

We define flood-prone lands in Candaba as the two-year return interval flood zone (Figure 5.3). Therefore, potential benefits and damages of livelihood practices associated with flood-prone land use are estimated considering the spatial distribution and extent of the two-year flood as derived from frequency analysis and rainfall-runoff simulation. We derive probabilistic benefits and flood risk from the product of the absolute benefit/damage estimate associated with a given flood hazard and the probability of the hazard's occurrence (Eq. 5.7 and 5.8). Plotting the estimated probabilistic benefits and damages across return periods, we obtain flood risk and probabilistic benefit curves (Figure 5.10). Since we model flood events with different frequencies (1.33- to 100-year return periods) we obtain absolute and probabilistic benefits/damages according to varying magnitudes of flood hazard and thus, characterize for potential livelihood benefits and risks associated to normal and extreme flooding conditions.

$$RI = P(x) \times D(x) \qquad \text{(Eq. 5.7)}$$

where, RI is flood risk, P the probability of flood magnitude x, and D is the estimated damage at flood hazard x.

$$BE = P(x) \times B(x) \qquad \text{(Eq. 5.8)}$$

where, BE is probabilistic benefit, P the probability of flood magnitude x, and B are estimated benefits in this case, from flood-prone land uses such as wild fish capture and rice agriculture.

5.2.5 Scenarios of flood-prone land use

We evaluate trade-offs between probabilistic benefits and flood risk associated with livelihood practices according to four possible scenarios of flood-prone land use (Table 5.1). We define a direct human use scenario that represents the current condition of land use and livelihood strategies of local people in Candaba. In the direct human use scenario, flood-prone lands are used during the dry season for rice cultivation. During the wet season, some flood-prone lands are cultivated for rice, while other areas are not cultivated, but used only for wild fish capture activities. We created seasonal land use maps (Chapter 3: section 3.3.1) to differentiate areas typically used for wild fish capture and rice cultivation during the wet season. Benefits and damages associated with wet-season rice cultivation accrue only in areas classified as agricultural land during the wet season. Area identified on the wet-season land use map as mixed water-vegetation accrue potential wet-season benefits only from wild fish capture (Figure 5.3 (a)). During the wet season, farmers may sustain damages to rice agriculture from seasonal floods. Thus, we refer to this scenario as the direct human use "risk" scenario. We assess absolute potential benefits in the direct human use "risk" scenario as the sum of potential benefits from both the wet and dry season agriculture and wild fish capture during the wet season, while damages are related to wet-season rice cultivation. Benefits from dry season agriculture are estimated using mean rice crop yields and farm gate prices from the 2011 dry season period, reported at village level by the Provincial Agriculturalist Office of Pampanga.

Table 5.1. Scenarios of flood-prone land use for the assessment of flood risk and probabilistic benefits in Candaba.

Scenarios	Flood-prone land use	Source of livelihood benefit
Direct human use "risk"	*Dry season:*	
	Rice crop plantations	Agriculture
	Wet season:	
	Mosaic of rice crop plantations and wild capture fisheries	Agriculture and wild fish capture
Direct human use "low risk"	*Dry season:*	
	Rice crop plantations	Agriculture
	Wet season:	
	Wild capture fisheries	Wild fish capture
Flood storage/conservation	Dry season:	
	Natural floodplain vegetation (*e.g.* grassland, marsh)	N/A
	Wet season:	
	Wild capture fisheries	Wild capture fisheries
Direct human "adapted" use	Dry season:	
	Rice crop fields with adaptive planting calendars	Adapted rice-planting agriculture
	Wet season:	
	Mosaic of rice crop fields with adaptive planting calendars and wild capture fisheries	Adapted rice-planting agriculture and wild fish capture

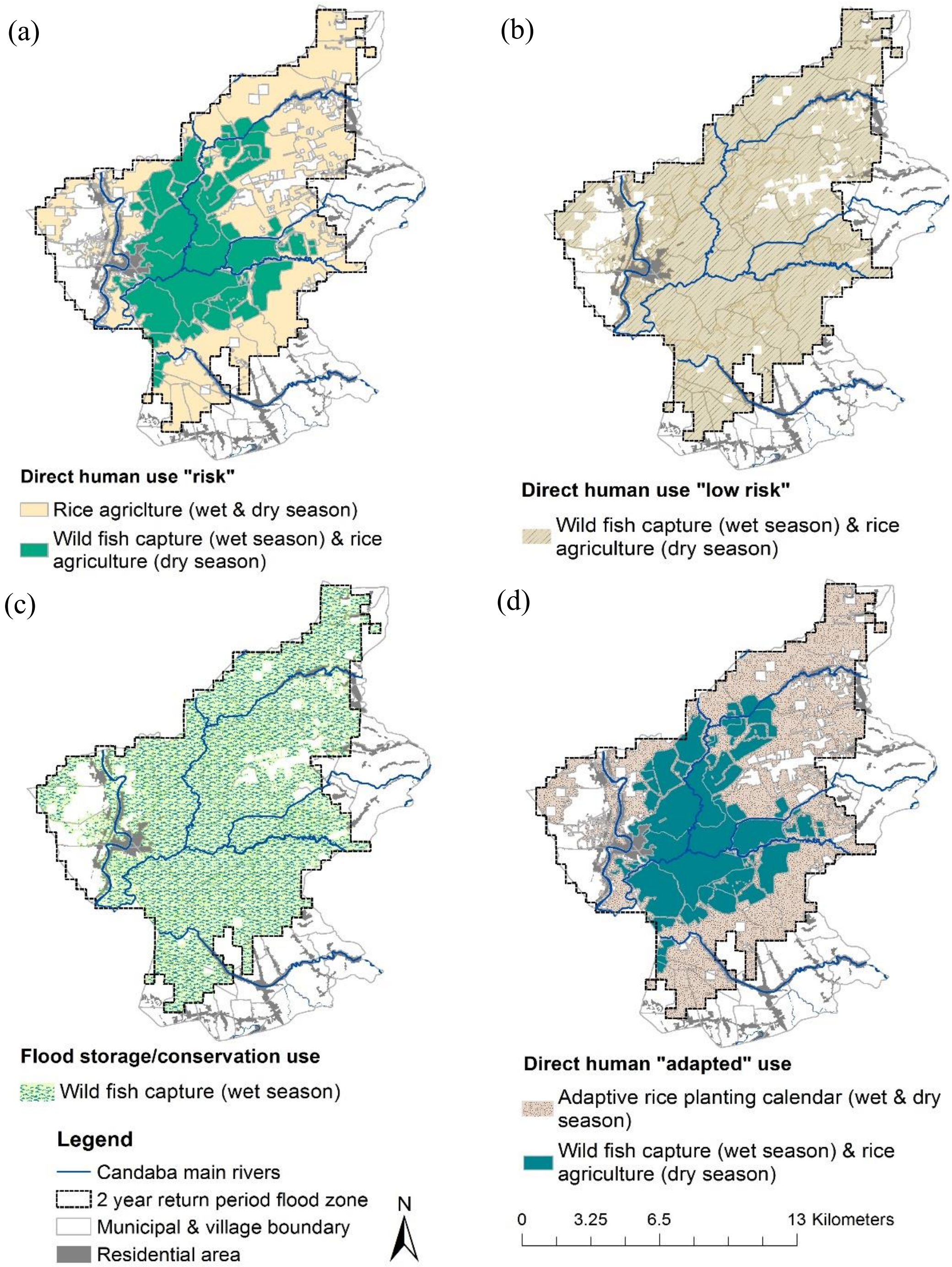


Figure 5.3. Scenarios of flood-prone land use: (a) direct human use “risk” scenario; (b) direct human use “low risk” scenario; (c) flood storage/conservation use scenario; and (d) direct human “adapted” use scenario.

We define additional scenarios to evaluate flood risk and probabilistic benefits on the basis of potential land use policies, which may determine possible configurations of flood-prone land use in the area. For instance, we consider an alternative direct human use condition based on the assumption that livelihood practices during the wet season are limited to prevent for potential damages. In this case, while people may cultivate rice in flood-prone lands during the dry season they are not allowed to plant wet-season rice within the two-year flood hazard zone. Community members may use flood-prone lands only for wild fish capture during the wet season. In this way, flood exposure is reduced and there is no potential for damage to wet season rice crops. For this scenario, therefore, the direct human use of flood-prone land entails "low risk". We assess then total potential benefits as the sum of dry season agriculture and wet season wild fish capture. The potential benefits from wild fish capture are estimated across the entire flood-prone area (Figure 5.3 (b)) and benefits from dry season agriculture are estimated as indicated previously for the direct human use "risk" scenario.

For the third scenario, we hypothesize a land use policy scenario in which direct human uses of flood-prone land are limited only to wild-capture fishing during the wet season. This scenario represents benefits that may accrue, if flood-prone lands are managed for flood storage and conservation purposes through strict application of land use designations or zoning. Therefore, for the "flood storage/conservation" scenario, we assess total potential livelihood benefits as wild fish capture during the wet season across the flood-prone area (Figure 5.3 (c)).

To evaluate the potential role of individual coping capacity we consider a fourth scenario based on local strategies that residents of Candaba practice to cope with regular inundation while benefiting from direct human uses of flood-prone land. For instance, many farmers in the area synchronize their seasonal planting schedule to the flood pulse to minimize potential damages and accrue benefits from having two crop cycles in a year (see Chapter 3: section 3.3.2). For this "adapted" use scenario we therefore assume that residents cultivating wet-season rice adjust their planting periods to harvest crops before peak seasonal floods. Exposure to inundation late in the season is reduced and there is no potential for damage to wet season rice crops. We also consider that flood-prone land which is not cultivated in the wet season is used alternately to support wild fish capture activities and dry season rice agriculture (Figure 5.3 (d)). Total potential benefits in this case are estimated by aggregating potential benefits from both wet and dry season agriculture and wet season wild fish capture. Potential benefits from wet season agriculture are estimated directly from reported yields and farm gate prices of the 2010 wet season period. The benefits from dry season and wet season wild fish capture are also evaluated as indicated in the previous scenarios.

5.3 Results

5.3.1 Frequency analysis and flood hazards

Probability plot correlations between Gumbel and GEV distributions and the annual maximum series of rainfall indicate an acceptable fit, 0.985 and 0.986, respectively. Analysis between empirical and modeled cumulative probabilities also show a good agreement for both distributions (Figure 5.4 (a)-(b)). We apply the Gumbel frequency curve for the probabilistic assessment of rainfall (Figure 5.5).

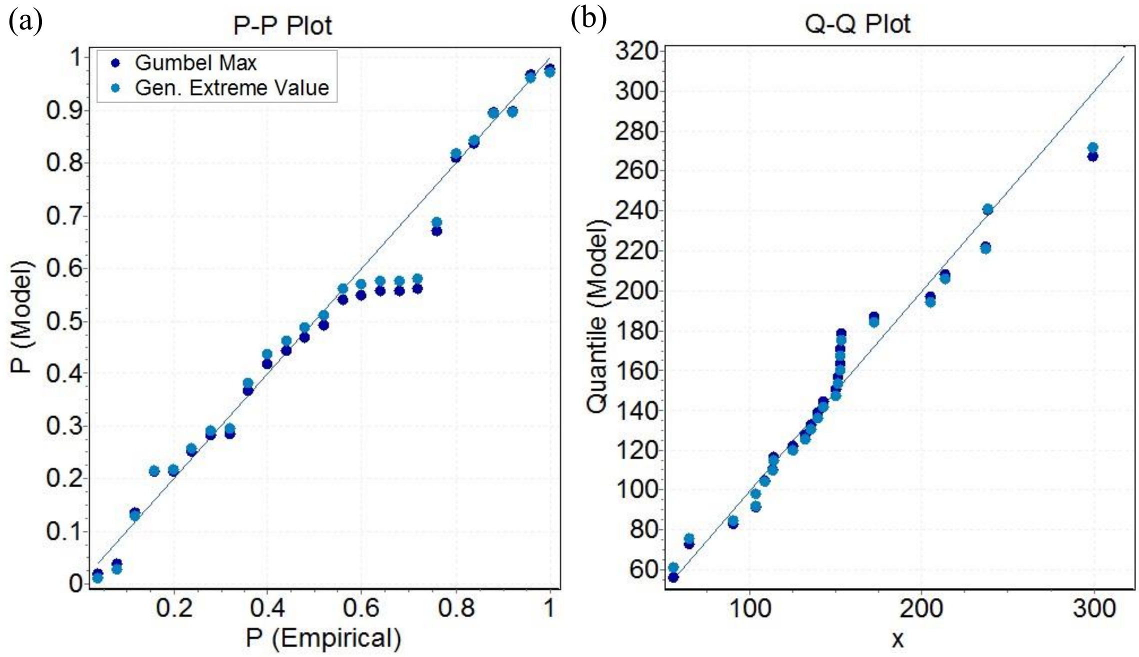


Figure 5.4. (a) P-P and (b) Q-Q plots of empirical and modeled 48-hour maximum accumulated rainfall.

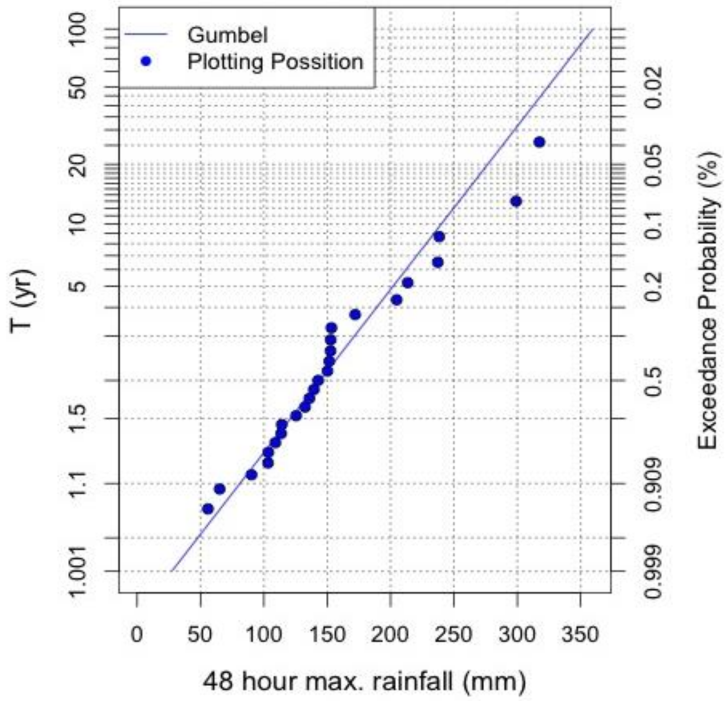


Figure 5.5. Frequency curve and observed 48-hour annual maximum rainfall (25 years) at Pampanga River basin, plotted on Gumbel paper.

Results of rainfall-runoff and inundation simulations indicate an increase in depth and extent of inundation following lower-frequency events of greater magnitude (Figure 5.6). However, we find that even high-frequency events inundate a significant portion of Candaba municipality. For example, simulated inundation from the 1.3- and 5-year return periods cover 76% and 88% of the municipal area, respectively. During a 100-year event, almost the entire municipality (96%) is likely to become inundated. Although we observe relatively little variability in inundation extent from different return periods, differences with respect to distribution and magnitude of inundation depth are more evident. For instance, simulations indicate maximum flood depths of 3-4 m during high-frequency events (1.3-2.5 flood years). Events of greater magnitude (5- and 10-year return period) lead to maximum inundation depths of 4-5 m, while flood depths up to 5-6 m can be expected from 50- and 100-year floods.

According to the simulations, the central to western region of the municipality is inundated to the greatest depth, with inundation extending to the northeast as the return period lengthens. This is likely the result of the combined effect of geomorphic depressions and convergence of tributary rivers in the central to western region of the municipality.

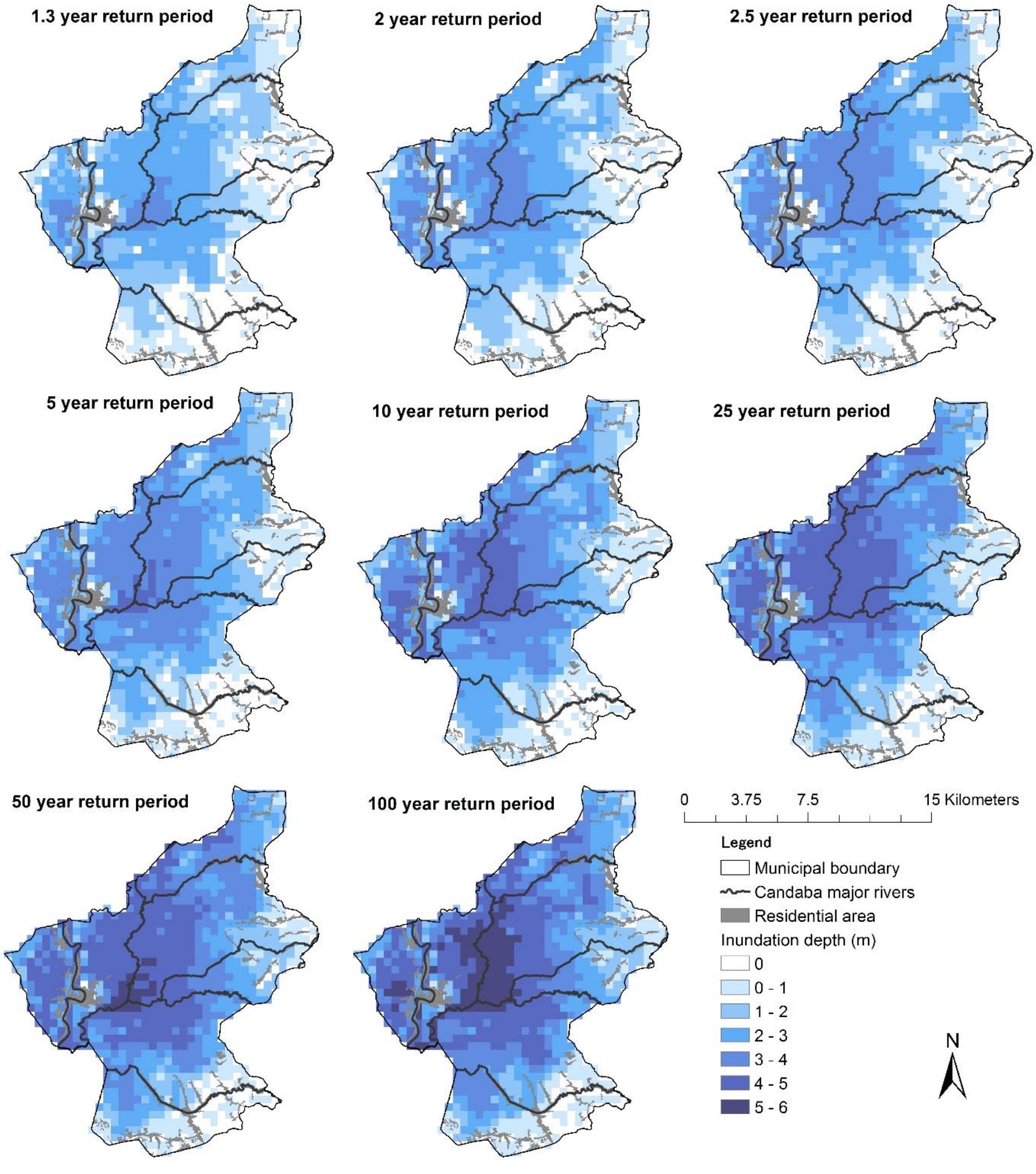


Figure 5.6. Simulated inundation extent and depth from different return periods of rainfall, Candaba municipality.

5.3.2 Absolute benefits and damages associated with use of flood-prone land

Benefits and damages vary between scenarios of flood-prone land use (Table 5.2; Figure 5.7 (a)-(d)), indicating trade-offs between potential damages and benefits. We find that in the direct human use "risk" scenario, rice crops in flood-prone lands are damaged to a 100% loss at a 10-year magnitude or greater. Thus, estimated damages associated with events of equal or lower probability to the 10-year flood remain constant (Figure 5.8). We also find that for the "risk" scenario, estimated benefits from wild fish capture activities are greater than rice benefits in the wet season at a 5-year or larger flood (Figure 5.9).

Table 5.2. Absolute potential benefits and damages from different scenarios of flood-prone land use at different return periods, Candaba area.

	Total benefits (million US $)								Total damages (million US $)							
Flood year	*1.3*	*2*	*2.5*	*5*	*10*	*25*	*50*	*100*	*1.3*	*2*	*2.5*	*5*	*10*	*25*	*50*	*100*
Direct human use "risk"	20.80	20.07	19.72	19.15	19.20	19.29	19.34	19.38	5.3	6.1	6.5	7.2	7.3	7.3	7.3	7.3
Direct human use "low risk"	18.94	19.19	19.30	19.58	19.80	20.04	20.18	20.32	n/a							
Flood storage/ conservation	0.39	0.64	0.76	1.03	1.25	1.49	1.64	1.77	n/a							
Direct human "adapted" use	26.23	26.35	26.40	26.52	26.61	26.70	26.75	26.80	n/a							

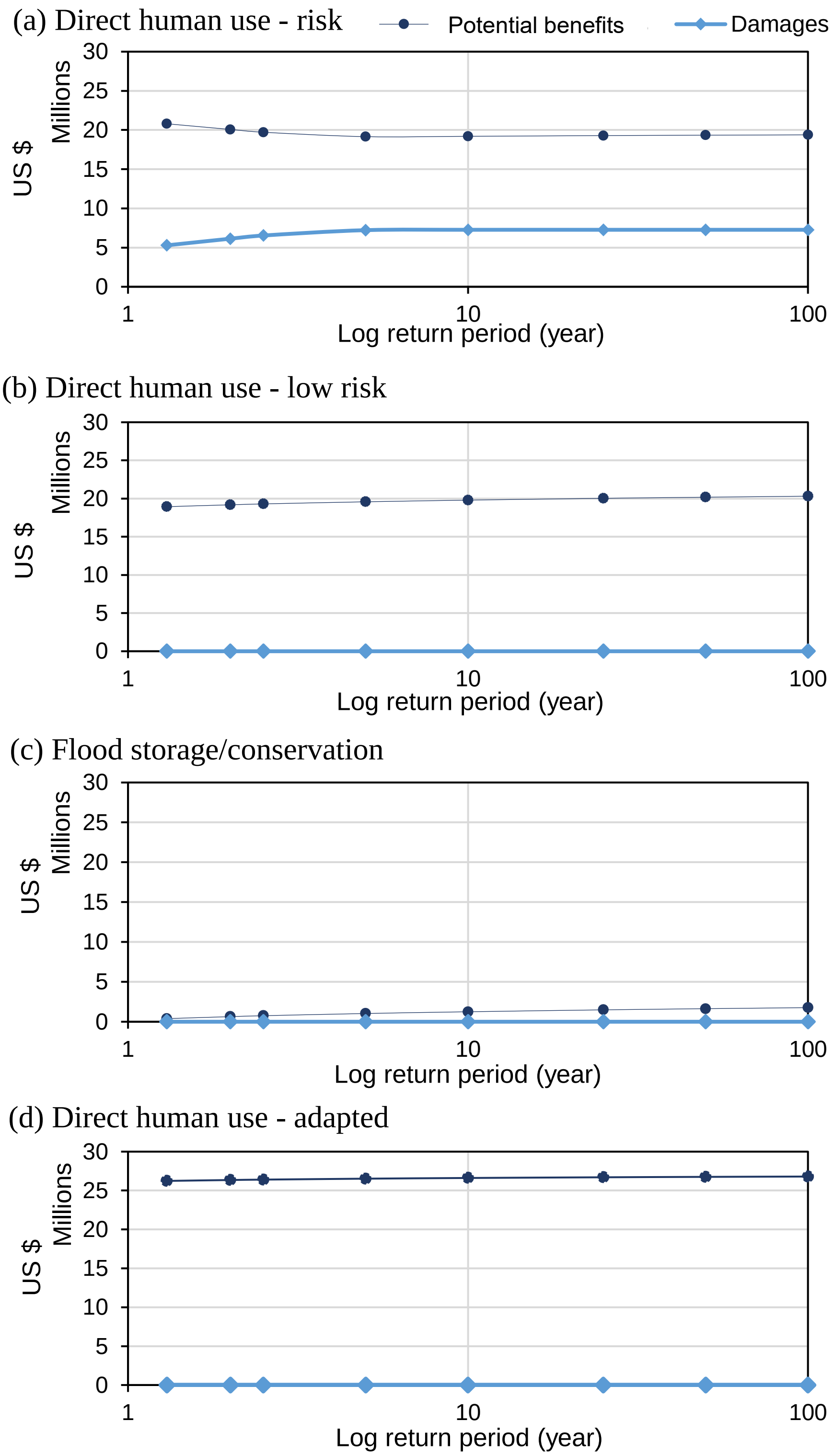


Figure 5.7. Absolute potential benefits and damages from different scenarios of flood-prone land use: (a) direct human use "risk"; (b) direct human use "low risk"; (c) flood storage/conservation use; and (d) direct human "adapted" use.

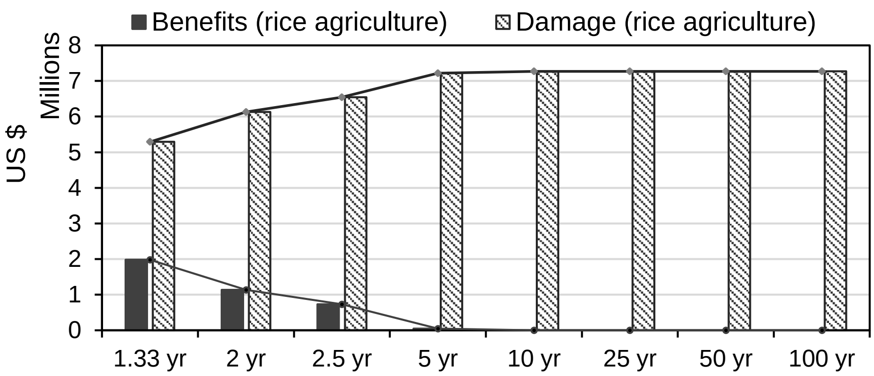


Figure 5.8. Benefits and damages of rice agriculture during the wet season, direct human use "risk" scenario of flood-prone land, Candaba area.

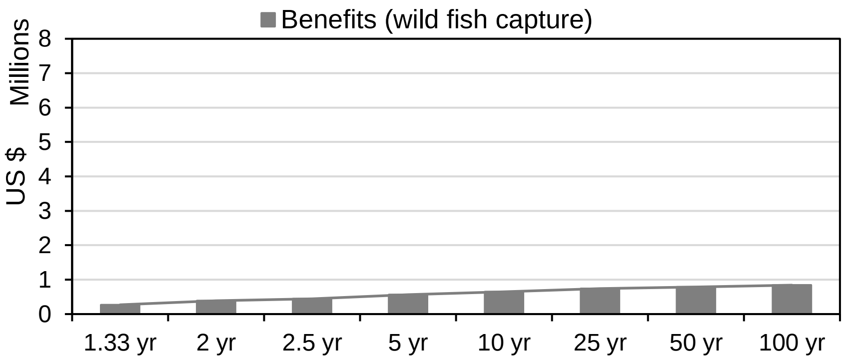


Figure 5.9. Benefits of wild fish capture during the wet season, direct human use "risk" of flood-prone land, Candaba area.

During events with a high probability of exceedance (1.3- to 2.5-year floods), potential benefits from the direct human "risk" scenario exceed potential benefits of the alternative policy scenarios ("low risk" and "flood storage/conservation"). However, potential benefits from the direct human "low risk" scenario surpass those of the current "risk" scenario in floods equal to or greater than 5-year events. Though for the full range of flood events, benefits from the direct human use (both "risk" and "low risk") exceed potential benefits from "flood storage/conservation" use. We find in addition that potential benefits from the direct human "adapted" use are greater than those of all the other scenarios.

5.3.3 Probabilistic benefits and damages (risk) associated with use of flood-prone land

Probabilistic net benefits and flood risk are derived from the product between the potential benefit/damage estimate associated with a given flood event and the probability of occurrence of the event. We find that probabilistic net benefits associated with current and policy scenarios of direct human use greatly exceed flood risk at all return periods (Table 5.3; Figure 5.10 (a) and (b)). Integrating over the range of investigated magnitudes of flood events with different frequencies, probabilistic net benefits associated with the direct human use "risk" scenario amount to US $ 91 million while the cumulative risks total US $ 33 million. Although the direct human use "risk" scenario entails significant risk associated with frequent events (US $ 4 – 0.7 million for <10-year floods), the probabilistic net benefits exceed risks by a margin of (US $ 40 million).

Table 5.3. Probabilistic benefits and flood risk from different scenarios of flood-prone land use, Candaba area.

	Probabilistic benefits (million US $)								Flood risk (million US $)							
Flood year	*1.3*	*2*	*2.5*	*5*	*10*	*25*	*50*	*100*	*1.3*	*2*	*2.5*	*5*	*10*	*25*	*50*	*100*
Direct human use "risk"	15.60	10.04	7.89	3.83	1.92	0.77	0.39	0.19	4.0	3.1	2.6	1.4	0.7	0.3	0.1	0.1
Direct human use "low risk"	14.20	9.59	7.72	3.92	1.98	0.80	0.40	0.20	n/a							
Flood storage/ conservation	0.29	0.32	0.30	0.21	0.12	0.06	0.03	0.02	n/a							
Direct human "adapted" use	19.68	13.18	10.56	5.30	2.66	1.07	0.54	0.27	n/a							

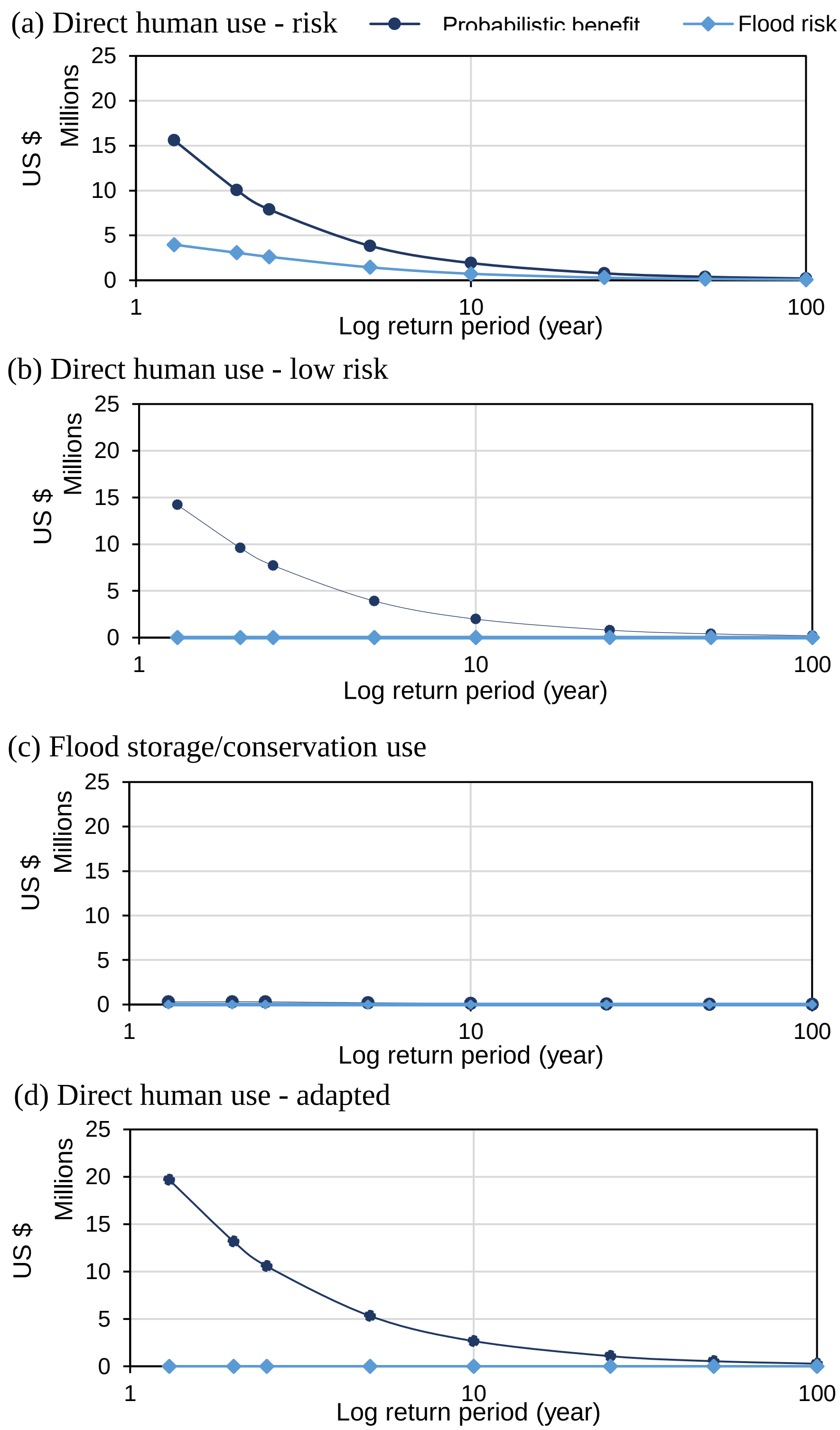


Figure 5.10. Flood risk and probabilistic benefits from different scenarios of flood-prone land use: (a) direct human use “risk”; (b) direct human use “low risk”; (c) flood storage/conservation use; and (d) direct human “adapted” use.

Probabilistic net benefits associated with current and policy scenarios of direct human use also greatly exceed probabilistic benefits of the alternative flood storage/conservation scenario (Table 5.3; Figure 5.10 (c)). Probabilistic benefits attained from wild fish capture only are considerably lower (US $ 6 million) than those associated with direct human use of flood-prone land (US $ 91 million and US $ 93 million for the "risk" and "low risk" scenarios, respectively). We find that the marginal benefit of direct human use of flood-prone land is US $ 85-87 million.

Comparing net benefits of the "risk" and "low risk" scenarios we find that at low return year intervals (1.3- to 2.5-year floods), probabilistic net benefits of the "risk" scenario (US $ 28 million) are greater than the "low risk" scenario (US $ 27 million). However, the opposite is true with respect to moderate events (5- to 10-year floods). Overall, net probabilistic net benefits associated with the direct human use "risk" scenario (US $ 91 million) are lower than those attained by the "low risk" scenario (US $ 93 million). We find in addition that probabilistic net benefits associated with the direct human "adapted" use scenario (US $ 125 million) far exceed those provided by the current "risky" and alternative policy scenarios (Table 5.3; Figure 5.10 (d)).

5.4. Discussion

5.4.1 Risks and benefits associated with use of flood-prone land in Candaba

The analysis of absolute and probabilistic benefits and damages related to four potential scenarios of flood-prone land use in Candaba indicates that direct human use of flood-prone land provides significant livelihood benefits associated with agriculture. In even the direct human use "risk" scenario, which entails some wet-season rice cultivation on flood-prone land, both absolute and probabilistic benefits outweigh potential damages and risks. Damages to agriculture are possible only in the "risk" scenario, as the alternative scenarios assume early crop harvest or do not entail cultivation of wet-season rice in flood-prone land. In the "risk" scenario, which represents current uses of flood-prone land in Candaba, local people often experience agricultural losses in the wet season. However, the behavior of wet-season cultivation is likely driven by the expectation of securing high livelihood benefits in some years from profitable agricultural land uses. We find that the alternative practice of wild fish capture entails little risk, but provides lower benefits than rice cultivation. Analysis of potential damages and benefits across a range of flood hazards reflects that during low-magnitude, high-frequency flood events (<2.5-year flood), the net benefits of wet-season rice cultivation are greater than the benefits from wild fish capture. However, rice crops in flood-prone lands are entirely lost following events that are equal to or larger than the 10-year flood while wild fish capture activities yield significant benefits across flood events of higher magnitude. People who practice combined wild fish capture and rice agriculture in flood-prone lands are thus able to secure livelihood benefits over a wider range of inundation conditions.

Comparing the direct land use scenarios of "risk" and "low risk" we find that sustaining both dry and wet season agriculture may secure greater livelihood benefits during years when the peak flood is of low magnitude. The alternative "adapted" use scenario indicates, however, that individual coping strategies such as shifting crop planting schedules in cultivated flood-prone land, may lead to secured agricultural benefits with reduced potential loss over a wider range of inundation conditions. Therefore, findings from the "adapted" scenario suggest that adjusting crop calendars and the combined practice of wild capture fisheries and rice agriculture in flood-prone land is associated with greater livelihood benefits than those of other scenarios across the full range of tested low- and high- magnitude events.

Analyzing the data probabilistically allows us to assess which land use maximizes benefits and minimizes risk over the range of computed hazard magnitudes. We find that despite the losses sustained to wet-season rice crops, net probabilistic benefits associated with the direct human use “risk” scenario (US $ 91 million) are slightly lower than those attained by the “low risk” scenario (US $ 93 million). However, the probabilistic net benefits associated with the “adapted” uses of flood-prone land for the area are greater (US $ 125 million).

5.4.2 Probabilistic benefits and flood risk from the use of flood-prone land in Candaba

Floods of different magnitudes are a meaningful representation of flood hazard in decision-making processes. While potential damages and benefits associated to varying flood hazards indicate the absolute socio-economic value of potentially incurred losses and gains, probabilistic assessment differs in that it provides additional information based on the likelihood that such gains/losses can be expected in any one year. Such analyses are significant because they draw the stochastic and complex behavior of hydrologic processes and their relation with socio-ecological systems into simple and objective understandings. The analysis of probabilistic floods is also an effective way to understand the likelihood of flooding with potential to provide information on the reliability and uncertainty in flood estimation (Domeneghetti et al. 2013). Mangers and decision-makers can thus use this information to support the design or definition of potential flood mitigation measures. Furthermore, once adequately informed a decision/policy-maker may weight management strategies by the probability of flooding and the corresponding effectiveness of the potential measures.

Since large flood events have a lower probability of occurrence, we observe in all scenarios that both flood risk and probabilistic benefits decrease as recurrence interval increases. An important behavior to note, however, is that probabilistic benefits and flood risk converge as flood hazard increases. Within the context of our analysis, benefits are relatively static and scale with the probability of flooding. This reflects the steady influence of dry season rice-benefits. For the "risk" scenario, fish and rice benefits in the wet season vary with respect to flood magnitude. While benefits of wet-season rice are high during low-magnitude high-probability events, benefits of wild fish capture account for the behavior we observe at high-magnitude, low-probability events. Damages to rice agriculture associated to "risky" use of flood-prone land also scale with probability, however, the absolute estimates of damages increase with flood hazard. Similarly, for the "adapted" scenario wild capture fish benefits vary with respect to inundation. In this case, however, both dry and wet season rice-benefits are relatively static and basically account for the behavior of benefits we observe at different probability events. In all scenarios of direct human use we find that probability benefits are greater at high, low-magnitude probability events (<1.3-year flood).

In the case of "flood storage/conservation" we find that probabilistic benefits peak at the 2-year return period and then decrease with flood magnitude, reflecting again the lower probability of large floods and a relatively static potential benefit as flood hazard increases. During the 2-year floods, simulated inundation depths of 3-4 m occupy a large extent of the study area and maximum wild fish yields occur at this flood level. Beyond the moderate flood level, absolute benefits from wild fish capture increase only incrementally with flood intensity. In flood-prone lands of Candaba, although inundation of greater depth and duration is associated with large events, we therefore observe relatively low variability in estimated fish benefits. This reflects a potential diminishing return of fish catch as inundation increases beyond 4 m depth. Responses to interviews indicate that inundation to depths above 4 m may be associated with dangerous conditions for both travel and capturing wild fish. The combination of high exceedance probability and peak absolute fish benefits largely explains why we observe the highest probabilistic benefits at the 2-year flood.

5.4.3 Risk-Benefit Assessment: a tool for decision-making and improving lives

The integrated assessment of flood risk and probabilistic benefits in Candaba evidence the potential that exists in quantitatively identifying trade-offs between risk and probable benefits associated with use of flood-prone lands. For instance, this information can be useful to establish which flood levels should be considered to support benefits and reduce flood risk. Often structural and non-structural measures such as levees, dams and flood zoning are designed with the objective to manage risk from floods up to 50-year or 100-year return intervals. As a consequence, the exposure to flood events of high-frequency is often eliminated. In areas such as Candaba, such rationale could have a negative impact on both livelihood benefits and ecosystem services, as we find that while people may sustain damages they also benefit from using flood-prone lands exposed to a wide range of recurrence intervals.

Findings from Candaba demonstrate that the marginal benefit of using risky areas exceeds potential flood risk by an estimated US$ 58 million. Though current use of flood-prone land entails risk, the marginal probabilistic benefits associated to high recurrence intervals (<10-year flood) are significant (US $ 40 million). The risk-benefit assessment further suggests that the marginal benefit of direct human use of flood-prone land is significantly large (US $ 85-87 million) compared to limited uses compatible with "flood storage/conservation" (US $ 6 million). Land use policies that limit or restrict uses of flood-prone lands may reduce risk and provide other types of benefits and ecosystem services. However, the implementation of measures within the context of Candaba that limit direct uses of flood-prone land to manage flood risk could translate into high socio-economic impacts for the local people. Especially if for instance, such measures do not include mechanisms or alternative strategies to help ensure livelihood sources to people who are either allowed to use limitedly flood-prone lands or reallocated. Evidence from practices to reduce flood risk in developing countries for example, reveal that the ability to secure a viable livelihood benefit is a key determinant explaining whether resettled people remain in the new location or settle back into the floodplains (Arnall et al. 2013, Weng Chan 1995).

Potential benefits from the use of flood-prone land in Candaba demonstrate that direct human uses are of significant value to local people through varied flood conditions. We find that direct uses of flood-prone land provide important livelihood opportunities, which are supported and maintained by seasonal inundation, for instance, as in the case of wild fish capture activities. Our analysis evidence that floods and the use of flood-prone land in the area is not associated to only potential losses or damages. As such, policies and measures to manage flood-prone lands should target a wider range of potential strategies that are not only confined or based upon limiting and preventing exposure to flood hazards. In this way, multiple benefits from floods and the use of flood-prone land can be supported while simultaneously managing flood risk.

Findings in this study indicate that only at low return year intervals (1.3- to 2.5-year floods) direct human use "risk" benefits are greater (US $ 28 million) compared to a potential "low risk" policy-driven scenario (US $ 27 million). This may suggest that residents could be better off if they decide not to farm in the wet season. In Candaba, however, we find that residents employ varied strategies to secure livelihoods from the use of flood-prone lands. For instance, some community members adapt their crop calendars to plant and harvest earlier in the wet season and thus are able to secure livelihood benefits from two rice harvests per year. In areas where people are unable to cultivate rice during the wet season due to severe and prolonged inundation, we also observe that some fishermen are more adept at utilizing wild fish capture fishery as supplemental income (see Chapter 3: section 3.4). As such, the influence of individual coping capacity may determine the level of captured benefits and has the potential to be used simultaneously as an effective strategy to reduce flood risks from the direct use of flood-prone land. We find that the accumulated probabilistic benefits from an "adapted" scenario in which such practices are implemented are potentially greater (US $ 125 million) than probabilistic benefits from other scenarios of flood-prone land use. For instance, the practice of adaptive strategies can lead to a marginal difference in probabilistic benefits of US $ 119 million compared to a scenario with limited uses or designations such as to support flood storage and nature conservation.

The integration of coping capacities and benefits into flood risk assessments may hold important value for the implementation of more effective flood management measures. For instance, informed decision-making that accounts for both the relative damages and benefits associated to different flood events, can lead to practices that support maximum potential benefits for the minimum flood risk. Management practices would be based on and account for the hydrologic processes and/or human behaviors that are essential to support and maintain the desired conditions. Strategies that are built on flexible and adaptive principles and/or through enhanced coping capacity may be good alternatives to achieve effectively such outcomes.

5.5. Conclusion

Flood management decision-making is usually supported by risk assessments, which often overlook the role of coping capacities and potential benefits from use of flood-prone lands. In this study we conduct an integrated assessment of flood risk and probabilistic benefits according to different scenarios of flood-prone land use. We consider a scenario that represents current "risky" uses of flood-prone land including both dry- and wet-season rice agriculture and wild capture fishing. An alternative policy-driven scenario which entails "low risk" is defined considering that flood-prone land use is allowed to sustain rice cultivation during the dry season only and wild fish capture activities in the wet season. For a third scenario, we assume a policy scenario where use of flood-prone land is restricted and only livelihood activities compatible with flood storage/conservation are allowed. To evaluate the role of coping capacity we define a fourth "adapted" scenario in which we consider the combined practice of wild capture fisheries and rice agriculture and adjusted rice planting periods.

While in the "risk", "low risk" and "adapted" scenarios maximum probabilistic benefits are associated with high-frequency events (<1.3-year flood), in the "flood storage/conservation" scenario maximum probabilistic benefits may occur at the 2-year flood. The current use of flood-prone land in Candaba to derive livelihood benefits is associated with flood damage. However, the probabilistic livelihood-benefits in this case are greater by a large margin (US $ 58 million) than the potential flood risk. Our findings also suggest that probabilistic livelihood-benefits from direct "risky" and "low risk" use of flood-prone land are larger (US $ 91-93 million) than probabilistic livelihood-benefits from "flood storage/conservation" (US $ 6 million). Though marginal benefits from the "risk" scenario are slightly larger (US $ 28 million) compared to benefits from "low risk" use (US $ 27 million) at low return year intervals (1.3- to 2.5-year floods), local people in the area implement variable coping strategies in response to flooding. For instance, some community members adapt their cropping calendars to sustain two rice crops per year while others utilize improved technology for capturing fish to derive greater yields. Such adaptations have the potential to allow local people to derive maximum livelihood-benefits from the direct use of flood-prone land for the minimum flood risk. Evidence from the "adapted" scenario in which we evaluate the effect of such strategies suggests that probabilistic benefits are potentially greater (US $ 125 million) than probabilistic benefits from other scenarios of flood-prone land use.

Our findings demonstrate the importance of taking into account the full range of flood events and their relation with both potential damages and benefits. In this way, management measures (structural or nonstructural) can be designed so that essential flood levels are supported and maintained to secure local livelihoods and promote natural hydrologic processes while minimizing potential flood damage. To manage flood risk while delivering multiple benefits, strategies that are based on enhanced coping capacities may offer effective and more sustainable solutions.

Chapter 6: Synthesis

In this study I present a framework and information tool that can be used by managers and policy-makers to identify practices that yield maximum socio-ecological benefits for the minimum flood risk. Important contributions of this work include the integrated analysis of flood risk and probabilistic benefits associated to policy scenarios of flood-prone land use. In addition, evidence on the potential role of coping capacity in determining risk-benefit trade-offs. Within the context of many developing countries, local communities have long adapted to flood exposure and may practice different strategies to procure benefits from seasonal inundation. In such cases, targeting coping capacities and socio-ecological benefits from flood-prone land use may offer opportunities to propose resilient and sustainable solutions for managing flood risk and river-floodplain systems.

6.1 Key concepts and definitions

Traditionally, flood risk analysis is defined as combining probabilities with negative consequences of floods to determine risk objectively (Merz, Kreibich et al. 2010). Identified flood risk is often used by managers and policy-makers to design and implement measures to manage floods and flood-prone land use. By following a similar approach, I propose the analysis of probabilistic benefits alongside flood risk to support decision-making. Probabilistic benefits are thus defined in this study as the product between probabilistic floods and the potential benefits associated to flood intensity. Examples of potential benefits in this case are livelihood resources and ecosystem services that people may accrue from floods and flood-prone land use such as, agricultural yields, wild fisheries, and soil moisture supply.

Is also important to note that the concept of coping capacity in disaster risk management is often defined as:

> "*the means by which people/organizations use resources and abilities to face adverse consequences that could lead to a disaster*" (UN/ISDR 2009).

Since definition of this term is arguably broad, a distinction is usually made between the *individual* human behavior and the *institutional* coping capacity for or by which the society, governments and institutions deal with natural disaster risks (Adger 2010). In this study, coping capacity is used to refer specifically to practices people may implement at the individual level in response to flood hazard risks. Examples of these types of strategies include adapting livelihood sources and flood-prone land use to seasonal inundation, temporally migrate or reallocate, or building residences to withstand certain levels of inundation.

6.2 Main findings

In Chapter 2, I introduce the conceptual framework of integrating probabilistic benefits into flood risk assessments to support floodplain management. The importance of evaluating the full range of potential benefits from flood-prone land use is addressed. However, livelihood benefits of direct floodplain use are distinguished from those that derive from flood- and floodplain-related ecosystem services. In many developing countries, for instance, local people derive multiple benefits from the direct human use of flood-prone land. In such cases, for example, agriculture and wild capture fisheries are often considered essential resources to secure both livelihoods and food supply. Tough direct human uses of flood-prone land can be associated to a wide range of livelihood benefits, such practices generally entail exposure to flood hazards. In order to manage potential flood risk in such contexts, the role of enhanced coping capacity as an effective mechanism is discussed. Because floodplain adaptation measures may involve risk-benefit trade-offs, we then elaborate on the concept of integrated assessment of flood risk and probabilistic benefits to assist decision-making. We argue that through parallel analysis of probabilistic damages and benefits a broad suite of measures may be evaluated to minimize flood risk while maximizing river-derived benefits.

To further support understandings of benefits from flood-prone land use and coping capacities in developing countries, in Chapter 3 I present evidence from Candaba floodplains, Philippines. Strategies that allow residents to cope with floods while benefiting from the use of flood-prone land were identified by combining information from field surveys, modelled inundation and remote sensing analysis. Main findings indicate that local people adapt by adjusting rice crop planting periods to be more synchronous with seasonal inundation. Residents may also shift from dry season agriculture to wild fish capture in the wet season. Estimated livelihood benefits in flood-prone communities of Candaba indicate that residents practicing these strategies accrue significant livelihood benefits (US $ 2,266/ha), which also compare to livelihood benefits of non-flooded villages (US $ 2,746/ha). This analysis therefore suggests that neglecting benefits from direct floodplain use may significantly affect the livelihoods of local people. Furthermore, management schemes targeting coping capacities may enhance resilience to seasonal flooding while supporting socio-ecological values.

The assessment of coping capacity and benefits from Candaba revealed that direct human use of flood-prone land is vital to secure livelihood benefits and provisioning services. Important provision services for local people are wild fish capture resources, which are supported and maintained by seasonal inundation. Evidence from temperate and tropical river-floodplains suggests that relations between fish productivity and flood intensity may occur in response to annual fluctuations in rainfall and pulsing or river flows (Dudley 1972; Welcomme 1985; Halls et al. 1999). In line with these principles, I present in Chapter 4 a characterization of wild fish capture activities in Candaba area. Using empirical evidence indicated by local fishermen, I evaluate the effect of flood pulse and technology use in wild fish capture productivity. Main findings indicate that wild fish capture yields from the use of motorized boats in the villages of Paralaya (3.0-15 kg/day) and San Agustin (6.5-25.3 kg/day) are greater than yields from non-motorized boats in both communities (0.8-4.0 and 5.1-8.8 kg/day, respectively). Total fish capture productivity from the use of motorized and non-motorized boats is also significantly related to intensity of inundation (R^2= 0.87 and 0.90, respectively). I thus conclude that wild fish capture yields in Candaba are influenced by the effect of varying flood pulses. Is important to mention that key findings from this analysis were used to derive models for the area of fish catch productivity as a function of flood intensity. These functions can be applied, for instance, to assess potential wild fish capture benefits across different levels of inundation.

Central to this study is the integrated assessment of flood risk and probabilistic benefits to support integrated management of flood-prone land. To this effect, I evaluate risk-benefit trade-offs associated to efforts at institutional/government level targeting in particular land use policies that may designate for example exclusive zones or restrict floodplain use. Potential scenarios driven by land use policies can lead to conditions where direct human uses of flood-prone land are permitted or uses compatible only with nature conservation and flood storage are allowed. In Chapter 5, I thus present an integrated assessment of flood risks and probabilistic benefits according to potential scenarios of flood-prone land use in Candaba. For this analysis, I consider policy-driven scenarios that may support, for instance, livelihood practices compatible with direct human uses (agriculture/wild fisheries) or flood storage/nature conservation (wild fisheries only). To characterize inundation from 1.3- to 100-year recurrence intervals in the area, I couple frequency analysis with rainfall-runoff-inundation modelling. In this way, I evaluate not only extreme flood events (*i.e.* 25- and 100-year return periods) but include low to medium events that represent normal flooding conditions according to the local people (*i.e.* 1.33- to 5-year return periods). Potential benefits and damages over varying probabilistic flood hazards are then estimated by combining simulated probabilistic floods with damage and benefit functions (*e.g.* fish capture and rice yield with flood intensity). Findings from this analysis reveal that although current "risky" use of flood-prone land is associated with damages, for all the investigated magnitudes of flood events with different frequencies, the probabilistic benefits exceed risks by a large margin (US $ 58 million). In addition, probabilistic livelihood benefits associated to direct human uses (current "risky" and policy-driven "low risk" scenarios) far exceed the benefits provided by the alternative "flood storage/conservation" scenario (difference of US $ 85-87 million). For this analysis, however, I consider an additional scenario to evaluate the role of individual coping strategies, such as adapting crop planting periods to the flood pulse of fishing rather than cultivating rice in the wet season. Findings suggest that land uses resulting from these practices minimize potential flood losses while allowing for valuable livelihood probabilistic benefits (US $ 125 million) in Candaba. Evidence from this study demonstrates the importance of evaluating beyond just extreme flood events and account for their relation to both potential damages and benefits in risk assessments. Management measures can be designed to reflect the local needs and contexts, which may lead to more sustainable and effective solutions.

6.3 Study contribution and policy implications

The integrated assessment of flood risk and probabilistic benefits in Candaba area evidence the potential that exists in quantitatively identifying trade-offs between risk and probable benefits associated with use of flood-prone lands. Flood risk assessments are often applied to quantify potential consequences associated mainly with extreme flood events. Structural and non-structural measures such as levees, dams and flood zoning are then designed with the objective to manage, for example, potential flood risk up to 50-year or 100-year return intervals. As a result, the exposure to flood events of high-frequency is often eliminated. In areas such as Candaba, such rationale could have a negative impact on both livelihood benefits and ecosystem services, as we find that while people may sustain damages they also benefit from using flood-prone lands exposed to a wide range of recurrence intervals.

In Candaba area, though current use of flood-prone land entails risk, the marginal probabilistic benefits associated to high recurrence intervals (<10-year flood) are significant (US $ 40 million). Inundation levels resulting from flood events of such frequencies (*i.e.* 3 to 4 meters maximum inundation depths) could be used to define thresholds and devise accordingly management measures. Dam operations and levees can be adjusted, for instance, to allow for such levels of inundation and thus support potential benefits in the area. The spatial distribution of probabilistic benefits and flood risk across recurrence intervals (Figure 6.1), in addition, may inform the design of policies aimed at designating flood zones or land use restrictions. In Candaba, for instance, areas located near the boundary of the 2-year flood zone indicate potential damages to agriculture at high frequency flood events. This information can therefore be used to define land use zones in the area where, for example, residents are only allowed to practice dry season agriculture and wild capture fisheries to reduce potential flood risk. Following these efforts, flood insurance policies can also be updated or planned based on the permitted land uses and expected/tolerable levels of inundation.

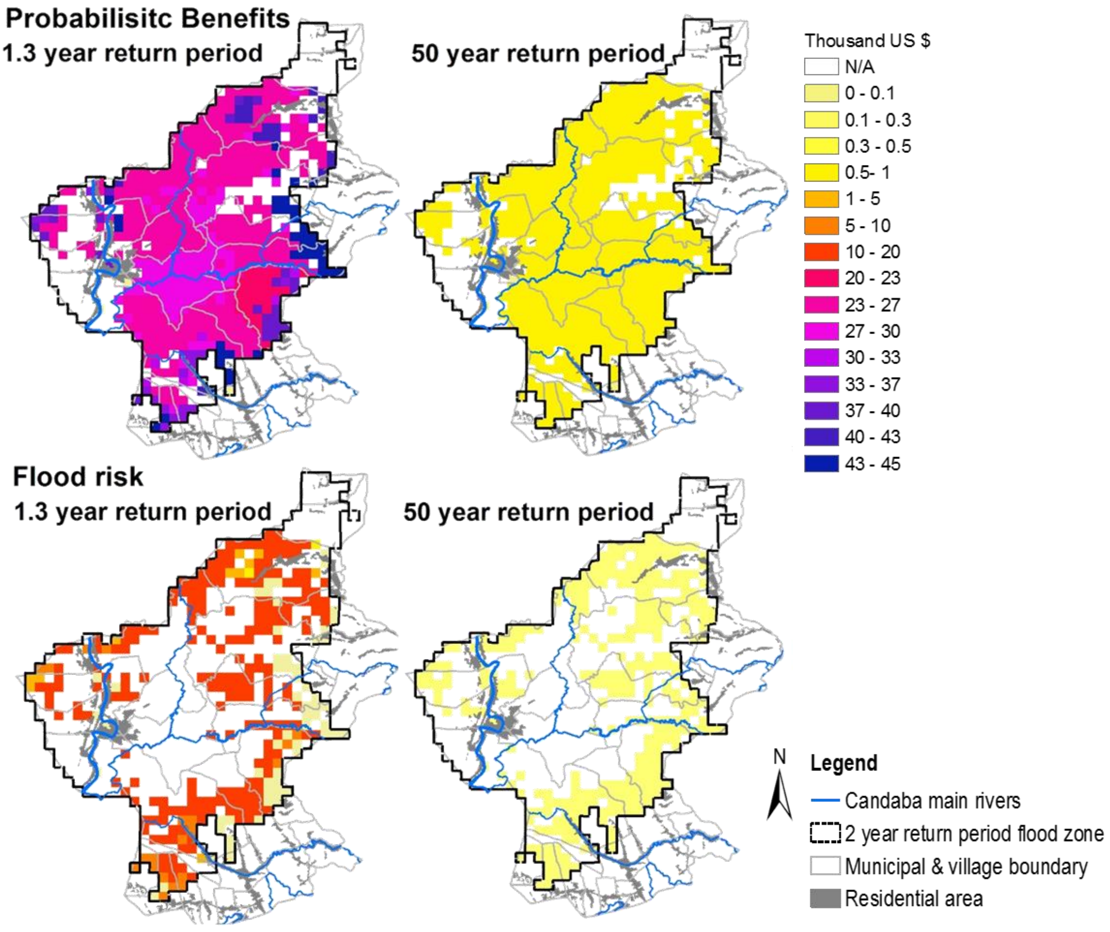


Figure 6.1 Probabilistic benefits and flood risk from direct human “risk” use of flood-prone land in Candaba.

Furthermore, on the basis of this information, structural measures such as levees, berms or floodwalls can be engineered with flexible designs or placed strategically, so that spatial and temporal distribution of acceptable levels of inundation are allowed, while potential damages in vulnerable areas are prevented. Is important to note, that evaluation of different scenarios of flood-prone land with our proposed framework can also facilitate identification of practices that may result in greater potential benefits for the minimum risk (Figure 6.2). Our findings reveal that individual coping strategies, such as adapting land uses and livelihood strategies, have the potential to manage more effectively flood risk while supporting significant capture of socio-ecological benefits.

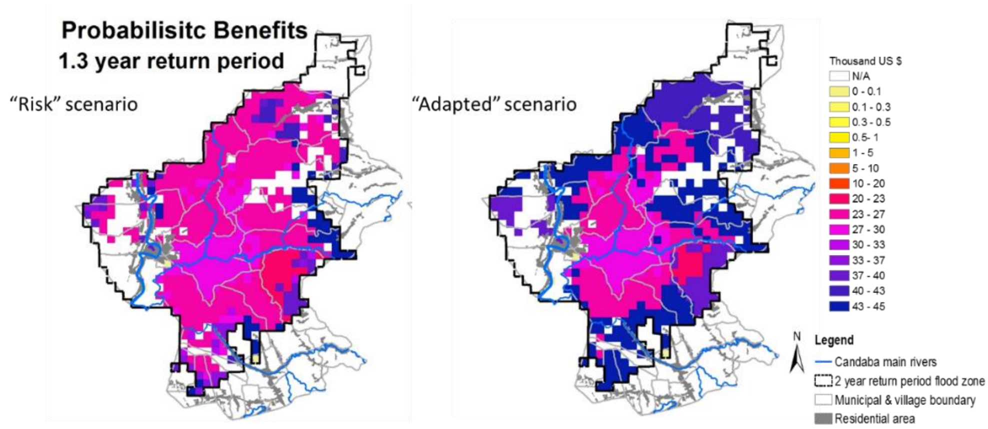


Figure 6.2 Probabilistic benefits from direct human "risk" versus "adapted" use of flood-prone land in Candaba.

Policy makers and managers in the area may thus utilize this information to improve current strategies for flood risk reduction or support additional efforts such as awareness programs, which may be aimed to enhance individual coping capacities. Identified risk-benefit trade-offs may elucidate which areas and efforts should be prioritized. For instance, findings from this study illustrate the potential of our proposed tool to evaluate measures both at institutional/government scale (land use policies) or human behaviors at the individual level (coping capacities). As such, decision-makers may apply this approach to evaluate different potential measures and select among practices conceived most effective to achieve multiple objectives. The integration of local practices and the benefits from flood-prone land use may translate into effective measures that could support sustainable livelihoods and natural hydrologic processes, while minimizing potential flood damage.

Tough evidence from Candaba floodplains demonstrate that integrated flood risk-probabilistic benefit assessment can be a promising tool, it is worth recognizing some limitations related to our analysis in the area. In this study, for instance, flood risk is evaluated representing one feature as we focus primarily on rice agriculture. However, floods usually result in damages to other sectors such as residential buildings and infrastructure or even human loss. Furthermore, extreme floods may also lead to long periods of interrupted access to lifeline utilities, markets, schools, and health services, which may have further socio-economic consequences. Similarly, we capture only part of the full range of potential benefits from the use of flood-prone land by targeting mainly benefits from wild fish capture and rice agriculture. Evaluation of important livelihood benefits and ecosystem services such as soil moisture and fertilization supply, eco-tourism and biodiversity were not addressed in this study. The estimation of flood risk including damages/losses to multiple sectors and evaluation of a wider range of benefits may lead to different trade-offs than those indicated by our analysis. As such, decision-makers may weight thresholds differently, select alternative practices or apply a different approach for the design of potential management measures.

Is also important to note, that in this study the potential benefits for example, associated to the current “risky” direct human use scenario, refer to the net probabilistic benefits of wild capture fisheries and rice agriculture. In this case, net probabilistic benefits reflect the product between flood hazard probability and the aggregated estimates of absolute rice and wild fish captured benefits. Estimates of absolute rice benefits denote the actual accrued gain from the total expected harvest according to the level of sustained inundation. In contrast, flood risk in our analysis is based on the estimated damages of rice agriculture, which reflect the loss with respect to flood exposure. In this case, the principle of evaluating the potential loss (damages) of rice agriculture and in parallel the accrued gain (benefit) is to capture and represent both aspects associated with the opportunity to sustain this type of activities in flood-prone lands. Is therefore important to acknowledge that defining and developing risk/benefit curves is crucial for the analysis and may bear potential limitations. As such, the further application of risk-benefit assessments must build upon careful definition and improvement of these functions.

For this study, the analysis of flood risk-probabilistic benefits associated to potential coping capacities was also limited to strategies such as adapted crop planting calendars and shifting of seasonal livelihood benefits (from dry season agriculture to wet season wild fish capture). Local people in Candaba indicated that these strategies are common practices and were thus prioritized. However, there are other examples of individual behaviors local people may implement to minimize potential flood risk while benefiting from the use of flood-prone land. For instance, residents of Candaba further indicated that alternative strategies during floods are securing incomes from household members working in Manila or other barangays. Identified coping strategies in the community of

Masantol, which is located near Candaba area, reveal that main strategies of local people consist of saving food in provision for flooding and reducing food intake during each meal in the wet season (Gaillard et al. 2008). As such, is worth noting the potential of expanding this analysis to include alternative coping capacities and their relation with flood risk-benefit trade-offs.

Any effort aimed at building coping capacities, however, must also take into account factors driving such social behaviors so that potential practices are adopted and implemented successfully. Tough we find that many farmers in flood-prone villages of Candaba adjust crop planting periods to minimize potential damages in the wet season, not all farmers adopt this strategy. Multiple factors often influence agricultural productivity, which can thus drive local people to employ different farming behaviors. For instance, farmers who adapt planting periods indicated that they establish their crops during transitional periods between the wet and dry seasons. The uncertain and fluctuating hydro-meteorological conditions (*i.e.* temperature, relative humidity, evapotranspiration, hours of sunshine, etc.) during these periods are likely to impact rice growth and thus potential yields. While potential damages from floods may be prevented, yields may be higher or lower than expected. People adapting planting calendars in Candaba also indicated that they use receding flood waters as initial input of soil moisture. In contrast, farmers cultivating areas less exposed to inundation largely rely on irrigation water during both the wet and dry seasons. Irrigation water in these areas is mainly provided and managed by the National Irrigation Administration of the Philippines, which allocates water volumes according to planned schedules every season. In order to access and benefit from serviced water, farmers of dry villages in Candaba are thus likely limited to planting during such periods. Additional socio-economic and management factors may also largely determine farmers' preferred timing of establishing crops. For instance, farmers may choose to plant during specific periods to avoid pests or benefit from fertilization inputs. Increased structural resilience in the area may also have led to reduced coping capacity of individual behaviors and traditional knowledge. Farmers may have changed preferences with regard to agricultural strategies as a result of intensification of land use and a false illusion of reduced risk following implementation of flood control structures. The expectation of receiving compensations from relief efforts by the government and international aid after sustaining agricultural damages from floods can be an additional influencing factor. Local managers must therefore take these constrains into account so that policies, measures and efforts targeting capacity building to enhance resilience are adopted and complied with successfully.

Though our risk-probabilistic benefit analysis has limitations to consider, this information can be useful to local decision-makers and managers in the area. The assessment can be improved by integrating other potential benefits and damages and integrating other scenarios of coping capacity. This tool and information can be directly applied to support development of policies and design measures to manage flood-prone lands. In developing countries, areas that are vulnerable to floods require solutions molded to the local contexts as well that could be nested with domestic and international frameworks such as the UN Water and Sustainable Goals. As such, the challenge lies in supporting and implementing measures that can meet with multiple sectors, scales, and objectives such as to procure safe drinking water, sanitation, water-ecosystem services, and flood protection. To do so, concrete interventions may build from pathways that integrate local experiences and societal needs. This information tool and conceptual framework proposed in this study may thus offer an entry point to facilitate constructive exchanges and consensus with the potential to translate into improved polices and thus best field practices.

Chapter 7: Conclusion

Flood management paradigms frequently emphasize relations between society and flood risk. From a single-objective perspective, reducing human vulnerability by *keeping people away from floods* is often an effective strategy to reduce flood risk. In the light of climatic variability, flood exposure uncertainty, and present socio-ecological demands, the suitability and effectiveness of hard-engineering approaches to manage floods are put to the test. In response to these challenges, many developed countries are now implementing joint flood risk-ecosystem approaches to manage floods and flood-prone lands from an engineering, social, and ecological perspective. Many implemented practices, however, emphasize recovering ecosystem integrity and reducing flood exposure to manage flood risk. Thus, the ultimate design of example practices frequently consists of natural river-floodplain systems where human activity is limited. We find that such configurations often favor societal benefits that are compatible with conservation and flood storage. In contrast, benefits from direct use of flood-prone lands such as agriculture, pasture or housing, are frequently discounted. In many developing countries, people often base livelihood strategies on hydrologic cycles and direct use of flood-prone lands. Direct transfer of practices from developed countries that limit uses of flood-prone lands or constrict access to flood-adapted livelihoods may be unlikely to succeed in such contexts.

To support decision-making processes that shape management of floods and river-floodplain systems, I focus this dissertation on presenting frameworks and information tools that can assist evaluation of practices suited to the challenges and opportunities of developing countries. Since most joint flood-risk ecosystem system models target a limited range of potential benefits from flood-prone lands, we propose a framework in which we distinguish between livelihood benefits of direct human use and ecosystem services. We also propose exploring the role of coping capacity as an effective mechanism to manage flood risk while supporting multiple benefits from direct uses of flood-prone land. Because floodplain adaptation measures may involve risk-benefit trade-offs, we also introduce the concept of integrated assessment of flood risk and probabilistic benefits, which can be used as an information tool to support decision-making. Through parallel analysis of probabilistic damages and benefits, a broad suite of management actions may be evaluated to minimize flood risk while maximizing river-derived benefits.

Because further understanding of socio-ecological benefits and mechanisms to manage flood risk in developing countries is necessary, we evaluate livelihood benefits and coping capacity in Candaba floodplains, Philippines. Flood-prone communities in this area employ livelihood adaptations to seasonal inundation, such as adapting crop calendars to the flood pulse and shifting from dry-season agriculture to wet-season wild catch fisheries. Local people in this case accrue significant benefits (US $ 2,266/ha), which are comparable to the livelihood benefits in non-flooded villages of the area (US $ 2,746/ha). Such findings therefore suggest that neglecting benefits from direct floodplain use may significantly affect local livelihoods. Targeting coping capacities may hold promise in enhancing resilience to seasonal flooding while supporting socio-ecological values.

In this study, I also apply empirical evidence reported by local fishermen to characterize wild capture fisheries and their relation with flood severity in Candaba area. Findings from this assessment indicate that total fish capture productivity from the use of different technology (motorized and non-motorized boats) is significantly related to the intensity of inundation (R^2= 0.87 and 0.90, respectively). Wild fish capture yields in Candaba are therefore influenced by the effect of varying flood pulses. Based on this analysis, I derive wild fish benefit models which can be useful to evaluate potential benefits from the use flood-prone land in this area.

Following efforts to apply our proposed conceptual framework, I conducted an integrated assessment of flood risk and probabilistic benefits in Candaba. Findings from this analysis reveal that although the current "risky" use of flood-prone land (seasonal agriculture and wild fish capture) is associated with flood damage, probabilistic benefits are greater by a large margin (US $ 58 million). In addition, findings suggest that the probabilistic livelihood-benefits associated to direct human use scenarios ("risk" and "low risk") are greater (US $ 91 and 93 million) than those from an alternative scenario that entails livelihood activities compatible with flood storage/conservation (US $ 6 million). Furthermore, a scenario in which coping capacities such as adapting crop planting periods to the flood pulse of fishing rather than cultivating rice in the wet season are considered, indicates potential for minimum flood losses while allowing for valuable livelihood probabilistic benefits (US $ 125 million). For all scenarios of flood-prone land use, I also find that maximum probabilistic benefits are associated with high-frequency events (<1.3- to 2-year floods).

Overall, in this study we demonstrate the importance of taking into account the full range of flood events and their relation with both potential damages and benefits. In addition, that information given by risk-benefit profiles according to different scenarios of flood-prone land use can be useful to identify practices (*e.g.* land use policies and/or individual coping capacities), which can potentially yield maximum probabilistic benefits for the minimum risk. As such, management measures (structural and nonstructural) can be designed to reflect the local contexts and thus, support and maintain flood levels and uses that are necessary to secure local livelihoods and natural hydrologic processes, while minimizing potential flood damage.

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Appendix 1

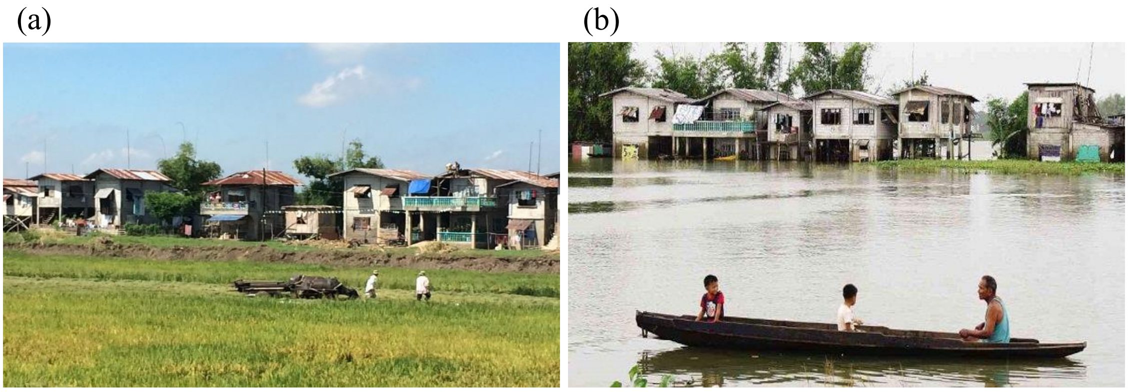


Figure A1. Land use during the (a) dry season and (b) wet season in the village of San Agustin, Candaba Municipality. Photo credits: (a) Andrea M. Juarez-Lucas; (b) Tonette Orejas

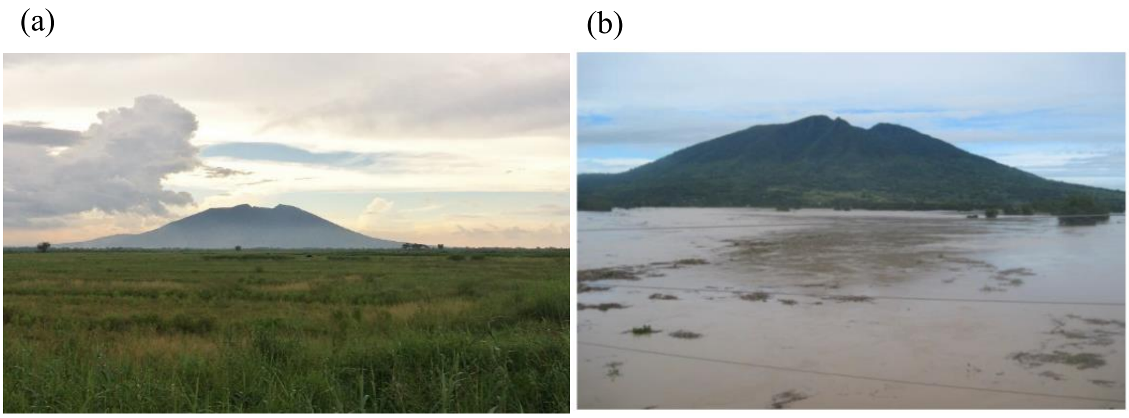


Figure A2. View of Mount Arayat from grasslands in Candaba swamp (a) dry season and (b) wet season. Photo credits: (a) Andrea M. Juarez-Lucas; (b) PRFFWC-PAGASA

(a) (b)

Figure A3. Wild fish capture activities in Candaba area during the wet season (a) use of screen and fishnet in waterways and (b) use of fishnet in open inundated floodplain. Photo credits: (a) Pampanga Talents ; (b) Ted Aljibe

Appendix 2

1. Questionnaire on flood risk and benefits from using inundation areas in Candaba Municipality (Households). *questions related only to livelihood activities are shown below

Question 6: Please also provide the following information about your main occupational activities.

1. **Please check which activities you perform each year and circle the months when you do them.**

Rice agriculture	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Agriculture (other crops)	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Fish farming (aquaculture)	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Wild fish capture	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Other:	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D

2. **What percentage (rough estimate) of your household income is gained through the following activities?**

Rice agriculture	. . . . (% of annual income)
Agriculture (other crops)	. . . . (% of annual income)
Fish farming (aquaculture)	. . . . (% of annual income)
Wild fish capture	. . . . (% of annual income)
Other:	. . . . (% of annual income)

3. **Please check the type of land where you perform the previous activities.**

Rice agriculture	Privately Own	/	Leasehold or Share tenancy	/	Municipal	/	Communal	/	Other
Agriculture (other crops)	Privately Own	/	Leasehold or Share tenancy	/	Municipal	/	Communal	/	Other
Fish farming (aquaculture)	Privately Own	/	Leasehold or Share tenancy	/	Municipal	/	Communal	/	Other
Wild fish capture	Privately Own	/	Leasehold or Share tenancy	/	Municipal	/	Communal	/	Other
Other:	Privately Own	/	Leasehold or Share tenancy	/	Municipal	/	Communal	/	Other

4. **Do you use the same land plot to perform any of the activities you have checked:** Yes / No

   If "Yes" please indicate which activities: . . . .

2. Questionnaire on flood risk and benefits from using inundation areas in Candaba Municipality (Barangay Leaders).

1. Please answer the following questions about occupational activities and land use in your Barangay.

i. Please check which of the following occupational activities are performed by the people living in your Barangay and circle the months when they do them.

Agriculture	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Duck production in rice plantations	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Aquaculture	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Eco-tourism (bird watching)	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D
Other:	Yes	/	No	J	F	M	A	M	J	J	A	S	O	N	D

i. Do people have rice plots or aquaculture plots outside the Barangay? Yes……… No………

ii. Which of the following activities often generate higher household incomes in your area? Please rank on a scale of 1-3: (1) highest, (2) medium, (3) lowest
(a) Agriculture only ………………
(b) Aquaculture only……………..
(c) Both agriculture (dry season) and aquaculture (wet season)……………..

iii. What is the approximate range of annual household income of people living in your Barangay?
From ………………. (Pesos) to ………………….. (Pesos)

iv. What percentage (rough estimate) of land is under the following types of land tenure in your Barangay?
(a) Privately own land ……………… (%)
(b) Leasehold or share tenancy land …………….. (%)
(c) Other…………….. (%)

2. Please answer the following questions about flood experiences in your Barangay.

i. Are there any areas in your Barangay that remain inundated every year throughout the entire flood season? Yes……… No………

ii. What percentage (rough estimate) of crop area in your Barangay was damaged by floods during the following years?
(a) 2013 …………….. (%)
(b) 2012 …………….. (%)
(c) 2011 …………….. (%)

iii. What percentage (rough estimate) of aquaculture area in your Barangay was damaged by floods during the following years?
(a) 2013 …………….. (%)
(b) 2012 …………….. (%)
(c) 2011 …………….. (%)

iv. Do people living in your Barangay find floods also beneficial to their agricultural and aquaculture activities? Yes…… No………

v. Which of the following years would you identify as good flood years for agricultural and aquaculture activities in your Barangay? Please select a year(s)

(a) 2013 ……………..
(b) 2012 ……………..
(c) 2011 ……………..
(d) 2010 ……………..
(e) 2009 ……………..
(f) Other years (please indicate)…………………

3. Questionnaire on flood risk and benefits from using flood-prone land in Candaba Municipality (semi-structured interviews with Barangay Leaders).

1. Please answer the following questions about occupational activities and land use in your Barangay.

ii. What are the main occupational activities of the people living the Barangay (e.g. agriculture, aquaculture, other)?

iii. Which occupational activity often generates the highest household income in the area?

iv. Do people who engage in agricultural activities sustain crop plantations during the dry season only or do they commonly grow crops during the wet season? Do people who engage in agricultural activities also perform aquaculture activities during the wet season?

v. Are the agricultural activities within the Barangay performed by the people living in this area only or are they also performed by people who live in other nearby Barangays?

vi. Please locate in the map the areas where crops plantations and aquaculture systems are often sustained.

vii. What is the average household income level of the people living in the Barangay (e.g. extremely low, low, average, or high)?

viii. What are the common types of land tenure in the Barangay (e.g. privately owned lands, leasehold or shared tenancy lands)?

2. Please answer the following questions about flood experiences in your Barangay.

vi. How often is your Barangay affected by floods and what type of damages do you experience the most (e.g. crops damage, aquaculture damage, house and property damage)?

vii. Please indicate if the seasonally inundated areas shown in the map are correct. Can you please indicate for how long these areas remain inundated? Can you also please indicate in the map which areas where inundated and for how long during the 2011 floods?

viii. What are the expected levels (depth and duration) of normal floods?

ix. In your opinion are there any benefits of using the flood-prone areas in your Barangay (e.g. place to live, opportunities for agriculture and fishery activities, both living and farming advantages, other)?

x. Which are the opportunities or advantages for the agricultural/aquaculture activities performed in the flood-prone lands?

xi. How the mentioned opportunities or advantages increase/decrease with respect to flooding?

3. Please answer the following questions about house settlements and other activities in your Barangay.

xii. Please locate in the map where residential houses are mainly concentrated in your Barangay.

xiii. What would you say is the main reason people choose to live in the flood-prone areas in your Barangay?

xiv. Does the majority of houses consist of two store residences or are built on top of stilts?

xv. Are there any bird watching activities for tourists organized by people living in your Barangay?

4. Questionnaire on flood risk and benefits from using flood-prone land in Candaba Municipality (semi-structure interviews with Barangay Leaders). *additional questions

1. How often is your area affected by floods?
2. Does your area remain inundated during the entire wet season? (If the answer is no, then how often and for how long does it get inundated during the wet season?)
3. What type of flood damages do you experience the most (e.g. crops damage, aquaculture damage, house and property damage, other)?
4. Can you name years in which floods in your area were normal/typical/average?
5. Can you tell the water level reached during the 2011 floods (in reference to a particular landmark or place)?
6. In your opinion, are there any benefits of using flood-prone areas (e.g. place to live, opportunities for agriculture and fishery activities, both living and farming advantages, eco-tourism, other)?
7. What are the opportunities or advantages for the agricultural/aquaculture activities you perform in the flood-prone land?
8. How do the mentioned opportunities or advantages increase/decrease with respect to flooding?
9. Do people who engage in agricultural activities sustain crop plantations during the dry season only?
10. Do people who engage in agricultural activities also perform aquaculture activities during the wet season?
11. Do people perform their agricultural or aquaculture activities in nearby Barangays? Which?
12. Are agricultural and aquaculture activities in your area mainly irrigated (or sustained by seasonal floods)?
13. Is there any type of tariff you pay (or people living in your area) for using irrigation water?
14. Are there any local irrigators/farmers/aquaculture/eco-tourism associations?
15. What would you say is the main reason people live in your area?

5. Data collection checklist on flood risk and benefits from using flood-prone land in Candaba Municipality (Government offices in Pampanga and Candaba area).

Category	Questions	Organization
Meteorological data	1. Do you have daily temperature and evapotranspiration records (time series) in Pampanga river basin?	PAGASA
Land use information	2. Do you have land use and development plans for Candaba municipality?	Pampanga Province office Candaba Municipality
	3. Do you have records of current land use and seasonal land use change in Candaba municipality?	Pampanga Province office Candaba Municipality
	4. Do you have information on existing types of land tenure in Candaba municipality (e.g. privately owned, leasehold or shared tenancy lands)?	Pampanga Province office Candaba Municipality
Agriculture and Fish production information	5. Do you have farming calendars for the following activities in Candaba municipality (AMRIS system)? -Rice crop plantations -Corn and watermelon plantations -Aquaculture	Pampanga Province office Candaba Municipality NIA offices
	6. Do you have records of annual yields for the following activities in Candaba municipality? -Rice crop plantations -Corn and watermelon plantations -Aquaculture	Pampanga Province office Candaba Municipality NIA offices BAS
	7. Do you have assessments of optimum water levels and duration for aquaculture activities?	Pampanga Province office Candaba Municipality NIA offices *Other?*
	8. Do you have information on requirements and costs of fertilizers for the following activities in Candaba municipality? -Rice crop plantations -Corn and watermelon plantations	Pampanga Province office Candaba Municipality BAS
	9. Do you have records of annual fertilizer use for the following activities in Candaba municipality? -Rice crop plantations -Corn and watermelon plantations	Pampanga Province office Candaba Municipality BAS
	10. Do you have yearly records of irrigation water supply and extent of irrigated areas in Candaba municipality (AMRIS system)?	Pampanga Province office Candaba Municipality NIA offices
	11. Do you have records of irrigation service fees in Candaba municipality (AMRIS system)?	Pampanga Province office Candaba Municipality NIA offices
	12. Do you have information on the use of floating gardens to grow vegetables in Candaba municipality or Pampanga province?	Pampanga Province office Candaba Municipality Philippine Rice Research Institute (Department of Agriculture)-Central Experiment Station

Residential use information	13. Do you have restrictions of land use and development in Candaba municipality and Pampanga province?	Pampanga Province office Candaba Municipality DPWH
	14. Do you have building codes/laws/guidelines specifically designed for flood prone areas within Candaba municipality and Pampanga province?	Pampanga Province office Candaba Municipality DPWH
Ecology and Nature conservation information	15. Do you have natural conservation plans for Candaba municipality?	Pampanga Province office Candaba Municipality DENR
	16. Do you have assessments of ecosystem services in Candaba municipality or Pampanga province?	Pampanga Province office Candaba Municipality DENR
	17. Do you have records of revenues from eco-tourism (bird watching) in Candaba municipality?	Pampanga Province office Candaba Municipality DENR

6. Questionnaire on flood risk and benefits from using flood-prone land in Candaba Municipality (semi-structured interviews with Government Officials). *additional questions

1. Do you have inundation maps or ground truth water level records of past flood events for Candaba area?
2. Do you have (daily/monthly) evaporation and temperature records of Pampanga river basin?
3. Do you have (daily/monthly) rainfall records of Pampanga river basin?
4. Do you have specific coordinates for water level stations in Pampanga river basin?
5. Which rating curves are normally used by your organization (JICA 2009, 2012)? Why?
6. Do you also have rating curves for Candaba and Sulipan water level stations?
7. Does Pantagaban dam have a significant effect on the Candaba swamp inundation dynamics?
8. Does Candaba floodway have a significant effect on the Candaba swamp inundation dynamics?
9. Do you have records of the diversion of waters in Candaba floodway?
10. Does overflow of secondary rivers have a significant effect on the Candaba swamp inundation dynamics?
11. What are the main influencing conditions that keep the duration/extent of inundation in Candaba swamp (natural/anthropogenic/both)?
12. Do you have any type of records of Candaba swamp inundation dynamics?
13. Do you have any records of serviced irrigated areas and water tariffs in Candaba area?
14. Does Candaba area remains inundated during the entire wet season? (If answer is no, then how often and for how long does it get inundated during the wet season?)
15. Can you name years in which floods in the basin were normal/typical/average?
16. Can you tell the water level reached during the 2011 floods (in reference to a particular landmark or place)?
17. In your opinion, are there any benefits of using flood-prone areas (e.g. place to live, opportunities for agriculture and fishery activities, both living and farming advantages, eco-tourism, other)?
18. What are the opportunities or advantages for the agricultural/aquaculture activities you perform in the flood-prone land?
19. How do the mentioned opportunities or advantages increase/decrease with respect to flooding?
20. Do people who engage in agricultural activities sustain crop plantations during the dry season only?

21. Do people who engage in agricultural activities also perform aquaculture activities during the wet season?

22. Do people perform their agricultural or aquaculture activities mainly in nearby Barangays? Which?

23. Are agricultural and aquaculture activities in Candaba area mainly irrigated (or sustained by seasonal floods)?

24. Is there any type of tariff people pay in Candaba area for using irrigation water?

25. Are there any local irrigators/farmers/aquaculture/eco-tourism associations?

7. Questionnaire on flood risk and coping capacity in flood-prone lands of Candaba Municipality (Barangay Leaders).

a) Please provide general information about your barangay.

1. Name of barangay: ________________________		
2. Total area of your barangay:	____________	ha
3. Total number of households in your barangay:	____________	No. households
4. Total population in your barangay:	____________	No. of people
5. Total number of farmers in your barangay:	____________	No. of farmers
6. Total number of fishermen in your barangay:	____________	No. of fishermen
7. Total number of people with other occupations in your barangay:	____________	No. of people (for example: store owners, drivers, construction workers, officers, etc.)
8. Please indicate the minimum annual income of people living in your barangay:	____________	Pesos (minimum annual income)
9. Please indicate the maximum annual income of people living in your barangay	____________	Pesos (maximum annual income)
10. Please indicate the average value of lands in your barangay:	____________	Pesos
11. Total number of two-story houses:	____________	No. of houses
12. Total number of elevated houses:	____________	No. of houses
13. Total number of households owning a craft:	____________	No. of households

b) Please provide information about floods in your barangay.

1. Please indicate for the following years:

	2013 "Maring"	2012 "SW Monsoon"	2011 "Pedring"	2009 "Pepeng"
Max. duration of inundated area	_______weeks	_______weeks	_______weeks	_______weeks
Max. water level	_______m	_______m	_______m	_______m
Min. water level	_______m	_______m	_______m	_______m
Damaged houses	_______total	_______total	_______total	_______total
Damaged roads	_______%	_______%	_______%	_______%
Evacuees	_______total	_______total	_______total	_______total
Evacuation centers	_______total	_______total	_______total	_______total
Affected families	_______total	_______total	_______total	_______total

2. Have there been other extreme flood experiences in your barangay? __________________

c) **Please answer the following questions about mechanisms to deal with floods in your barangay.**

1. **What are main mechanisms adopted by people in your barangay to deal with floods?**

Type of mechanism	Likelihood: 1 Unlikely	2 Even	3 Likely
Household preparedness: house buildings and assets			
1. Living in elevated/two-story house	1	2	3
2. Temporally move to elevated/two-story houses	1	2	3
3. Use flood-resistant construction materials	1	2	3
4. Store belongings on elevated ground	1	2	3
5. Keep yard animals on elevated ground	1	2	3
6. Store food/goods for periods of disrupted communication	1	2	3

Type of mechanism	Annually Likelihood: 1 Unlikely	2 Even	3 Likely	2011 "Pedring" Likelihood: 1 Unlikely	2 Even	3 Likely	Indicate number of years farmers have been implementing mechanism
Household preparedness: transportation/commuting							
1. Switch to motorized or non-motorized craft	1	2	3	1	2	3	
Household evacuation:							
2. Temporally move to evacuation centers	1	2	3	1	2	3	
Household Recovery:							
3. Claim flood-damage insurance	1	2	3	1	2	3	
4. Request micro-credits	1	2	3	1	2	3	
Community preparedness: infrastructure							
5. Elevated/levee roads	1	2	3	1	2	3	
Community recovery: infrastructure							
6. Effective restoration of damaged structures	1	2	3	1	2	3	
Other mechanisms:							
	1	2	3	1	2	3	
	1	2	3	1	2	3	
	1	2	3	1	2	3	

2. Which are the main reasons for adopting and supporting implementation of mechanisms to deal with floods in your barangay?

Household preparedness: house buildings and assets			
1. Living in two-story/ elevated house	2. Temporally move to elevated/two story houses	3. Use flood-resistant construction materials	4. Store belongings on elevated ground
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past floods ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past floods ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past floods ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past floods ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

Household preparedness: house buildings and assets (Cont.)		*Household preparedness: transportation/commuting*	*Household evacuation:*
5. Keep yard animals on elevated ground	6. Store belongings on elevated ground	7. Switch to motorized or non-motorized craft	8. Temporally move to evacuation centers
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

Household recovery:		*Community preparedness: infrastructure*	*Community recovery: infrastructure*
9. Claim flood-damage insurance	10. Request micro-credits	11. Elevated/levee roads	12. Effective restoration of damaged structures
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among Community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among Community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among Community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among Community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

Other mechanisms:			
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):	Check major factors supporting implementation of mechanisms (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

8. Questionnaire on flood risk and coping capacity in flood-prone lands of Candaba Municipality (Barangay Leaders of Fisheries Associations).

a) Please provide general information about your barangay.

1. Name of Barangay: ________________________
2. Total number of fishermen in your barangay: _____ No. of fishpond owners; _____ No. of people involved in river fish capture; _____ No. of people involved in seasonal flooded-area fish capture; _____
3. Please indicate the maximum duration of inundated area used for fish capture in your barangay: _____ No. of weeks
4. Please indicate the seasonal inundated area used for fish capture in your barangay: _____ ha
5. Total fishpond area in your barangay: _____ ha
6. Minimum fishpond depth in your barangay: _____ meters
7. Maximum fishpond depth in your barangay: _____ meters
8. Average height of raised nets in fishponds: _____ meters
9. Total number of fishery motorized crafts in your barangay: _____ No. of fishery motorized crafts
10. Total number of fishery non-motorized crafts in your barangay: _____ No. of fishery non-motorized crafts
11. Please indicate the main sources of consumption of captured fish in your barangay: ( ) Household consumption; ( ) Municipal market; Other buyers:_____________
12. Please indicate the minimum annual income of fishermen in your barangay: _____ Pesos (minimum annual income)
13. Please indicate the maximum annual income of fishermen in your barangay: _____ Pesos (maximum annual income)

b) Please provide information about agriculture activities in your barangay.

1. **Please indicate for the following years:**

	2013 "Maring"	2012 SW Monsoon	2011 "Pedring"	2009 "Pepeng"
Number of captured fish in seasonal flooded area	____fish/day	____fish/day	____fish/day	____fish/day
Fish yields from motorized crafts in seasonal flooded area	____Kg/day	____Kg/day	____Kg/day	____Kg/day
Fish yields from non-motorized crafts in seasonal flooded area	____Kg/day	____Kg/day	____Kg/day	____Kg/day
Fish price	____Pesos	____Pesos	____Pesos	____Pesos
Costs of aquaculture production	____Pesos	____Pesos	____Pesos	____Pesos
Fishpond area damaged/affected by floods	____ha	____ha	____ha	____ha

2. **Have there been any other extreme flood experiences in your barangay? ____________________**

c) Please answer the following questions about mechanisms to deal with floods in your barangay.

1. What are main mechanisms adopted by farmers in your barangay to deal with floods?

Type of mechanism	Annually			2011-"Pedring" (Sept., 16 – Oct., 4)			Indicate number of years farmers have been implementing mechanism
	Likelihood: ← →			Likelihood: ← →			
	1 Unlikely	2 Even	3 Likely	1 Unlikely	2 Even	3 Likely	
Preparedness: fishermen							
1. Avoid use of hazardous areas	1	2	3	1	2	3	
2. Fishpond owner combine fish with duck and *kangkong* production	1	2	3	1	2	3	
Preparedness: infrastructure							
3. Raised nets in fishponds to prevent fish loss	1	2	3	1	2	3	
During floods: fishermen							
4. Switch to fish capture in open flooded areas during wet season	1	2	3	1	2	3	
5. Obtain food or materials from other resources	1	2	3	1	2	3	
6. Sustain diverse or multiple sources of income	1	2	3	1	2	3	
7. Seasonal migration	1	2	3	1	2	3	
8. Temporally work outside barangay	1	2	3	1	2	3	
Recovery:							
9. Community members support affected households	1	2	3	1	2	3	
10. Effective access to relief support	1	2	3	1	2	3	
Other mechanisms:							
	1	2	3	1	2	3	
	1	2	3	1	2	3	
	1	2	3	1	2	3	
	1	2	3	1	2	3	

2. What are main mechanisms adopted by farmers in your barangay to deal with floods?

Preparedness: fishermen		*Preparedness: infrastructure*
1. Avoid use of hazardous areas	2. Fishpond owner combine fish with duck and *kangkong* production	3. Raised nets in fishponds to prevent fish loss
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

During floods: fishermen			
4. Switch to fish capture in open flooded areas during wet season	5. Obtain food or materials from other resources	6. Sustain diverse or multiple sources of income	7. Seasonal migration
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

During floods (continuation): fishermen	*Recovery:*		*Other mechanisms:*
8. Temporally work outside barangay	9. Community members support affected households	10. Effective access to relief support	
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

Other mechanisms (continuation):	
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Assistance from government ( ) Perceived effectiveness of strategy

9. Questionnaire on flood risk and coping capacity in flood-prone lands of Candaba Municipality (Barangay Leaders of Agriculture Associations).

a) Please provide general information about your barangay.

1. Name of Barangay: ________________________
2. Total number of farmers in your barangay: _______________ No. of farmers
3. Total agricultural area in your barangay: _______________ ha
4. Please check the main types of crops in your barangay: ( ) Rice ( ) Corn ( ) Watermelon ( ) Vegetables Other: ________________
5. Please check the main sources of consumption of harvested crops in your barangay: ( ) Household consumption ( ) Municipal market Other buyers:____________
6. Please indicate the maximum duration of inundation in agricultural areas in your barangay: _______________ No. of days
7. Please indicate the number of rice crop planting in a year in your barangay: _______________ No. of rice planting in a year
8. Please indicate the minimum income of farmers per rice harvest in your barangay: _______________ Pesos (minimum income per rice harvest)
9. Please indicate the maximum income of farmers per rice harvest in your barangay: _______________ Pesos (maximum income per rice harvest)

b) Please provide information about agriculture activities in your barangay.

3. Please indicate for the following years:

	2014	2013	2012	2011
Gross rice yields (dry season)	______Kg ______ha	______Kg ______ha	______Kg ______ha	______Kg ______ha
Gross rice yields (wet season)	______Kg ______ha	______Kg ______ha	______Kg ______ha	______Kg ______ha
Palay price (dry season)	______Pesos/Kg	______Pesos/Kg	______Pesos/Kg	______Pesos/Kg
Palay price (wet season)	______Pesos/Kg	______Pesos/Kg	______Pesos/Kg	______Pesos/Kg
Cost of rice production (dry season)	______Pesos	______Pesos	______Pesos	______Pesos
Cost of rice production (wet season)	______Pesos	______Pesos	______Pesos	______Pesos
	2013-“Maring”	2012-SW Monsoon	2011-“Pedring”	2009-“Pepeng”
Damaged rice crops by floods	______ha	______ha	______ha	______ha

4. Have there been any other extreme flood experiences in your barangay? ___________________

c) Please answer the following questions about mechanisms to deal with floods in your barangay.

1. What are main mechanisms adopted by farmers in your barangay to deal with floods?

Type of mechanism	Annually			2011-"Pedring" (Sept., 16 – Oct., 4)			Indicate number of years farmers have been implementing mechanism
	Likelihood: ← →			Likelihood: ← →			
	1 Unlikely	2 Even	3 Likely	1 Unlikely	2 Even	3 Likely	
Preparedness:							
1. Plant flood-tolerant rice	1	2	3	1	2	3	
2. Plant in dry season only	1	2	3	1	2	3	
3. Avoid use of hazardous areas	1	2	3	1	2	3	
4. Save/store agriculture products for wet season	1	2	3	1	2	3	
ring floods:							
5. Adjust crop calendar	1	2	3	1	2	3	
6. Early harvest	1	2	3	1	2	3	
7. Switch agriculture to fish capture in wet season	1	2	3	1	2	3	
8. Obtain food or materials from other resources	1	2	3	1	2	3	
9. Sustain diverse or multiple sources of income	1	2	3	1	2	3	
10. Seasonal migration	1	2	3	1	2	3	
11. Temporally work outside barangay	1	2	3	1	2	3	
covery:							
12. Community members support affected households	1	2	3	1	2	3	
13. Effective access to relief support	1	2	3	1	2	3	
Other mechanisms:							
	1	2	3	1	2	3	
	1	2	3	1	2	3	
	1	2	3	1	2	3	
	1	2	3	1	2	3	

2. Which are the main reasons for adopting and supporting the mechanisms to deal with floods in your barangay?

Preparedness:			
1. Plant flood-tolerant rice	2. Plant in dry season only	3. Avoid use of hazardous areas	4. Save/store agriculture products for wet season
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy

During floods:			
5. Adjust crop calendar	6. Early harvest	7. Switch agriculture to fish capture in wet season	8. Obtain food or materials from other resources
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy

During floods (continuation):			*Recovery:*
9. Sustain diverse or multiple sources of income	10. Seasonal migration	11. Temporally work outside barangay	12. Community members support affected households
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy

Recovery (continuation):	*Other mechanisms:*		
13. Effective access to relief support			
Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):	Check main triggers for adopting mechanism (1-3 max.):
( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area	( ) Inherited from previous generations ( ) Learned experience from past flood events ( ) Capacity and awareness programs ( ) Best strategy among alternatives ( ) Reduce damage/loss for benefits of living/using the area
Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):	Check major factors supporting implementation of mechanism (3- 5 max.):
( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy	( ) High flood water levels ( ) Long duration of floods ( ) Strong flood current ( ) Ability to afford/access equipment ( ) High income ( ) Keeping skills, knowledge and awareness updated ( ) Trust and solidarity among community members/leaders ( ) Active support from local groups, committees, associations ( ) Active support/assistance from government ( ) Perceived effectiveness of strategy

10. Questionnaire on the recreational value of the Wildlife Reserve (Bird Sanctuary) Vizal San Pablo, Candaba Municipality (semi-structured interviews with key informants).

a) General information of key informant.

10. Name of informant: ____	
11. Occupation: ____	
12. Location of residence: ______________________________________	
13. Please indicate source of information:	land owner ☐ site's manager/administrator ☐ tour guide ☐ municipal officer at tourist center ☐

b) General information on the Wildlife Reserve.

14. When was the Wildlife Reserve (Bird Sanctuary) established? _______________________________________	
15. What is the total area (ha) of the Reserve? ____	
16. Please indicate which are the main recreational attractions at the Reserve:	birdwatching ☐ walking trails ☐ camping ☐ fishing ☐ environmental education ☐ other:________________
17. Please indicate the type of land use and area (ha) before the Reserve was established during the wet and dry seasons, respectively:	Dry season: Land use / Area(ha) Wet season: Land use / Area(ha)
18. Please indicate the current land use and area (ha) in the Reserve during the wet and dry seasons, respectively:	Dry season: Land use / Area(ha) Wet season: Land use / Area(ha)
19. Please indicate which of the following land management practices are implemented in the Reserve:	natural regeneration of vegetation ☐ reforestation ☐ natural flooding ☐ natural drainage ☐ artificial drainage ☐ shifting cultivation ☐ other: ___________________

c) General information of visitors.

20. When is the Reserve open for visitors? Indicate the months:	Jan☐ Feb☐ Mar☐ Apr☐ May☐ Jun☐ Jul☐ Aug☐ Sep☐ Oct☐ Nov☐ Dec☐
21. What is the visiting schedule? Indicate opening days and hours:	Mon☐ Tue☐ Wed☐ Thru☐ Fri☐ _______________________hours Sat☐ Sun☐ _______________________hours
22. Please indicate how often do people visit the area:	daily ☐ weekly ☐ monthly ☐ every 2 months ☐ every 3 months ☐ Other: ________________

23. When do people visit the area the most? Indicate the months and days in a week:	Jan ☐ Feb ☐ Mar ☐ Apr ☐ May ☐ Jun ☐ Jul ☐ Aug ☐ Sep ☐ Oct ☐ Nov ☐ Dec ☐ Mon ☐ Tue ☐ Wed ☐ Thru ☐ Fri ☐ Sat ☐ Sun ☐
24. What is the estimated total number of visitors in a year? ______________________________	
25. Please indicate the percentage of annual visitors according to their type of trip:	Individual_______% Family_______% Group________% Other:________%
26. Please indicate the percentage of annual visitors according to their nationality:	Filipino_________% Foreigner_______%
27. Please indicate the percentage of annual local visitors according to their place of residence:	Candaba Municipality__________% Pampanga province____________% Nueva Ecija province____________% Bulacan province____________% Metro Manila___________% Other_________%

d) Value of site to visitors.

28. Please indicate the average time visitors spend at the site:	3 hours or less ☐ 3-6 hours ☐ 6-9 hours ☐ 9-12 hours ☐ 12-24 hours ☐ 24 hours or more ☐ If time spent at site is more than 24 hours, please indicate the average number of days:_____________
29. Please indicate the percentage of main purpose of visits:	Recreational_________% Scientific/Research_______% Environmental education________% Other:______________%
30. Please indicate the percentage of preferred recreational activity by visitors:	Birdwatching________% Site's walking trails________% Camping_______% Fishing _______% Landscape appreciation______% Other:__________%
31. What is the entrance fee per person?	________________PHP
32. What is the lodging fee per person?	________________PHP/day
33. Please indicate any other relevant expenses of visitors in the area (e.g. tours, food, drinks, etc.):	<table><tr><th>Type of expense</th><th>Estimated amount (PHP)</th></tr><tr><td></td><td></td></tr></table>

e) Information on access to site.

<table>
<tr><td>34. Please indicate the main type of transportation used by visitors to access the site:</td><td>Bus and tricycle ☐ Tricycle only ☐ Vehicle ☐</td></tr>
<tr><td>35. Please indicate the key access points to reach the site from Metro Manila:</td><td><table><tr><th>Access points
from Metro Manila to Bird Sanctuary</th></tr><tr><td></td></tr></table></td></tr>
<tr><td>36. Please indicate the approximate one-way travel cost from Metro Manila to the Reserve:</td><td><table><tr><th>Bus
fare (PHP)</th><th>Tricycle fare
(PHP)</th><th>Vehicle
(PHP cost/km)</th></tr><tr><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>37. Please indicate the approximate one-way travel time from Metro Manila to the Reserve:</td><td><table><tr><th>Bus travel
time</th><th>Tricycle
travel time</th><th>Vehicle
travel time</th></tr><tr><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>38. Please indicate the approximate one-way travel distance from Metro Manila to the Reserve:</td><td>_____________km</td></tr>
<tr><td>39. Please indicate other important access points to reach the site when traveling from areas other than Metro Manila:</td><td><table><tr><th>Other access points to the Bird Sanctuary</th></tr><tr><td></td></tr></table></td></tr>
</table>

11. Questionnaire on fisheries activities at barangay level, Candaba Municipality (semi-structured interviews with Fisher Folks).

IMPORTANT NOTE: Interviews should only include information about wild fish-capture activities in open flooded areas during the WET SEASON. Information on fishing methods during the dry season, for example use of fyke nets "*bokatot*" and catch basins "salandra", and permanent fish ponds should not be included in this survey. Only general information on fishing methods and other activities during the dry season should be included in section a) questions 6 and 7.

a) General information of fisher folks.

1. Name of fisher folk: ___________________________________	
2. Age:	15-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ >60 ☐
3. Gender:	F ☐ M ☐
4. Please indicate your average income per day from wild fish capture in open flooded areas during the wet season:	______________PHP/day
5. Please indicate the months when you do fishing activities during the wet season:	May ☐ Jun ☐ Jul ☐ Aug ☐ Sep ☐ Oct ☐ Nov ☐
6. Please indicate what activities you do during the dry season:	agriculture ☐ fishing ☐ other ☐
7. Please indicate what type of fishing activity do you practice during the dry season:	None ☐ specify fishing activities:________________________

b) Fishing technology and man effort during the wet season.

8. What type of fishing gear do you use to capture wild fish from open flooded areas in the wet season?	fly rod and reel ☐ hook and line ☐ small fishnet ☐ fishpot/fish trap ☐ fishnet "*lambat*" ☐ fish cage ☐ temporal fishpond ☐ other:_____________
9. What type of fish craft (*banca*) do you use to capture wild fish from open flooded areas in the wet season?	None ☐ Motorized ☐ Non-motorized ☐
10. Please indicate the number of people per day that help you capture wild fish from open flooded areas in the wet season:	None ☐ 1 ☐ 2 ☐ 3 ☐ 4 or more ☐
11. How many hours a day do you spend capturing wild fish from open flooded areas in the wet season?	1-2 per day ☐ 2-4 per day ☐ 4-6 per day ☐ 6-8 per day ☐ 8 or more ☐
40. How many days a month do you spend capturing wild fish from open flooded areas in the wet season?	1 day ☐ 2 days ☐ 3 days ☐ 3-5 days ☐ 5-7 days ☐ 7-14 days ☐ 14-30 days ☐

41. When do you <u>capture</u> wild fish from open flooded areas? Indicate the time and months during the wet season:	at the onset of wet season only ☐ after typhoon season only ☐ during the onset of wet and typhoon seasons ☐ Specific months: May ☐ Jun ☐ Jul ☐ Aug ☐ Sep ☐ Oct ☐ Nov ☐

c) Fishing costs during the wet season.

42. Please indicate the estimated cost of fishing gear you use to capture wild fish from open flooded areas in the wet season:	_______________PHP
43. For motorized crafts used in wild fish capture during the wet season, please indicate the following: Estimated diesel cost per day Size of motor Operation hours of motor per day	___________PHP ___________motor HP ___________hours/day

d) Flood height and fishing yields.

44. Please indicate, the approximate flooded area (ha) where you capture wild fish during the wet season:	_______ha
45. Please indicate, what is the minimum flood height for capturing wild fish from open flooded areas in the wet season?	__________meters
46. How much wild fish do you catch per day when flood height is 0.5 meter in open flooded areas in the wet season?	_____kg/day
47. How much wild fish do you catch per day when flood height r is 1 meter in open flooded areas in the wet season?	_____kg/day
48. How much wild fish do you catch per day when flood height is 2 meters in open flooded areas in the wet season?	_____kg/day
49. How much wild fish do you catch per day when flood height is 3 meters in open flooded areas in the wet season? for example, during "Pepeng" in 2009	_____kg/day
50. How much wild fish do you catch per day when flood height is 4 meters in open flooded areas in the wet season? for example, during "Pedring" in 2011	_____kg/day
51. Please indicate, what is the maximum flood height for capturing wild fish from open flooded areas in the wet season?	__________meters

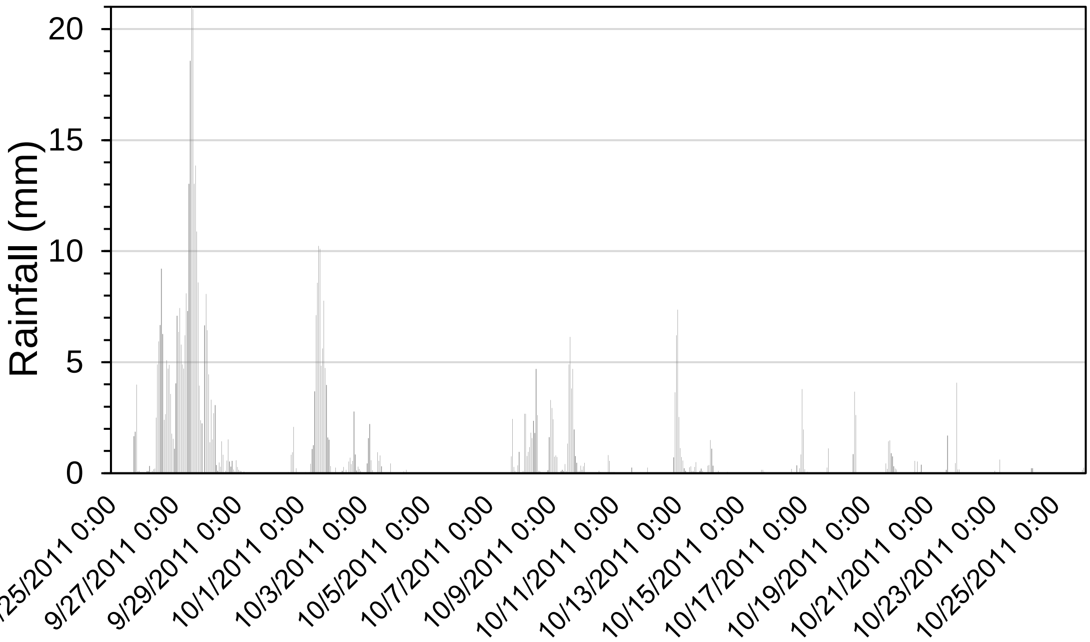
52. Please indicate the percentage of catch per day according to the type of fish in the wet season (e.g. tilapia, catfish, mudfish, other):	<table><tr><th>Type of fish/day</th><th>Percentage (%)</th></tr><tr><td>Tilapia Catfish Mudfish Other:______</td><td></td></tr></table>
53. Please indicate how much captured fish from open flooded areas is lost or disposed of in the wet season:	________kg/day

e) Fish catch value.

54. Please indicate the percentage of captured wild fish from open flooded areas in the wet season according to type use/sale:	Household consumption________% Sale to intermediary_________% Direct sale to market________%
55. Please indicate the sales price of captured wild fish from open flooded areas in the wet season according to type of fish:	<table><tr><th>Type of fish</th><th>PHP/kg</th></tr><tr><td>Tilapia Catfish Mudfish Other:_________</td><td></td></tr></table>

Figure A4. Field survey activities conducted in Candaba area: data collection in (a) provincial and (b) municipal offices; (c) focus group with local leaders in San Agustin; and interviews to (d) barangay leaders, (e) household owners, and (f) fisher folks. Photo credits: Andrea M. Juarez-Lucas

Appendix 3



A5. Design rainfall pattern (Sep 25-Oct 25, 2011).