The evaluation of vulnerability to flooding

Colin Green

The author

Colin Green is Professor of Water Economics, Flood Hazard Research Centre, Middlesex University, Enfield, UK.

Keywords

Floods, Hazards, Risk assessment, Risk management

Abstract

From a systems perspective, vulnerability can be defined as the relationship between a purposive system and its environment, where that environment varies over time. Which environmental perturbations are significant therefore depends upon the objectives of the system as only those perturbations that can inhibit the achievement of these objectives are significant. That system must decide whether to adjust in advance to each potential perturbation or to rely upon a recovery path when that perturbation occurs. In each case, it must then decide upon the adjustment or recovery path to adopt. In particular, the basic resources available to a household are time and energy where the rates at which these can be directly or indirectly, through earning income, converted to consumption are crucial. Perturbations can reduce the energy available as well as reduce the efficiencies with which time and energy can be converted to income.

Introduction

"Vulnerability" is only one of a number of concepts associated with hazard management where common understanding tends to break down as soon as we seek to define exactly what we mean by the concept in question. As shown below, a wide range of differing concepts have been termed "vulnerability":

- the potential for attributes of a system to respond adversely to the occurrence of hazardous events (Yamada *et al.*, 1995);
- the extent to which a given hazard would impact on a property by reason of its materials or layout (Clark *et al.*, 1998);
- a characteristic of individuals and groups of people who inhabit a given natural, social and economic space, within which they are differentiated according to their varying position in society into more or less vulnerable individuals and groups (Cannon, 1993);
- a measure, for a given population or region, of the underlying factors that influence exposure to the hazardous event and predisposition to adverse consequences (Downing, 1993);
- a function of a system's ability to cope with stress and shock (Nicholls and Klein, 2000);
- the propensity of an endangered element due to any kind of natural hazard to suffer different degrees of loss or amount of damage depending on its particular social, economic, cultural and political weaknesses (Alcantara-Ayala, 2002);
- the propensity of social and ecological systems to suffer harm from external stresses and shocks (International Council for Science, 2002);
- the extent to which a natural or social system is susceptible to sustaining damage from climate change (IPCC, 2001);
- the degree of incapability to cope with the consequences of climate change and accelerated sea-level rise (IPCC, 1992).

Polanyi (1969) argued that we can communicate using words to denote general concepts without an explicit or shared definition of the concept in question. But, whilst we may be able to discuss vulnerability reasonably satisfactorily without defining or agreeing exactly what we mean by vulnerability, in order to measure it we must define vulnerability in explicit terms for some specific purpose.

Part of the problem is that "vulnerability" is used implicitly or explicitly as a conjunction: relating something or someone who is vulnerable to something else as a source of potential harm because of some property of the subject or the object. Vulnerability implies something therefore

Disaster Prevention and Management
Volume 13 · Number 4 · 2004 · pp. 323-329
 · ISSN 0965-3562
DOI 10.1108/09653560410556519

Disaster Prevention and Management
Volume 13 · Number 4 · 2004 · 323-329

about the relationship between the subject and the object as well as the relevant characteristics of either or both the object and the subject of the argument. The meaning of "vulnerability" may thus be context specific rather than being a universal concept. What we mean by "vulnerability" may consequently depend upon the nature of the decision that must be made and what that decision involves. We are only interested in vulnerability in order to try to reduce it and if we cannot change it, then the question of what we mean by vulnerability is of purely intellectual interest.

The conjunctive definition of vulnerability implies four key elements:

(1) a purposive system;
(2) where it is the specific objectives of that system that are important to the definition of vulnerability;
(3) a dynamic environment in which the variation can help or hinder the achievement of these objectives; and
(4) a variety of potential mediating variables between the system and the environment, of adaptive strategies for the system, and means of modifying the environment.

Adopting this approach means that it is necessary to start by defining what is the desired state which it is sought to achieve or maintain. In turn, it is those variations in the environment which have a potential to adversely affect that state that are challenges; hence, challenges or hazards are constructed from the definition of desirability rather than being objectively present.

The system also responds to the changes, or perturbations, in the environment in ways which seek to minimise the displacement away from the system's objective. Those perturbations pose a greater or lesser challenge to the system in trying to achieve its objectives, and those perturbations may differ in their nature as well as their magnitude. Indeed, some of those perturbations may be advantageous but we typically reserve the concept of vulnerability to disadvantageous aspects of those perturbations. So, for example, whilst crop yields vary from year to year, a bumper crop being as much part of that variation as crop failure, we tend to speak of vulnerability to crop failure rather than of sensitivity to variability in crop yield. Similarly, floods and droughts are simply labels given to some extremes in river flows (Green, 2002). In seeking to modify those variations, it is necessary to consider the effect upon the whole cycle of variation and not just on a part. In the case of floods, afforestation is often recommended as a means of source control, of reducing runoff and hence flood flows in rivers. However, afforestation will also change runoff in dry periods and hence may have adverse consequences in low flow periods (Calder, 2003) both in terms of the availability of water for abstraction from the river and in damaging the ecosystem of the river.

What the purposive system seeks to do is to achieve the highest possible, and generally an increasing, level of attainment of its objectives over time whilst minimising the extent and duration of deviations from this trajectory as a result of environmental perturbations. This necessarily involves trade-offs between the average level of attainment of the objectives, the susceptibility of the system to shocks, and the rate at which it recovers from those shocks. In making those trade-offs, it must have regard to the entire spectrum of perturbations to which it may be exposed, and, in consequence, it must decide upon which perturbations to focus, where to direct attention and resources. In short, we cannot discuss vulnerability to flooding in isolation; flood may be a negligible hazard when compared to the other hazards that exist.

The initial reduction in the quality of life, the shock, is determined by the challenge and the susceptibility of the system to that form of challenge. The ideal is to recover to the previous trajectory of the state which it is sought to achieve or maintain in the shortest possible time, but it is not necessarily the case that it will be possible to return to that previous trajectory.

Assessing vulnerability

It is a truism of a systems' approach that what is a system and its environment at one scale are, at a wider scale, simply a single system within further environment. Scale issues are central to the assessment of vulnerability; a household may be vulnerable to an event when neither the local community nor the country as a whole is vulnerable. Equally, the resources available to a household to recover from a shock will depend upon what resources it can call upon from outside, from the social networks in which it is embedded. The !Kung of the Kalahari cope with a highly volatile environment by having geographically widely spread social networks which give them entitlements to support when local resources are scarce because of environmental variation (Fagan, 2000). Hence, it is necessary to define what system it is whose vulnerability we are concerned to assess and enhance.

The vulnerability of households

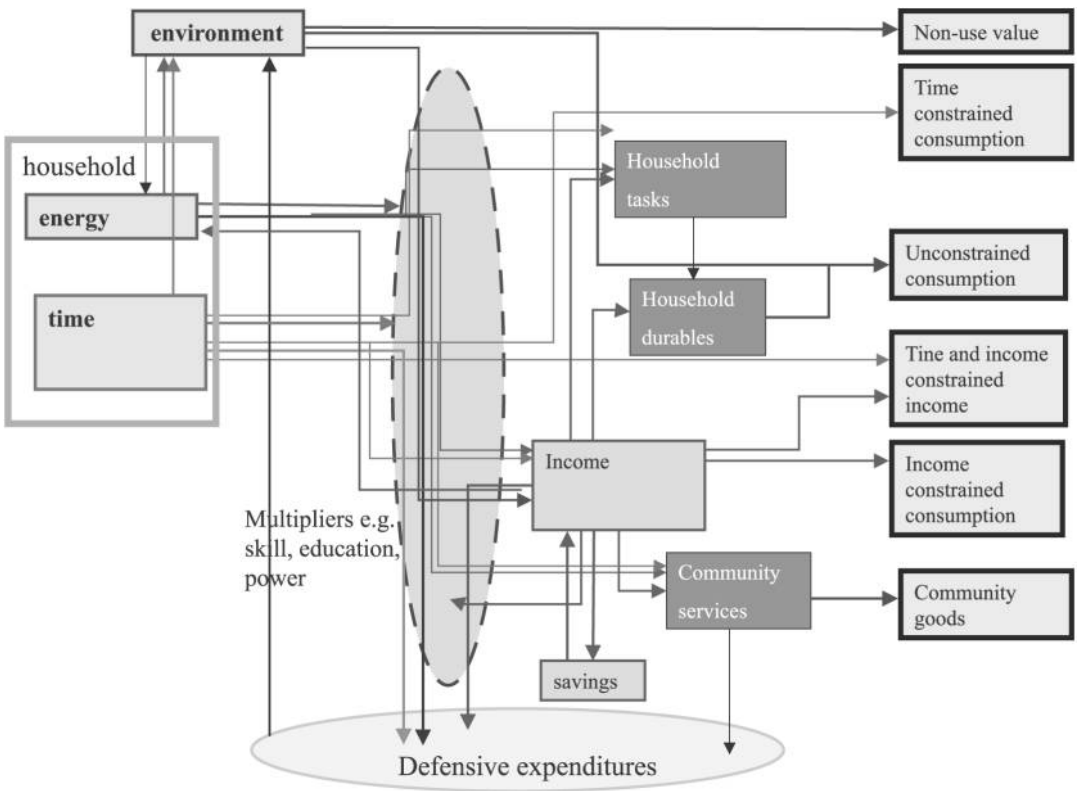
Since most of us spend the greater part of our lives as members of one or another household, the household is the obvious basic unit. Whilst it is

Disaster Prevention and Management
Volume 13 · Number 4 · 2004 · 323-329

difficult to give a universally applicable definition a household (Roberts, 1991), we can recognise one when we see one. The household may be taken to seek to increase over time their quality of life, widely defined to include more than their standard of living. Indeed, that quality of life may include their expectations of life after death. Here, however, that element of the quality of life corresponding to the traditional economic definition of utility is quite sufficiently complex for analysis.

The sustainable livelihoods model (Ashley and Carney, 1999) can be adopted to form the basis of a systems' model of a household (Figure 1). The basic resource available to the household is the environment where, for instance, an arable field is simply a highly modified ecosystem but one that still depends primarily upon solar energy for energy, biological processes for nutrients, and, directly or indirectly, rainfall as a source of water (Loomis and Connor, 1992). Members of a household have two basic resources available to them: time and energy. Give a general objective of at least maintaining the quality of their life they have to decide how to allocate that time and energy between production and consumption. Time and energy much be devoted either to the environment in order to obtain the food necessary to replenish energy, or to earning income to buy the required food. Some time and energy are required to maintain the household, some are allocated as a contribution to communal goods and services, and, in anything other than a wholly subsistence economy, some time and energy must be devoted to income generation. In turn, that household then has a further series of choices: whether time and energy devoted to income result in the provision of some form of consumption at a lower cost in time and energy than if the household used that time and energy to provide that consumption directly. Similarly, the household has to decide when time, energy and/or income devoted to the communal provision is more efficient than the individual household seeking to provide that good or service directly. Households can invest some of their time, energy and income in multipliers such as education and skills which result in an improvement in the ratio of outputs to the inputs of time, energy and income. For example, Jacobs and Asokan (2000) report that the productivity on some trial farms in India was approximately doubled simply by providing the local farmers with the knowledge available to US farmers. In a static world, providing that households reinvest in multipliers, the result would be continual growth in the quality of life. In practice, the natural environment is constantly varying and the household is set within a wider social-economic

Figure 1 A systems view of a household



Disaster Prevention and Management
Volume 13 · Number 4 · 2004 · 323-329

environment which also varies over time. The household is confronted on the one hand with droughts, floods, disease, and pests and on the other by variations in crop prices, the costs of inputs, economic depressions and recessions, and, not infrequently, unrest or war. Households have to be risk managers; they have to consider what variations are most likely in the future and the consequences of each source of variation. Logically, they focus upon those with the highest probability and greatest impact. In the UK, the risk of a flood in an area may be relatively low as compared to the risk of burglary or car theft, or of unemployment. Over much of the world, the risk of a flood is comparatively low as compared to that from disease or crop failure as a result of pests, crop disease or drought. Given the limited resources of time, energy and income, the problem for the household is where and how to allocate these resources between the different hazards.

The household have some choices, which may include where to settle, and more generally what to do, including to what extent to invest in defensive expenditures either to reduce the challenges or to enhance coping capacity where the resources available for defensive expenditure depend upon the average return on the energy and time they expend. If on average, this return is high then it may outweigh the average loss from local environmental or socio-economic perturbations, or the higher return in one locality as compared to that from elsewhere may generate sufficient resources to support defensive expenditures. Hence, flood plains have often been found to be the best places for settlement; the higher crop production compared to other potential sites outweighing the losses from floods. That informal urban development often takes place in areas where the risks of flooding or landslide are high illustrates either that other risks are greater, or that the gains in economic security from those areas compared to others is sufficient to outweigh the risks from flooding or landslide.

A perturbation in the environment can then have five direct effects which will in turn affect the household's quality of life:

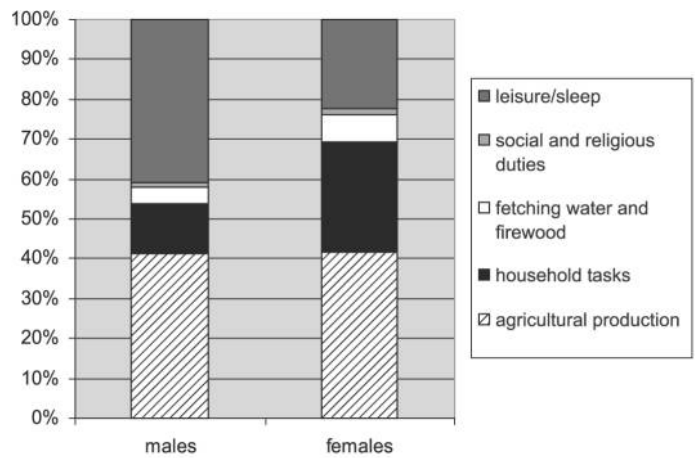
(1) to reduce the energy available to the household (e.g. through disease);
(2) a reduction in outputs from the environment (e.g. food, water);
(3) to reduce income as a result of opportunities being lost or reduced to sell energy and time in the form of labour, or the returns to this time and labour;
(4) damage or destruction to household durables including the home itself; and
(5) a reduction in the availability of community services including health care.

There is considerable evidence (Green and Penning-Rowsell, 1986, 1989; Tapsell and Tunstall, 2001) that floods do affect people's health but we currently lack the capacity to predict who will be affected to what extent by which kind of floods (Green *et al.*, 1994; Floyd *et al.*, 2003). Ill-health clearly directly affects a household's quality of life but it also reduces the energy available for all purposes, including income generation and recovery from the flood.

In turn, time and energy will have to be redirected to recover from the perturbation. Time will have to be used for clean up and repair, household tasks will increase unless the home is totally destroyed, and care will be required of those who are ill. More time and energy are also likely to be required to fetch clean water. Given that time is finite, the time diverted to one activity must mean that some activity now absorbs less time. Since women are already differentially burdened with work, the net effect will often be to further over-burden women with work. Figure 2 shows that in the dry period in Sri Lanka, women are already having less than six hours sleep a night and this pattern of time allocation is not atypical.

Income, which will probably fall, will also have to be deployed. Here, the proportion of household income which is spent upon food is crucial. When this proportion is high, then the household is highly exposed to any perturbation that will result in an increase in food prices. In this regard, households in Argentina and Ethiopia, for example, are much more exposed than are households in the UK (Figure 3). That the proportion of household income that is spent on food falls as a proportion of income is a general rule, first stated by Ernst Engel in the nineteenth century. One of the dramatic changes in the

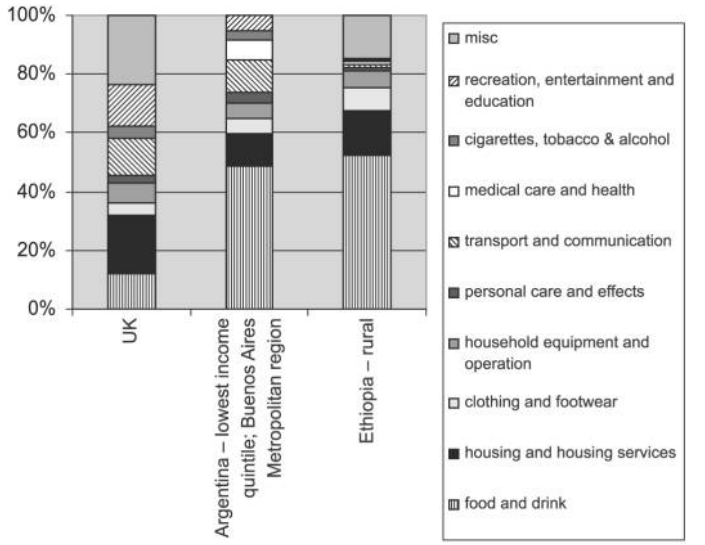
Figure 2 Time allocation



Source: Momsen (1991)

Disaster Prevention and Management
Volume 13 · Number 4 · 2004 · 323-329

Figure 3 Household expenditure



developed world over the last 100 years has been the fall in this proportion and if the volatility of food prices has historically been very high (Clark, 2003, Fischer, 1996) then this volatility has become less significant.

Floods have a direct effect upon the quality of life; there is consistent evidence (Green *et al.*, 1994; Tapsell and Tunstall, 2001) that the loss of memorabilia such as photographs, having to leave home for some period, and the disruption to life that result from living in a wet and damaged home are often regarded by flood victims as worse than the damage to their home itself and its replaceable contents. The relatively easy bit is to assess is this damage to the building, the furniture and fittings with standard methods of assessment having been adopted in many countries (Green *et al.*, 2000).

Because it is relatively easy to assess these losses, usually this is the only element included in the assessment of the household losses, we do not usually seek to examine the trajectory of the quality of life after the flood. By implication, if these losses did not occur or were immediately replaced after a flood, then the quality of life after a flood would be identical to that prior to the flood. But we know this to be untrue (Tapsell and Tunstall, 2001). What is not known however is whether a flood can result in a permanent diminution in the quality of life of those affected.

What does this imply about the interventions that can be made to reduce vulnerability? In general terms, the three generic systems options available are:

(1) seek to reduce the challenge, to reduce the magnitude of the perturbation or its nature;
(2) to filter out that perturbation before it impinges upon the system in question; or
(3) reduce the impact of that perturbation upon the system by changing the nature of the system.

At the scale of the household, which of these options are open to household will be limited by resources (Paul, 1984), with there being greater scope to reduce the impact of the perturbation that either reducing the challenge or filtering out the perturbation. In those terms, one of the most effective means of adjustment by the household is to make friends, form kinship links, or more generally to form a community or society. On the one hand, this creates a web of entitlements and obligations that can be called upon in the event of a disaster; on the other, the resulting economies of scale and access to resources enables a wider range of adaptations to be adopted. So, the issue then becomes one of how that community or society should intervene.

In pre-industrial societies, the majority of the population was or is supported through agriculture and food takes up the highest proportion of household income, the primary intervention has always been to protect agriculture. Firstly, to drain land so as to reduce the risk of crop loss through saturated soil and, where floods typically coincide with the full development or harvest of the crop, flood protection as well. Conversely, in the service and industrial based economies of the developed world where agriculture is also heavily subsidised, agricultural land is used either to store and convey flood waters or is being reconverted back to its original wetlands or washlands. It is not an exaggeration to say that the role of agriculture in society and in the economy essentially determines the flood risk management policy adopted.

Generally, flood warnings have been viewed as ways of reducing flood losses (Penning-Rowsell *et al.*, 2000). Viewed from a wider perspective of vulnerability, those at risk should probably be advised to adopt the following priority for act:

(1) collect in a safe place those things necessary for a comfortable survival (e.g. water, radio, blankets, food, medications);
(2) save irreplaceable items (e.g. photographs, papers);
(3) collect those things which will aid recovery (e.g. insurance details, telephone contacts, cleaning gear and tools); and
(4) move those high value, low weight items that can be moved without the risk of injury.

Since the provision of health care is important is important not only in its own right but also because chronic or acute health problems reduce the energy available for all activities and not simply income generation, health care is a key area for support. Since women are likely to be over-loaded

Disaster Prevention and Management
Volume 13 · Number 4 · 2004 · 323-329

with tasks, the logic is to target action to reduce the time and energy they must spend in the whole variety of tasks that they will be struggling to undertake.

Modifying vulnerability to flooding

In general terms, the three generic systems options were described earlier as: reduce the challenge; filter out that perturbation before it impinges upon the system in question; or reduce the impact of that perturbation upon the system by changing the nature of the system.

So, on the coasts, it is the energy of storms which potentially results in coastal erosion and flooding and there are three general approaches to reducing the challenge:

(1) attenuate the energy (e.g. salt marshes, mangrove forest);
(2) resist the energy (e.g. a concrete sea wall); and
(3) absorb the energy (e.g. shingle bank, beach, sand dune system).

Similarly, with regard to rivers, the generic options are:

- source control, storage (e.g. detention basins, wetlands, dams, washlands);
- separation (e.g. embankments); and
- modification of the system (e.g. flood proofing, land use control).

In the case of both the coast and rivers, the general principle should be to manage all floods and not just some (Green *et al.*, 2000); not to design to cope with an event of some specified probability of occurrence. Modifications of the system itself tend to buy a reduction in the consequences of a perturbation at cost of reducing the average performance of the system. The three main strategies possible are:

(1) get bigger;
(2) increase diversification; and
(3) reduce concentration.

Getting bigger reduces the relative size of the possible impact of the perturbation. Households can adopt this strategy by forming communities and thence societies. At the national level, being a small country is inherently problematic; being a small country exposed to large scale perturbations such as cyclones is to be very vulnerable. Increasing diversification and concentration can generally only be bought at the cost of reduced efficiency, with the loss of economies of scale and scope, and the pattern of economic development has been towards specialisation and concentration.

Conclusions

The test of a definition of vulnerability is effectively the insights it gives into how vulnerability may be reduced. Hence it is the vulnerability of the object of the relationship with which we are concerned; as a purposive system, this vulnerability depends upon what are its objectives. Changing or redefining the system's objectives may then be a way of reducing vulnerability. At the same time, vulnerability has to be considered in the context of the entire spectrum of perturbations to which that system is exposed, and include consideration of those perturbations which present positive opportunities. Flood risk management has to be considered in this wider framework of objectives and other perturbations.

The systems' approach has a number of further implications for definition of vulnerability:

(1) Vulnerability is path dependent: the vulnerability of someone or something at any point of time depends upon what has previously happened to that person or thing. Thus, a flood that immediately follows a drought will affect a community more severely than a community has not experienced such a drought (Buckle *et al.*, 2000). Similarly, drought stressed crops are more susceptible to disease and pests than those that are not so stressed (Loomis and Connor, 1992).
(2) This path dependency necessarily means that vulnerability is time varying. But, vulnerability is time varying in other ways as well; whereas a flood when the crop is ready for harvesting typically destroys the crop, an identical flood at another time in the year may have little or no affect (Higgin, 1981).
(3) Finally, as a relationship between subject and object, vulnerability has to be understood as being constructed rather than being innate; not least because the essential purpose of studying vulnerability is to change it by modifying the subject, the challenge posed, the capacity of the object to cope with that challenge or by modifying the relationship between the two.

References

Alcantara-Ayala, I. (2002), "Geomorphology, natural hazards, vulnerability and prevention of natural disasters in developing countries", *Geomorphology*, Vol. 47 No. 2-4, pp. 107-24.

Ashley, C. and Carney, D. (1999), *Sustainable Livelihoods: Lessons from Early Experience*, Department for International Development, London.

Buckle, P., Mas, G. and Smale, S. (2000), "New approach to assessing vulnerability and resilience", *Australian Journal of Emergency Management*, Winter, pp. 8-14.

Calder, I.R. (2003), "Forests and water – closing the gap between public and science perceptions", paper presented at the Stockholm Water Symposium, Stockholm.

Cannon, T. (1993), "A hazard need not a disaster make: vulnerability and the causes of 'natural' disaster", in Merriman, P.A. and Browitt, C.W.A. (Eds), *Natural Hazards*, Thomas Telford, London.

Clark, G. (2003), *The Price History of English Agriculture, 1209-1914*, University of California, Davis, CA.

Clark, G.E., Moser, S.C., Ratick, S.J., Dow, K., Meyer, W., Emani, S., Jin, W., Kasperson, R.E., Kasperson, J.E.X. and Schwarz, H. (1998), "Assessing the vulnerability of coastal communities to extreme storms: the case of Revere, MA, USA", *Mitigation and Adaptation Strategies for Global Change*, Vol. 3, pp. 59-82.

Downing, T.E. (1993), "Concepts of vulnerability to famine and applications in Subsaharan Africa", in Bohle, H.G., Downing, T.E., Field, J.O. and Ibrahim, F.O. (Eds), *Coping with Vulnerability and Criticality: Case Studies on Food Insecure Peoples and Places*, Breitenbach, Saarbruecken and Fort Lauderdale, FL, pp. 205-59.

Fagan, B. (2000), *Floods, Famines and Emperors*, Pimlico, London.

Fischer, D.H. (1996), *The Great Wave: Price Revolutions and the Rhythm of History*, Oxford University Press, New York, NY.

Floyd, P., George, C., Tunstall, S., Tapsell, S., Green, C., Jones-Lee, M. and Metcalf, H. (2003), "The appraisal of human-related intangible impacts of flooding", paper presented at the 38th DEFRA Conference on Flood and Coastal Defence, Keele.

Green, C.H. (2002), "Flood management from the perspective of integrated water resource management", paper presented at the 2nd International Symposium on Flood Control, Beijing.

Green, C.H. and Penning-Rowsell, E.C. (1986), "Evaluating the intangible benefits and costs of a flood alleviation proposal", *Journal of the Institution of Water Engineers and Scientists*, Vol. 40 No. 3, pp. 229-48.

Green, C.H. and Penning-Rowsell, E.C. (1989), "Flooding and the quantification of 'intangibles'", *Journal of the Institution of Water and Environmental Management*, Vol. 3 No. 1, pp. 27-30.

Green, C.H., Parker, D.J. and Tunstall, S.M. (2000), *Assessment of Flood Control and Management Options*, World Commission on Dams, Cape Town, available at: www/dams.org

Green, C., van der Veen, A., Wierstra, E. and Penning-Rowsell, E. (1994), "Vulnerability refined: analysing full flood impacts", in Penning-Rowsell, E.C. and Fordham, M. (Eds), *Floods Across Europe*, Middlesex University Press, London.

Higgin, R.J. (1981), "An economic comparison of different flood mitigation strategies in Australia", unpublished PhD thesis, School of Civil Engineering, University of New South Wales, Sydney.

International Council for Science (2002), *Resilience and Sustainable Development*, Series on Science for Sustainable Development No 3, International Council for Science, Paris.

IPCC (1992), "Emission scenarios for the IPCC: an update", in Houghton, J.T., Callnader, B.A. and Varney, S.K. (Eds), *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment*, Cambridge University Press, Cambridge, pp. 75-95.

IPCC (2001), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (Eds), Cambridge University Press, Cambridge.

Jacobs, G. and Asokan, N. (2000), "Knowledge for development: vision 2020", presentation to the Planning Commission, Government of India, New Delhi.

Loomis, R.S. and Connor, D.J. (1992), *Crop Ecology: Productivity and Management in Agricultural Systems*, Cambridge University Press, Cambridge.

Momsen, J.H. (1991), *Women and Development in the Third World*, Routledge, London.

Nicholls, R.J. and Klein, R.J.T. (2000), "Some thoughts on impacts and adaptation to climate change in coastal zones", in de la Vega-Leinert, A.C. and Tol, R.S.J. (Eds), *Proceeding of SURVAS Expert Workshop on European Vulnerability and Adaptation to impacts of Accelerated Sea-Level Rise, Hamburg, 19-21 June*, Flood Hazard Research Centre, Enfield.

Paul, B.M. (1984), "Perception of and agricultural adjustment to floods in Jamuna floodplain, Bangladesh", *Human Ecology*, Vol. 12 No. 1, pp. 3-19.

Penning-Rowsell, E.C., Tunstall, S.M., Tapsell, S.M. and Parker, D.J. (2000), "The benefits of flood warnings: real but elusive, and politically significant", *Journal of the Chartered Institution of Water and Environmental Management*, Vol. 14, pp. 7-14.

Polanyi, M. (1969), "On body and mind", *The New Scholasticism*, Vol. 43 No. 2, pp. 195-204.

Roberts, P. (1991), "Anthropological perspectives on the household", *IDS Bulletin*, Vol. 22, pp. 60-6.

Tapsell, S.M. and Tunstall, S.M. (2001), *The Health and Social Effects of the June 2000 Flooding in the North East Region*, Flood Hazard Research Centre, Enfield.

Yamada, K., Nunn, P.D., Mimura, S., Machida, S. and Yamamoto, M. (1995), "Methodology for the assessment of vulnerability of South Pacific island countries to sea-level rise and climate change", *Journal of Global Environment Engineering*, Vol. 1 No. 1, pp. 101-25.

This article has been cited by:

1. Christian KuhlickeSoziale Verwundbarkeit und die Folgen des Klimawandels 105-117. [CrossRef]
2. Jie Liu, Zhenwu Shi, Dan Wang. 2016. Measuring and mapping the flood vulnerability based on land-use patterns: a case study of Beijing, China. *Natural Hazards* . [CrossRef]
3. Somogy Varga. 2016. Exploitation, Vulnerability, and Market-Driven Governance. *Journal of Social Philosophy* **47**:1, 90-113. [CrossRef]
4. Ľubomír Solín. 2015. Recent Slovak flood protection relative to integrated flood risk management. *International Journal of River Basin Management* **13**:4, 463-473. [CrossRef]
5. I Chervanyov, Y Varyvoda. 2015. Assessment of Geoecological Vulnerability as a Tool for Coping Capacity Development to Emergencies. *The Advanced Science Journal* **2015**:1, 45-52. [CrossRef]
6. Shang-Shu Shih, Sheng-Chi Yang, Huei-Tau Ouyang. 2014. Anthropogenic effects and climate change threats on the flood diversion of Erchung Floodway in Tanshui River, northern Taiwan. *Natural Hazards* **73**:3, 1733-1747. [CrossRef]
7. Younghun Jung, Yongchul Shin, Chun Hwa Jang, Donghyuk Kum, Young Sug Kim, Kyoung Jae Lim, Hyun Bae Kim, Tae Sun Park, Seung Oh Lee. 2014. Estimation of flood risk index considering the regional flood characteristics: a case of South Korea. *Paddy and Water Environment* **12**:S1, 41-49. [CrossRef]
8. Bibliography 307-322. [CrossRef]
9. Giedrius Kaveckis, Benjamin BechtelLand Use Based Urban Vulnerability to Climate Change Assessment . [CrossRef]
10. Christian Geiß, Hannes Taubenböck. 2013. Remote sensing contributing to assess earthquake risk: from a literature review towards a roadmap. *Natural Hazards* **68**:1, 7-48. [CrossRef]
11. Dagmar Haase. 2013. Participatory modelling of vulnerability and adaptive capacity in flood risk management. *Natural Hazards* **67**:1, 77-97. [CrossRef]
12. N. Nirupama, Amanda Maula. 2013. Engaging public for building resilient communities to reduce disaster impact. *Natural Hazards* **66**:1, 51-59. [CrossRef]
13. Ľ. Solín. 2012. Spatial variability in the flood vulnerability of urban areas in the headwater basins of Slovakia. *Journal of Flood Risk Management* **5**:4, 303-320. [CrossRef]
14. Niru NirupamaDepartment of Civil Engineering, York University, Toronto, Canada. 2012. Risk and vulnerability assessment: a comprehensive approach. *International Journal of Disaster Resilience in the Built Environment* **3**:2, 103-114. [Abstract] [Full Text] [PDF]
15. David McEntireDepartment of Public Administration, University of North Texas, Denton, Texas, USA. 2012. Understanding and reducing vulnerability: from the approach of liabilities and capabilities. *Disaster Prevention and Management: An International Journal* **21**:2, 206-225. [Abstract] [Full Text] [PDF]
16. Jenq-Tzong Shiau, Ching-Nuo Chen, Chang-Tai Tsai. 2012. Physiographic Drainage-Inundation Model Based Flooding Vulnerability Assessment. *Water Resources Management* **26**:5, 1307-1323. [CrossRef]
17. Sebastian Scheuer, Dagmar Haase, Volker Meyer. 2011. Exploring multicriteria flood vulnerability by integrating economic, social and ecological dimensions of flood risk and coping capacity: from a starting point view towards an end point view of vulnerability. *Natural Hazards* **58**:2, 731-751. [CrossRef]
18. David McEntireDepartment of Public Administration, Emergency Administration and Planning, University of North Texas, Denton, Texas, USA. 2011. Understanding and reducing vulnerability: from the approach of liabilities and capabilities. *Disaster Prevention and Management: An International Journal* **20**:3, 294-313. [Abstract] [Full Text] [PDF]
19. Gordon Walker, Kate Burningham. 2011. Flood risk, vulnerability and environmental justice: Evidence and evaluation of inequality in a UK context. *Critical Social Policy* **31**:2, 216-240. [CrossRef]
20. Di Jin, Jian Lin. 2011. Managing tsunamis through early warning systems: A multidisciplinary approach. *Ocean & Coastal Management* **54**:2, 189-199. [CrossRef]
21. Nguyen Mai Dang, Mukand S. Babel, Huynh T. Luong. 2011. Evaluation of food risk parameters in the Day River Flood Diversion Area, Red River Delta, Vietnam. *Natural Hazards* **56**:1, 169-194. [CrossRef]
22. Sam Cole. 2010. The regional portfolio of disruptions, protection, and disasters. *The Annals of Regional Science* **44**:2, 251-272. [CrossRef]
23. John Handmer. 2008. Risk Creation, Bearing and Sharing on Australian Floodplains. *International Journal of Water Resources Development* **24**:4, 527-540. [CrossRef]

24. Timothy J. Eveleigh, Thomas A. Mazzuchi, Shahram Sarkani. 2008. Spatially-aware systems engineering design modeling applied to natural hazard vulnerability assessment. *Systems Engineering* **10**:3, 187-202. [CrossRef]
25. Ruud Raaijmakers, Jörg Krywkow, Anne van der Veen. 2008. Flood risk perceptions and spatial multi-criteria analysis: an exploratory research for hazard mitigation. *Natural Hazards* **46**:3, 307-322. [CrossRef]
26. Raymond Misomali, David McEntireRising Disasters and Their Reversal . [CrossRef]
27. Colin Green, Loraine McFadden. 2007. Coastal Vulnerability as Discourse About Meanings and Values. *Journal of Risk Research* **10**:8, 1027-1045. [CrossRef]
28. T.J. EveleighSchool of Engineering and Applied Science, The George Washington University, McLean, Virginia, USA T.A. MazzuchiSchool of Engineering and Applied Science, The George Washington University, Washington, District of Columbia, USA S. SarkaniInfrastructure Safety and Reliability Laboratory, School of Engineering and Applied Science, The George Washington University, Washington, District of Columbia, USA. 2006. Systems engineering design and spatial modeling for improved natural hazard risk assessment. *Disaster Prevention and Management: An International Journal* **15**:4, 636-648. [Abstract] [Full Text] [PDF]