Flood risk management under climate change: a hydro-economic perspective

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ABSTRACT

Most developing countries, like Nepal, are expected to experience the greatest impact of climate change (CC) sooner and on a greater magnitude than other developed countries. Increase in the magnitude and frequency of extreme rainfall events is likely to increase the risk of flooding in rivers. The West Rapti River basin is one of the most flood prone and also one of the most dynamic and economically important basins of Nepal. This study elicits the willingness to pay (WTP) from the local people in the basin to reduce risks from possible floods due to CC. The WTP for flood mitigation in different flood hazard zones and flood scenarios were determined using referendum method and a face to face questionnaire survey. From a total of 720 households across all flood zones, a stratified randomly selected sample of 210 households was surveyed. The sample included households from a range of socio-economic backgrounds. The average WTP varied by flood hazard zone and within each zone, by CC-induced flood scenarios. The average WTP of respondents was highest for the critical flood prone zone, followed by moderate and low flood prone zones. Similarly, within each zone, the average WTP increased with increasing flood magnitudes due to CC. The variation of average WTP of respondents in different flood prone zones and scenarios indicate different levels of perceived severity. Moreover, the introduction of the concept of 'man-day' or 'labour-day' in WTP research is a novel and applicable methodological approach, particularly in the South Asian region. The findings of this study are useful for policy implications for the design of participatory flood management plans in the river basin.

Key words | climate change, flood scenarios, willingness to pay

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INTRODUCTION

Most developing countries are in tropical or arid regions, and are expected to experience the greatest impact of climate change (CC) sooner and on a greater magnitude than temperate regions (FAO 2017). Nepal is a developing country lying at the central part of the Himalayan range (Maraseni *et al.* 2005, 2014). The average annual rainfall of the country is about 1,750 mm, ranging from more than 5,000 mm in the central part to less than 250 mm in the higher Himalaya in the north (Maraseni *et al.* 2014; Shrestha *et al.* 2014). Summer monsoon brings around 80% of the annual rainfall in Nepal, the rain being more intense in the east, declining westwards, while the winter rain falls heavily in the north-west and declines to the southeast. Higher intensity rainfall but fewer rainy days, with no significant change in the total amount of annual precipitation has been experienced in recent years (Botzen 2013; Devkota *et al.* 2016). Since there is a direct relationship between rainfall and river flow, the probability of occurrence of flooding events in the country has increased recently. The aim of this study is to determine the level of willingness to pay (WTP) for flood risk management under CC in the West Rapti River Basin in Nepal.

How people perceive CC directly influences their willingness to pay (WTP) to reduce the associated risks. Veronesi *et al.* (2014) and Zhai & Suzuki (2008) report that perceptions of CC with regard to long term changes in temperature and/or an increase in rainfall positively affect the WTP for the

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reduction of such risks. Similarly, taking predicted future average temperatures as an indicator of CC, Akter & Bennett (2011) show that individuals who accept these predictions are likely to exhibit a higher WTP for mitigation measures. Conversely, people who believe that temperatures are not rising globally or locally are less likely to be willing to pay for such preventive actions (Carlsson *et al.* 2012; Botzen & van den Bergh 2012). People who perceive long term changes in climate are more willing to pay to reduce the climate related risks than people that do not perceive any change (O'Neill *et al.* 2016).

Several studies (Hoffman & Spitzer 1993; Meyerhoff 2006) have helped identify different dimensions of WTP, especially when climate related damage is more likely expected to increase in the coming decades. Tol (2013) estimated that the global average costs of CC damage lie between 2% and 3% of global GDP. Application of economic instruments for environmental management has been dealt with by O'Connor (1996) and Osberghaus (2017). Liebe *et al.* (2011) and Lytle & Poff (2004) highlight the importance of WTP for disaster insurance so that insurers can assess the future profitability of offering coverage against damage caused by natural disasters. Insurance demand increases with increased flood probabilities due to CC and increased levels of expected flood damage (Wertenbroch & Skiera 2002; Zhai *et al.* 2006; Botzen *et al.* 2009; Lo 2013). In industrialized countries, the WTP for the (uninterrupted) provision of potable water to households or the willingness to accept interruption was elicited (Ghanbarpour *et al.* 2014). The study found a high WTP, not only to secure the households' own water provision, but also to maintain a good ecological status of the river. WTP is further constrained by household income and the disutility from flood risks measured through higher or lower flood damage costs and risk aversion according to people's attitude to flood protection (Lera-López *et al.* 2012). WTP for flood mitigation or amelioration among owners of houses, agricultural and forest lands varies according to individual location, dependency on natural resources, income and social situation (Hall *et al.* 2003; Maraseni *et al.* 2005; Maraseni & Xinquan 2011) and exposure to CC induced flood scenarios. However, the relationship between such flood risks and WTP for flood mitigation has not yet been examined at the community level of underdeveloped countries like Nepal.

It is therefore possible to evaluate the WTP for flood mitigation by the flood affected people under climatic uncertainty, so that an assessment can be made of the perception of the community about flood risk management. The results of this study, therefore, provide a basis for the appraisal of policy options, allocation of resources and monitoring performance of substantial government investment in flood management (Hensher *et al.* 2005). Such assessments are important to support policy makers' decisions on how to deal with emerging risks of CC in the water sector and where to set priorities.

THE STUDY AREA

The West Rapti River (WRR) originates in the Lesser Himalaya and flows through the Siwaliks and Terai plain of Nepal before joining the Ganga River in India. Geographically, the study area extends from 27°56′50″ to 28°02′30″ North latitudes and 81°45′00″ to 81°40′00″ East longitudes. The total catchment area within the Nepalese territory is 6,500 km^2 and the elevation varies from about 131 m (at the Indian border) to 3,620 m above the sea level. About 45% of the basin consists of hills, whereas the remaining 55% is occupied by plains of the Nepal in Terai. The basin includes two districts of Nepal, namely, Dang and Banke (Figure 1). There are 39 Village Development Committees (VDCs) and two municipalities in Dang, whereas 46 VDCs and one municipality in Banke. Among these, only five VDCs (Gangapur, Kamdi, Holiya, Lalmatiya and Sohanpur) with 720 households are affected by floods (CBS 2012).

METHODOLOGY

The study area was classified into three different zones or strata based on the extent of previous flooding (i.e. depth of the inundation and the frequency of flooding). These are identified as: the critical flood prone zone (Zone 1); moderate flood prone zone (Zone 2); and low flood prone zone (Zone 3). The total household (HH) numbers in each zone were derived from the District Development Committee profile: 144 in the HH critical zone; 274 in the moderate zone; and 302 in the low flood prone zone. Initially, stratified random sampling with

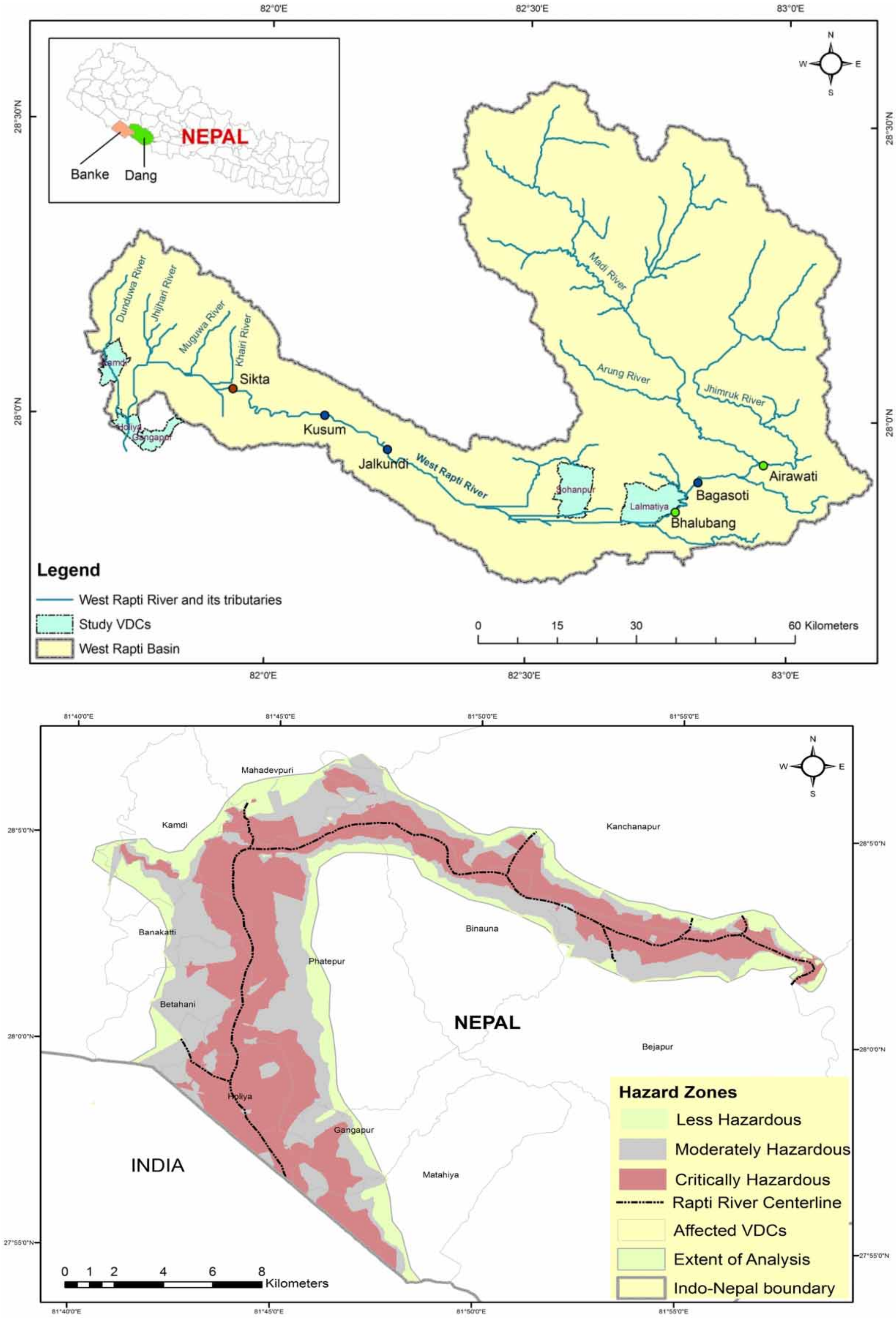

Figure 1 | Location map of study area with flood severity zones (West Rapti River Basin of Nepal).

proportion to HH number was considered as a basis of allocating the sampling effort in each zones. However, for obvious reasons, the critical flood prone zone had more serious flood related problems than the other two zones. Therefore, more samples were taken from Zone 1 (38%) than from Zone 2 (30%) or Zone 3 (24%) (Table 4). In each of the zones, HHs were allocated a number and HHs to be sampled were selected randomly using a random number table so that each and every HH had an equal chance of being selected. Finally, out of 720 flood affected HHs, 210 HHs were selected to participate in the face-to-face semi-structured questionnaire survey. Prior to conducting the survey, the questionnaire was pre-tested with the focus groups and translated into Nepalese language.

In each HH, the head of the HH, who was deeply involved in all financial and flood related activities, was interviewed. If the head of a HH was not available, another senior member available at the house was interviewed. If none is available at the first attempt, some additional attempts (up to five) were made until someone was interviewed from the selected HH. Therefore, the response rate of selected HH was 100%.

Contingent valuation (CV) method extracted WTP for minimum water quality levels for boating, fishing or swimming in the United States. This was followed by a later large study concerning the value of water quality (Viscusi *et al.* 2008). A similar study was conducted by Roberts *et al.* (2008), examining uncertainty of people's WTP for flood risk management in developed countries. However, for developing countries, a different approach is more appropriate for measuring the WTP at the grass root level. In such countries, where most of the people are unemployed and, thus, their income levels are very low, using 'man-day' as a unit of WTP is a promising approach. In this study, the National Oceanic and Atmospheric Administration Panel (NOAA) guidelines (Arrow *et al.* 1993) were strictly followed and WTP for mitigating floods under different flood scenarios were estimated with the man-day approach.

Scenario development

The Government of Nepal (GoN) envisages managing the flood problem in the WRR as a priority basin (GoN/ADB 2016). This is expected to reduce: (1) the risk of casualties; (2) the loss of private properties such as houses, agricultural and forest lands, livestock, etc.; and (3) the loss and damage of public lands and infrastructure. By developing flood controlling mechanisms, the GoN plans to guarantee protection of lives, private and public goods, and property.

Four CC induced flood scenarios (in terms of inundation depth and water logging time were proposed: (I) the current flood scenario; (II) a flood scenario for 2030; (III) a flood scenario for 2070; and (IV) a flood scenario for 2100. Readers are referred to (Devkota 2014) for details. During the survey, all the four flood scenarios were shown on a map and also on a laptop to the community (Devkota *et al.* 2014). Information of various flood prone areas, depth and its frequencies were presented for different scenarios. Through this process, respondents were quickly able to calculate their damage costs corresponding to the flood scenarios and come up with their WTP accordingly. It is assumed that when respondents calculate the amount that they are willing to pay for flood mitigation under each scenario, they take into account the expected flood damage to their property. Respondents were informed of the importance this study could have to the government and other stakeholders for developing and implementing flood mitigation policies.

Pre-testing of questionnaire and its final setting

In order to produce the WTP of respondents, a bidding game method was used. During the reconnaissance survey, the questions were pre-tested and refined using words/language which was locally appropriate to the group of people being interviewed. The wording of the question was as follows:

> *Would you vote in favour of reducing your annual loss due to flood in terms of labour days each year to protect life and properties?*
>
> *Yes / No*

If 'yes', what would be the highest amount/labour days you would pay per year?

Flood scenarios	Scenario I	Scenario II	Scenario III	Scenario IV
WTP in labour days				

If 'no', why do you say 'no'? What is the least amount/labour days you would pay?

Flood scenarios	Scenario I	Scenario II	Scenario III	Scenario IV
WTP in labour days				

Respondents' characteristics

In order to triangulate the validity of the responses, WTP values were cross-checked with the estimated (by respondents) damage costs of flood to agricultural crops and livestock, and impacts on their total income, as was done in Maraseni *et al.* (2008). Appropriate statistical tests were conducted to see whether there were any statistically significant differences in WTPs associated with income and damage cost classes.

We were aware of flaws of WTP method. One of the major drawbacks of WTP method is that it seeks responses to a hypothetical question that do not involve cash outlays. Therefore, they may overstate their WTPs. In order to avoid this problem: (1) wording of questions were carefully chosen; (2) they were given an option of labour-day (man-day, instead of cash) as a means of WTP so that they know the real value of their response; and (3) they were reminded that their disposable incomes will decrease by the same amount. Moreover, the context and scenarios were briefed many times in a plain language until they clearly understood the issues and possible implications.

RESULTS

Willingness to pay by flood zones

Whether there are any differences in WTP between the respondents living in different flood prone areas is a key question for policy makers. In order to answer this question, the study area was divided into three flood severity zones (low, moderate and critical) and WTP were assessed for each zone and for all four flood scenarios.

As expected, the average WTP of respondents was highest within the critical flood prone zone and the lowest in the low flood prone zone (Table 1). Similarly, the average WTP of respondents increased from Scenario I to Scenario IV.

Table 1 | Willingness to pay by flood zones

Flood prone areas (zones)	WTP (man-days/yr) for Scenario I	WTP (man-days/yr) for Scenario II	WTP (man-days/yr) for Scenario III	WTP (man-days/yr) for Scenario IV	F value	Significance
Critical flood prone (Zone 1) ($N = 54$)						
Mean	4.67	6.93	8.37	10.22	4.51	**0.004**
SD	1.74	2.77	3.21	3.47		
Moderate flood prone (Zone 2) ($N = 83$)						
Mean	4.34	5.81	7.73	9.76	2.93	**0.009**
SD	1.73	2.18	2.59	3.27		
Low flood prone (Zone 3) ($N = 73$)						
Mean	3.78	5.37	6.77	8.55	3.13	**0.006**
SD	1.44	2.26	2.68	3.22		
F value	4.85	6.92	5.39	4.56		
Significance (*p*-value)	**0.009**	**0.001**	**0.005**	**0.012**		
Total ($N = 210$)						
Mean	4.23	5.94	7.56	9.46		
SD	1.67	2.44	2.85	3.36		

Scenario I = current flood situation; Scenario II = potential flood level for 2030; Scenario III = potential flood level for 2070; and Scenario IV = potential flood level for 2100.

The average WTP of respondents between the different zones were statistically significantly different ($p < 0.05$), as were WTPs within the flood hazard zones for the various scenarios ($p < 0.05$).

Income of respondents by flood prone zones

WTP for flood mitigation actions could also be influenced by income level, especially those incomes which are directly affected by flooding. Farm and livestock are the major sources of income in the study area and are highly impacted by floods. Table 2 presents the survey results for average farm and livestock incomes within each flood zone. The highest average farm and livestock income was reported by respondents within the critical flood prone area, followed in turn by those in the moderate and low flood prone areas. This may, in part, be due to the larger size of farms and higher reliance on farming and livestock activities in the critical flood prone area compared to other areas.

Average annual damage cost of respondents by flood zones

Another factor that critically affects the WTP of respondents is flood related damage costs already incurred (Zhai 2006).

Table 2 | Farm and livestock income by flood zones

Flood prone areas (zones)	Farm income (US$)	Livestock income (US$)[a]
Critical flood prone ($N = 54$)		
Mean	1,652	218
SD	952	244
Moderate flood prone ($N = 83$)		
Mean	1,228	211
SD	779	213
Low flood prone ($N = 73$)		
Mean	1,132	164
SD	538	206
Total ($N = 210$)		
Mean	1,328	197
SD	780	219

[a]*Note: Conversion rate: US$1 = NRs92 (Date 25/04/2014).*

The WTP for different flood zones and average annual damage from 2010 to 2014 is shown in Table 3. As expected, the low flood prone zone has the lowest average annual damage per family (US$88) during that period. The average damage cost is higher in the moderately affected zone and highest in the critically affected zone. The mean WTP of these three zones are statistically significantly different ($p < 0.000$) at over 99.99% confidence level.

DISCUSSION

The application of WTP in terms of man-days or labour-days is rare in the developing world and is particularly novel to this South Asian Region. This is very useful for developing countries that is something they can contribute easily (culturally acceptable, too), where a man-day is very easy to explain and commonly understood. Total average annual household income of the study area is about US$1,328 (Table 4), while average annual livestock income is US$197. The total farm and livestock income is slightly higher than the national average (US$1,256). More than 50% of the flood plain residents included in the study

Table 3 | Average annual damage in last 5 years by flood zones

Flood prone areas (zones)	Average annual damage cost in last 5 years (US$)
Critical flood prone ($N = 54$)	
Mean	147
SD	100
Moderate flood prone ($N = 83$)	
Mean	106
SD	75
Low flood prone ($N = 73$)	
Mean	88
SD	57
Total ($N = 210$)	
Mean	110
SD	80
Significance (p-value)	**0.000**

Source: Field survey.

Table 4 | Summary of willingness to pay

Flood prone areas	Sample size (210) House hold no.	Income (US$) Farm	Livestock	Flood damage (2010–2014) (US$)	Willingness to pay (US$) Scenario I	Scenario II	Scenario III	Scenario IV
Critical flood prone (Zone 1)	54	1,652	218	147	18	26	31	39
Moderate flood prone zone (Zone 2)	83	1,228	211	106	16	22	23	37
Low flood prone (Zone 3)	73	1,132	164	88	14	20	20	32
Average		**1,328**	**197**	**110**	**17**	**22**	**28**	**36**

appear to live below the poverty line (<US$2 per day) (Bhirthal & Digvijay 2012).

The average WTP of respondents decreased from the critical to low flood prone zones and, within each zone, WTP increased from Scenario I to Scenario IV. As noted, the average WTP for Scenario IV was the highest (equivalent to US$36), followed by Scenario III (US$28), Scenario II (US$22) and Scenario I (US$17). Considering the scale and magnitude of flood damage, these figures seem realistic. In addition, WTPs were positively correlated with livestock and agricultural crop incomes and incurred flood damage costs. Information about WTP for different zones and flood scenarios provide an evidence-base which will help decision makers to develop and implement robust and equitable flood mitigation plans and programs.

WTP varied with income level within each flood hazard zone. The relationship between income and average WTP for various scenarios was positively correlated with farm income and livestock income. The income from farms was found to be highest for the critical flood prone zone. People living in this zone have comparatively more land and irrigation is easier because of the proximity to the river. This increases the possibility of cultivating paddy, and therefore improving livelihoods. Moreover, two crops per year are possible due to the greater availability of water. Furthermore, the soil is also highly fertile in this zone due to regular deposition of alluvial soil by the river. Local people also can grow cash crops such as watermelon, cucumber, and pumpkin in the floodplain area. As the distance increases from the river, the land does not get irrigation facilities and thus rain fed agriculture is prominent in such areas. Also, rice production decreases, as do the chances of growing other cash crops. At the same time, cropping frequency also goes down.

In addition to flood damage cost, socio-economic factors such as age, gender and education level have influenced the level of WTPs. In summary, for all flood scenarios analysed: (1) mean WTPs were statististically significantly different between the different age groups ($p \leq 0.05$) and mean WTP was highest for the 35 to 44 year age group; (2) mean WTP of female respondent was found higher than that of male respondents ($p \leq 0.05$); and (3) average WTP of literate people was found higher than illiterate people ($p \leq 0.05$). For detailed discussion of socioeconomic factors and their relationships with WTPs, please see Devkota (2014).

The average WTP of respondents was highest within the critical flood prone zone and the lowest in the low flood prone zone. Similarly, the average WTP of respondents increased from Scenario I to Scenario IV. The average WTP of respondents between the different zones were statistically significantly different ($p < 0.05$), as were WTPs within the flood hazard zones for the various scenarios ($p > 0.05$).

On average, the estimated flood damage cost in the study area was $US110 per household per year. Most flood damage costs were due to property and crop damage, followed by loss or damage to livestock. The results support the argument that the higher the damage, the greater the WTP, comparable to the results of Botzen *et al.* (2009) and Abbas *et al.* (2015). However, the damage cost could vary both spatially and temporally (O'Neill *et al.* 2015). Floods in a place with high value property and at the time of harvesting crops would incur more damage. Therefore, WTP estimates derived from perceived impacts of all potential costs are very useful for developing flood mitigating policies, programs and projects

(Blocker & Rochford 1986; Morss *et al.* 2005; Brouwer *et al.* 2009). Further, comprehensive WTP studies considering direct costs of physical property as well as indirect costs associated with the psychology and livelihoods of the local people in the flood prone areas could be extremely useful for the planning and policy makers.

People were victims of floods for many years and how to resolve this issue was unanimous and indisputable interest of all respondents. Therefore, their response and support for this research was spontaneous and praiseworthy, and there was neither any political bias in this research nor were the respondents forced to elicit their response and WTPs.

CONCLUSION

Results of this study showed that income levels of the residents and the extent of flood damage costs influenced WTP for various flood scenarios. The average WTP value of respondents was greater in the critical flood prone zone than in moderate and less flood prone zones. This applied equally for all flood scenarios. Similarly, the average WTP of respondents increased from Scenario I to Scenario IV. This research has further explored and enriched the understanding of differential impacts of CC on floods from a hydro-economic perspective. Moreover, the introduction of the concept of 'man-day' or 'labour-day' in WTP research is a novel and applicable methodological approach, particularly in the South Asian region. Application of this methodology and the results of this study could be instrumental for the fair allocation of resources. Although a more comprehensive study is warranted, this finding provides a rational basis for the appraisal of policy options and resources allocation. Similarly, this assessment is likely to be one of the several sources of evidence that decision makers may employ while making difficult and often highly contested long term planning and flood risk management decisions.

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REFERENCES

Abbas, A., Amjath-Babu, T. S., Kächele, H. & Müller, K. 2015 Non-structural flood risk mitigation under developing country conditions: an analysis on the determinants of willingness to pay for flood insurance in rural Pakistan. *Natural Hazards* **75**, 2119–2135.

Akter, S. & Bennett, J. 2011 Household perceptions of climate change and preferences for mitigation action: the case of the carbon pollution reduction scheme in Australia. *Climatic Change* **109**, 417–436.

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner, R. & Schuman, H. 1993 Report of the NOAA panel on contingent valuation. *Federal Register* **58**, 4601–4614.

Bhirthal, P. & Digvijay, S. N. 2012 Livestock for higher, sustainable and inclusive agricultural growth. *Economics and Politics* **47**, 16–26.

Blocker, T. & Rochford, A. 1986 *Critical evaluation of the human costs of flooding*. Prepared for U.S. Army Corps of Engineers, Tulsa District, Contract DACW-56-850160.

Botzen, W. J. W. 2013 *Managing Extreme Climate Change Risks Through Insurance*. Cambridge University Press, Cambridge, UK.

Botzen, W. J. W. & van den Bergh, J. 2012 Risk attitudes to low-probability climate change risks: WTP for flood insurance. *Journal of Economic Behaviour and Organizations* **82**, 151–166.

Botzen, W., Aerts, J. & van Den Bergh, J. 2009 Dependence of flood risk perceptions on socioeconomic and objective risk factors. *Water Resource* **45**, 10440.

Brouwer, R., Akter, S., Brander, L. & Haque, E. 2009 Economic valuation of flood risk exposure and reduction in a severely flood prone developing country. *Environment and Development Economics* **14**, 397–417.

Carlsson, F., Kataria, M., Krupnick, A., Lampi, E., Löfgren, A., Qin, P., Chung, S. & Sterner, T. 2012 Paying for mitigation: a multiple country study. *Land Economics* **88**, 326–340.

CBS (Central Bureau of Statistics) 2012 *National Population and Housing Census 2011*. National Planning Commission Secretariat, Government of Nepal, Kathmandu, Nepal.

Devkota, R. P. 2014 *Flood Adaptation Strategies Under Climate Change in Nepal: A Socio-Hydrological Analysis*. University of Southern Queensland, Queensland, Australia.

Devkota, R. P., Maraseni, T. N. & Cockfield, G. 2014 An assessment of willingness to pay to avoid climate change induced flood. *Journal of Water and Climate Change* **5**, 569–577.

Devkota, R. P., Pandey, V. P., Bhattarai, U., Shrestha, H., Adhikari, S. & Dulal, K. N. 2016 Climate change and adaptation strategies in Budhi Gandaki River Basin, Nepal: a perception-based analysis. *Climatic Change* **140** (2), 195–208.

FAO 2017 *Forestry for A low-Carbon Future: Integrating Forests and Wood Products in Climate Change Strategies*. FAO Forestry Paper 177, p. 180.

Ghanbarpour, M. R., Saravi, M. M. & Salimi, S. 2014 Floodplain inundation analysis combined with contingent valuation: implications for sustainable flood risk management. *Water Resources Management* **28**, 2491–2505.

Government of Nepal (GoN)/Asian Development Bank (ADB) 2016 *Water Resources Project Preparatory Facility Package 3: Flood Hazard Mapping and Preliminary Preparation of Flood Risk Management Projects Grant No. 0299-NEP*. Technical Assistance Consultant's Report by Lahmeyer International and Total Management Services Pvt. Ltd, Nepal.

Hall, J. W., Evans, E. P., Penning-Rowsell, E. C., Sayers, P. B., Thorne, C. R. & Saul, A. J. 2003 Quantified scenarios analysis of drivers and impacts of changing flood risk in England and Wales: 2030–2100. *Global Environmental Change* **5**, 51–65.

Hensher, D., Shore, N. & Train, K. 2005 Households' willingness to pay for water service attributes. *Environmental Resource and Economics* **32**, 509–531.

Hoffman, E. & Spitzer, M. L. 1993 Willingness to Pay vs. Willingness to Accept: Legal and Economic Implications. *Washington University Law Quarterly* **71** (1), 59–114.

Lera-López, F., Faulin, J. & Sánchez, M. 2012 Determinants of the willingness-to-pay for reducing the environmental impacts of road transportation. *Transportation Research Part D: Transport and Environment* **17**, 215–220.

Liebe, U., Preisendörfer, P. & Meyerhoff, J. 2011 To pay or not to pay: competing theories to explain individuals' willingness to pay for public environmental goods. *Environment and Behavior* **43**, 106–130.

Lo, A. Y. 2013 The role of social norms in climate adaptation: mediating risk perception and flood insurance purchase. *Global Environmental Change* **23**, 1249–1257.

Lytle, D. A. & Poff, N. L. 2004 Adaptation to natural flow regimes. *Trends Ecology Evolution* **19**, 94–100.

Maraseni, T. N. & Xinquan, G. 2011 An analysis of Chinese perceptions on unilateral clean development mechanism (uCDM) projects. *Environmental Science & Policy* **14** (3), 339–346.

Maraseni, T. N., Cockfield, G. & Apan, A. 2005 Community based forest management systems in developing countries and eligibility for clean development mechanism. *Journal of Forest and Livelihood* **4**, 31–42.

Maraseni, T., Maroulis, J. & Cockfield, G. 2008 An estimation of willingness to pay for asparagus (*Asparagus racemosusWilld.*) collectors in Makawanpur District, Nepal. *Journal of Forest Science* **54** (3), 131–137.

Maraseni, T. N., Neupane, P., Lopez-Casero, F. & Cadman, T. 2014 An assessment of the impacts of the REDD + pilot project on community forests user groups (CFUGs) and their community forests in Nepal. *Journal of Environmental Management* **136**, 37–46.

Meyerhoff, J. 2006 Stated willingness to pay as hypothetical behaviour: can attitudes tell us more? *Journal of Environment Planning and Management* **49**, 209–226.

Morss, R. E., Wilhelmi, O. V., Downton, M. W. & Gruntfest, E. 2005 Flood risk, uncertainty, and scientific information for decision making: lessons from an interdisciplinary project. *Bulletin of the American Meteorological Society* **86**, 1593–1601.

O'Connor, D. 1996 Applying Economic Instruments in Developing Countries: From Theory to Implementation, Economic And Environment Program For Southeast Asia OECD Development Centre, Paris, France.

O'Neill, E., Brennan, M., Brereton, F. & Shahumyan, H. 2015 Exploring a spatial statistical approach to quantify flood risk perception using cognitive maps. *Natural Hazards* **76**, 1573–1601.

O'Neill, E., Brereton, F., Shahumyan, H. & Clinch, J. P. 2016 The impact of perceived flood exposure on flood-risk perception: the role of distance. *Risk Analysis* **36**, 2158–2186.

Osberghaus, D. 2017 The effect of flood experience on household mitigation – evidence from longitudinal and insurance data. *Global Environmental Change* **43**, 126–136.

Roberts, D. C., Boyer, T. A. & Lusk, J. L. 2008 Preferences for environmental quality under uncertainty. *Ecological Economics* **66**, 584–593.

Shrestha, S., Babel, M. & Pandey, V. 2014 *Climate Change Vulnerability Assessment. Climate Change and Water Resources.* CRC Press (Taylor and Francis Group), Boca Raton, FL, USA, pp. 183–208.

Tol, R. S. 2013 Targets for global climate policy: An overview. *Journal of Economic Dynamics and Control* **37** (5), 911–928.

Veronesi, M., Chawla, F., Maurer, M. & Lienert, J. 2014 Climate change and the willingness to pay to reduce ecological health risks from wastewater flooding in urban centers and the environment. *Ecology* **98**, 1–10.

Viscusi, W. K., Huber, J. & Bell, J. 2008 The economic value of water quality. *Environment Resource Economics* **41**, 169–187.

Wertenbroch, K. & Skiera, B. 2002 Measuring consumers' willingness to pay at the point of purchase. *Journal of Market Resources* **39**, 228–241.

Zhai, G. 2006 *Public Preference and Willingness to pay for Flood Risk Reduction, A Better Integrated Management of Disaster Risks: Toward Resilient Society to Emerging Disaster Risks in Mega-Cities*. Terrapub 57Á87, Tokyo, Japan.

Zhai, G. & Suzuki, T. 2008 Effects of risk representation and scope on willingness to pay for reduced risks: evidence from Tokyo Bay, Japan. *Risk Analysis* **28**, 513–522.

Zhai, G., Sato, T., Fukuzono, T., Ikeda, S. & Yoshida, K. 2006 Willingness to pay for flood risk reduction and its determinants in Japan. *Journal of the American Water Resources Association* **42**, 927–940.

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