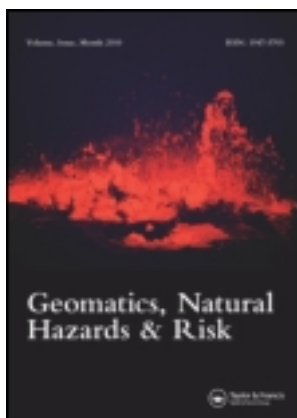


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Disaster risk and vulnerability in Pakistan at a district level

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During the last 30 years, Pakistan has undergone extreme transformations with respect to population and economic conditions. As a hazard-prone country with more people living in high-risk areas than ever before it is increasingly important to pro-actively address natural and man-made hazards and the cumulative risks that they pose at multiple spatial and temporal scales. In this study an assessment has been undertaken of hazards that were selected on the basis of their frequency and severity. Hazard potential and vulnerability factors were first derived on the basis of expert opinion. A combination of these factors was then used to create an integrated total risk assessment map that addresses the socio-economic, environmental and physical dimensions of vulnerability for the districts of Pakistan. The total integrated vulnerability map reveals the damage potential and coping capacity of each district, providing support to decision makers and to end users such as local authorities, non-governmental organizations and disaster prevention officers, enabling them to (a) decide what is an acceptable level of risk, (b) determine the level of protection and (c) decide which predefined mitigation measure to apply.

1. Introduction

Pakistan is situated within a hazard-prone region and is exposed to a variety of natural disasters such as floods, cyclones, earthquakes, landslides and droughts. Rapid population growth, uncontrolled development and unmanaged expansion of infrastructure are the most common factors that result in more people being vulnerable to natural hazards than ever before (Cardona *et al.* 2003). The burden of natural disasters in Pakistan can be underlined by the fact that they have been responsible for the deaths of 6037 people in the period from 1993 to 2002, with a further 8.9 million people also affected (World Disasters Report 2003). More than 80 000 people died and 3.5 million lost their homes in a single event: the earthquake of 8 October 2005. A consistent major problem for Pakistan's authorities is that natural hazards occur more or less regularly at all scales. Furthermore, disaster management in Pakistan, particularly with regard to natural hazards, focuses mainly on rescue and relief processes. There is a dearth of information and little understanding of the processes involved in hazard identification, risk assessment and management, and the relationship between people's livelihoods and disaster preparedness (WCDR 2005). Disaster management policy in Pakistan does not make adequate use of recent

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developments in scientific methodologies, methods and tools for cost-effective and sustainable interventions.

As our conceptual basis we started from the hypothesis that every hazard has a spatial dimension that determines when a hazard turns into a disaster, and hence may influence vulnerability to spatially relevant natural hazards (Cutter 1996 a,b).

The impacts that disasters have on humans are not solely dependent on their exposure to the hazard, but also on how capable they, and their surroundings are of anticipating, resisting, coping with, and recovering from, their effects (Wisner *et al.* 2004, Greiving 2006). We may consider particular environments to be hazard or disaster agents and the origins of risk and disaster to lie in the physical environment (Gilbert 1995). From this perspective disasters are regarded as a function of external agents and communities as the victims of extreme events (Hewitt 1983, Flint and Luloff 2005). Alternative perspectives also exist that place societal conditions at the centre of the disaster descriptions and interpretations, in which disasters are not necessarily the inevitable outcome of a hazard's impact but a result of intersections between hazards and everyday vulnerabilities (Hewitt 1998, Flint and Luloff 2005). Spatial planning may therefore become crucial to keeping a balance between the two viewpoints. Spatial planning may contribute effectively to disaster risk reduction but according to the United Nations Development Programme (UNDP), many countries still lack clear guidelines on how to deal with hazards and risk on a spatial planning level (UNDP 2004). The Kashmir earthquake 2005 increased awareness in the general public and public administration of the overall high level of risk in Pakistan, and the fact that it is steadily increasing. It is however not sufficient to restrict policies to the response phase of the disaster management cycle: hazard mitigation activities are also crucially important if lives are to be saved and damage reduced, and preparedness is an essential component of any sustainable planning practice. Evidence from scientific literature and best practice examples around the world makes it clear that Pakistan does not have in place appropriate spatial planning tools. Even if we accept that awareness of natural hazards and their associated risks has increased over recent years in Pakistan, the effectiveness of the majority of planning and management related activities will remain limited while they remain based on single hazard approaches.

One assessment of social vulnerability to environmental hazards that used county-scale indicators across the United States (Cutter *et al.* 2003) has provided guidance for this study of Pakistan, but in this case the available data are incomplete. Some simplifications are therefore necessary when designing a methodology for Pakistan, as there is insufficient hard data available for an understanding of social vulnerabilities at a local level, or of the interactions between biophysical and social vulnerabilities. Proxy indicators have instead been derived: some were derived directly from census data while others were developed from auxiliary data using GIS analyses. Studies of relevant literature (e.g. Cutter 1996a, b, Clark *et al.* 1998, Tralli *et al.* 2005, Greiving 2006, Fleischhauer 2006, Birkmann and Wisner 2006, Birkmann 2007) have revealed that integrated multi-hazard risk approaches are still rare in many parts of the world. This is despite improved scientific understanding and the ability to disseminate temporal geospatial information that can potentially be integrated with demographic and socioeconomic data. The means are available to develop comprehensive risk mitigation planning and improved disaster response. The scientific community recognizes the manifold interactions between the hydrosphere, atmosphere, biosphere and solid Earth as a complex system (Tralli *et al.*

2005), and that geospatial information in general, and GIS and remote sensing in particular, today provide a synoptic planning perspective for a multiplicity of spatial scales with variable temporal resolution. There is clear evidence that the use of recent technologies, internationally coordinated observation systems, and modelling, can help characterize, monitor and possibly forecast a wide range of devastating events and their effects. Remote sensing and geospatial information tools and techniques, including numerical modelling, have advanced considerably in recent years (Tralli *et al.* 2005, Joyce *et al.* 2009).

The nature of spatial planning requires a multi-risk approach that analyses all relevant hazards as well as the vulnerability of a particular area. In §3.2 of this article we integrate socio-economic, environmental and physical dimensions of vulnerability in order to estimate the damage potential and coping capacity. Our approach cannot, however, be regarded as all-inclusive due to the versatile nature of vulnerability, and also due to the limitations on data availability as explained in §3.1.1.

Vulnerability is a relatively new approach that links hazard distributions with risk research and refers to the susceptibility of individuals, communities or regions to natural or technological hazards (Cutter 1996a, b, Cutter *et al.* 2003, Kumpulainen 2006, Birkmann, 2007). Vulnerability is a condition, but at the same time it is also a process resulting from physical, social and environmental factors that increase the susceptibility of a community or area to the impact of a hazard (ADRC 2005). Vulnerability also encompasses the concepts of response and coping, since it is dependent on the potential of a community or area to withstand or react to a disaster. Westgate and O'Keefe (1976) suggested vulnerability has a social character and is not limited to potential physical damage or to demographic determinants. It is stated that disasters only occur when the losses exceed the capacity of the population to support or resist them.

Pakistan lies between 23° 35' to 37° 05' N latitude and 60° 50' to 77° 50' E longitude (figure 1). It touches the Hindukush Mountains in the north and extends from the Pamirs to the Arabian Sea. The country has a total area of 796 095 km². It consists of such physical regions as: (a) the Himalayas, which cover its northern part, and K-2 in its north western part; (b) the Balochistan plateau; (c) The Potohar Plateau and salt range; and (d) The Indus plain, the most fertile and densely populated area of the country. It gets its sustenance from the Indus River and its tributaries. Most of Pakistan has a generally dry climate and receives less than 250 mm of rain per year, although northern and southern areas have noticeable climatic differences. The average annual temperature is around 27°C, but temperatures vary with elevation from -30°C to -10°C during the coldest months in mountainous and northern areas of Pakistan. The plains of the Indus valley are extremely hot in summer with cold and dry weather in winter. The coastal strip in the south has a moderate climate. Due to the rainfall and high diurnal range of temperature, humidity is comparatively low. Only the coastal strip has high humidity.

The following sections describe the use of GIS and geospatial datasets to study and assess risks and vulnerabilities in Pakistan due to earthquakes, draughts, floods and cyclones. Only natural hazards are considered herein. Convincing examples of hazards and risks analyses can be found in Fleischhauer (2006) and Greiving (2006). In §2.2 we develop district profiles for both individual hazards and multiple hazards. Our objective is to highlight the contributions of GIS-based analyses to understanding, mapping and classifying hazards, risks and vulnerabilities even when the



Figure 1. Map of Pakistan. Available in colour online.

datasets are inconsistent, incomplete or partially contradictory. Our research aims to provide critical information to support decision-making by spatial planners, emergency managers and other decision makers in Pakistan.

2. Hazard assessment

2.1 Hazard scenarios in Pakistan

Pakistan is subject to a range of natural disasters including floods, cyclones, earthquakes, landslides and drought. In this subsection we summarize some basic facts concerning four of the major hazards, which are relevant to this hazard risk and vulnerability study.

- (1) *Earthquakes:* Pakistan lies within a seismic belt and therefore suffers from frequent small and medium magnitude earthquakes (GSP 2001). Earthquakes commonly occur along the Himalayas and Karakorum ranges and parts of Hindu Kush in the north of the country, in the Koh-e-Suleiman Range in the west with Chaman fault line along Quetta, Zob and Mekran fault line affects Gawadar district along the sea of the south-west coast.

- (2) *Cyclones*: According to the World Disaster Report 2003, the 960 km long coastal belt of Pakistan is occasionally battered by cyclones causing widespread loss to life and property, especially in the coastal districts of Gawadar, Badin and Thatta.
- (3) *Floods*: Pakistan is one of the five South Asian countries that have the highest annual average number of people physically affected by floods (UNDP 2001). The alluvial plains of the Indus river system formed as flood plains and remain vulnerable to recurrent flooding. Riverine floods occur during the summer monsoons. Flash floods and landslide hazards occur frequently in the northern mountains. Districts along the Indus plain are particularly affected by riverine floods, while hill torrents tend to affect the hilly districts located in the northern and western parts of Pakistan.
- (4) *Drought*: Pakistan is one of the countries that is expected to be hit hardest by the effects of global warming, and drought is one of the possible consequences of global warming resulting in a sharp fall in water table levels and drying up of wetlands (PMD 2002). Districts along the south-western and eastern parts of Pakistan have become severely affected by drought.

2.2 Hazard assessment methodology

In order to reduce risks to the population it is necessary to determine (a) the spatial and temporal patterns of risk i.e. the specific locations and time periods for different hazards, (b) the likely degree of severity for particular hazards, and (c) the level of exposure to those hazards (World Disasters Report 2003). Unfortunately, many factors combine to make this a difficult task, including the lack of appropriate and comparable detailed data concerning the exact spatial location and extent of individual hazards, their intensities and their duration. As mentioned previously, Pakistan is prone to many natural hazards, but because of the limitations on data availability only four hazard types have been selected for analysis in this study. Although these four major hazard types (earthquakes, cyclones, floods and droughts) are certainly very important for Pakistan they do not represent an exhaustive list. They all threaten communities and have thus been characterized by the number of hazard occurrences (based on historical records for each district) along with their intensities. Since each type of hazard has its own specific characteristics with respect to intensity and frequency it is impossible to come up with a single classification for all hazard types. Each hazard type was therefore initially classified separately on the basis of the combined frequency and intensity of each hazard type into one of four classes (1 = unaffected, 2 = low level, 3 = medium level, 4 = high level), using the Jenks Natural Breaks Classification method provided as one of the classification choices in ArcGIS (see figure 1). The individual methodologies used for each hazard type selected and the data sources exploited are set out below.

2.2.1 Earthquake hazards. The distribution of seismic zones and historical records of earthquake events measured and analysed by the Geological Survey of Pakistan (GSP) were used to identify those districts most prone to earthquakes. Figure 2(c) shows distributions for various categories of earthquake-affected districts, where a 'high' classification refers to those districts located in high seismicity zones (between

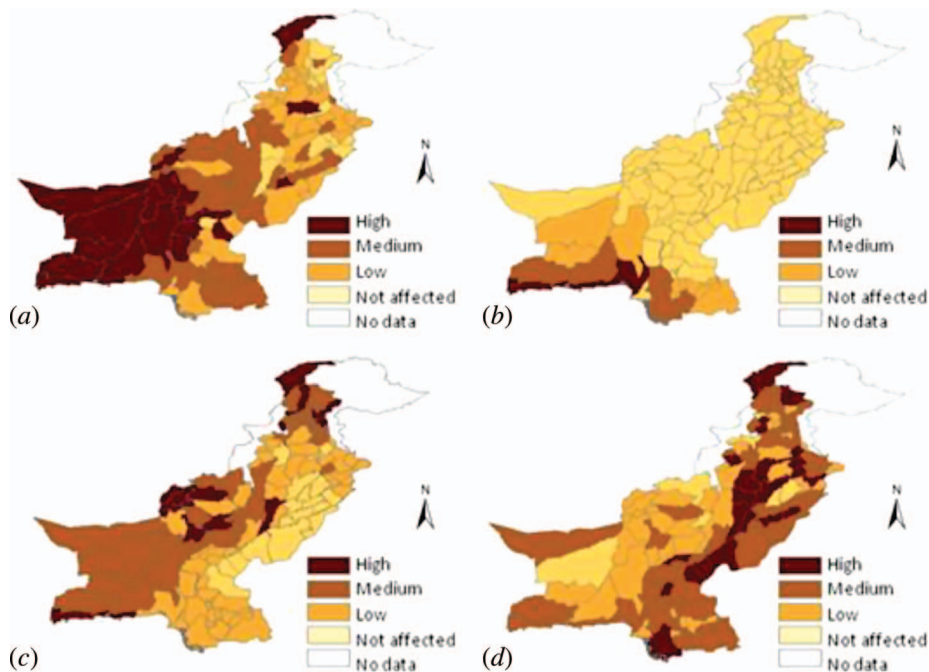


Figure 2. Major hazards in Pakistan (a) drought, (b) cyclone, (c) earthquake, (d) flood: results from the hazard assessment by district. Available in colour online.

8.0 and 5.9 on the Richter magnitude scale) that are frequently affected by medium and low intensity earthquakes, 'medium' refers to districts situated in the medium seismicity zone (between 5.0 and 3.9 on the Richter magnitude scale) that are occasionally affected by low intensity earthquakes, 'low' refers to districts in low seismicity zones (between 3.0 and 1.0 on the Richter magnitude scale) that are rarely affected by earthquakes, and 'not affected' (less than 1.0 on the Richter magnitude scale) refers to those districts that are neither in a seismic zone nor affected by earthquakes.

2.2.2 Cyclone hazards. The number of cyclonic events and their intensities measured by the Pakistan Meteorological Department (PMD), along with related information from various reports by the World Meteorological Organization (WMO) and the United Nations Organization UNO, were utilized to rank the districts that are prone to cyclones as having high, medium or low cyclone potential (figure 2(b)).

2.2.3 Flood hazards. Data from three different sources have been combined by means of GIS: (1) a flood distribution map for Pakistan from the WMO, (2) the most flood prone districts, as investigated by the PMD, (3) those districts that are most likely to be affected, as indicated by the Federal Flood Commission of Pakistan. These were used to derive flood hazard rankings for the individual districts of Pakistan as shown in figure 2(d). Districts located along rivers and commonly affected by seasonal or flash floods are ranked highly, while those that are less

commonly affected are ascribed a medium rank. Those districts rarely affected by floods are ascribed a low rank and those never affected by floods are described as 'not affected'.

2.2.4 Drought hazards. A drought situation map for Pakistan from 2001 developed by the Pakistan Agricultural Research Council (PARC) and the National Agricultural Research Council (NARC), which was based on a water balance (aridity index) technique, was used to identify drought-prone districts. The percentage departure of the aridity index from the mean was used to define the various categories of drought severity. Up to 10% variation was classed as a very low level of drought, 11–25% to low, 26–50% as medium and > 50% as severe (figure 2(a)).

2.3 Total hazard classification

Some types of hazard are more important (in terms of frequency and intensity) than others and different weights have therefore been assigned accordingly. The Delphi method developed by Helmer (1966) is based on expert opinions and has been adopted in this study to assign weights for each type of hazard (see figure 3). The opinions of experts taken into account in this study are mostly from academic institutions (i.e. universities), from disaster management organizations at national/provincial level and from research and development institutions (PMD, Pakistan Space and Upper Atmosphere Research Commission [SUPARCO], GSP etc.).

An integrated total hazard map was then created by adding together the weighted intensities of individual hazard types and then classifying them into one of four classes of overall hazard: 1 (not affected), 2 (low), 3 (medium) and 4 (high), respectively. The hazard assessment was applied to each district and all rankings are for entire districts with no provision for sub-district analysis.

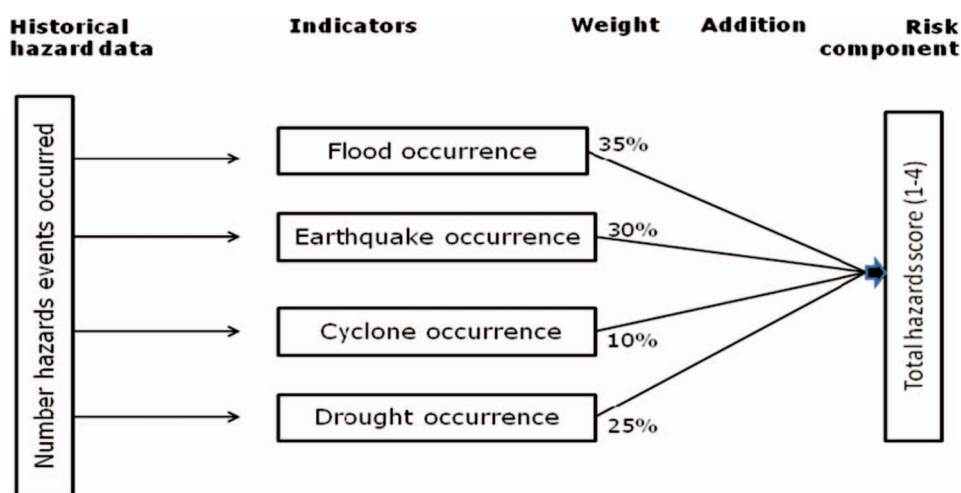


Figure 3. Calculation of total hazard scores (modified from Greiving 2006).

3. Vulnerability assessment

The hazards-of-place approach developed by Cutter (1996) incorporates multi-hazards or multiple stressors and population information at specific spatial scales (Clark *et al.* 1998, Cutter *et al.* 2000, Wu *et al.* 2002, Azar and Rain 2007). In fact, this approach delineates the hazard potential and its densities relationship to population sensitivities, at scales that are meaningful for local to regional interventions (Cutter *et al.* 2003). The vulnerability assessment in this study aims to analyse conditions (socio-economic, physical and environmental) that characterize underdevelopment and that render the poorest communities more vulnerable to natural hazards. The following section describes the methodology adopted for the assessment of vulnerability to selected types of hazard. The appropriate vulnerability indicators were identified, defined and then the total vulnerability is derived.

3.1 Vulnerability assessment methodology

Pakistan is divided into 138 districts within five provinces (Sindh, Punjab, Baluchistan, Khyber Pakhtunkhwa, Gilgit-Baltistan), plus Federally Administrated Areas (FATA) and the semi-autonomous region Azad Kashmir. Some districts have had to be extracted from our analysis due to the unavailability of data, and this analysis is therefore based on only 107 districts. The following sources were used to gather data on the various districts:

- Landuse/landcover data (derived from Landsat satellite data),
- Census Report Pakistan, 1981 and 1998
- Published statistical reports: FAO (2009), WFP (2001) and UNDP (2001)
- Pakistan Socio-Economic Survey (1999)

3.1.1 Vulnerability indicator selection. In order to measure vulnerability, indicators that cover both damage potential and coping capacity based on socio-economic, physical, and environmental consideration were selected for use. Two groups of indicators were differentiated: (a) damage potential indicators, which apply to physical structures that can be damaged by a hazard and estimate the scale of possible damage in a particular region; and (b) coping capacity indicators, which reflect the ability of a community or a region to prepare for, or respond to, a particular hazard (Kumpulainen 2006). The absence of vulnerability-related datasets (socio-economic, environmental etc.) not only constrained our approach to the vulnerability assessment for the districts, but also limited the number of possible indicators. It has, however, been possible to identify nine indicators related to poverty, health, education and environment, which are shown in table 1.

3.1.2 Vulnerability indicator descriptions. A high population density can increase the potential damage in an area and the situation can be worsened by a combination of limited access to health facilities and low income levels. The 'house structure' indicator generally represents the physical vulnerability of an area, but it can be indicative of the social status of a community. Hence, a high proportion of mud houses (kacha houses) may reduce the coping capacity of an area against flooding, for example, and increase the potential damage. It is widely agreed in the literature

Table 1. Vulnerability indicators.

Categories of vulnerability	Indicators	Used in calculation	Class ranges
Population	Population density	People/km ²	≥ 2000 (high) 1999 to 800 (medium) 799 to 200 (low) < 200 (very low)
Poverty	House structure (kacha or mud house)	Houses (%)	≥ 73 (high) 72 to 47 (medium) 46 to 22 (low) < 22 (very low)
	Income	Monthly household income (\$)	≥ 1.75 (very low) 1.74 to 1.25 (low) 1.24 to 1 (medium) < 1 (high)
	Sanitation	Houses with no improved water facilities (%)	≥ 90 (high) 89 to 60 (medium) 59 to 30 (low) < 30 (very low)
Education	Education	Literacy ratio (%)	≥ 50 (very low) 49 to 30 (low) 29 to 10 (medium) < 10 (high)
Health facilities	Total hospital facilities (total number of doctors per 1000 population + total number of nurses per 1000 population + total number of hospital beds per 1000 population)	Number of hospital facilities per 1000 population	≥ 4 (very low) 3.9 to 2.5 (low) 2.5 to 1 (medium) < 1 (high)
Degree of dependency	Age dependency ratio	Children per household (%)	≥ 90 (high) 89 to 60 (medium) 59 to 30 (low) < 30 (very low)
Economic activities	Agricultural land	Total district area (%)	≥ 90 (very low) 89 to 60 (low) 59 to 30 (medium) < 30 (high)
Environment	Total forest land	Total district area (%)	≥ 50 (very low) 49 to 30 (low) 29 to 10 (medium) < 10 (high)

that one of the most important factors when considering vulnerability at a local scale is the level of income (Bishop 1998). It is generally assumed that households with high incomes or wealth are less vulnerable than those with low income or wealth (Staines 2002); high income levels can therefore be said to increase coping capacity and reduce vulnerability. Another important indicator is the degree of dependency within households (IFRC 1999). Children and the elderly are considered to be the most vulnerable groups during disaster events, but only child dependency ratios have been used in this study due to the lack of demographic information available from

the districts concerning the elderly. The 'literacy ratio' measures a community's ability to understand written information. It is assumed that people with a low educational level do not seek, find or understand information concerning risks, which ultimately decreases their coping capacity and hence means that they are more vulnerable. The 'hospital bed per 1000 population' indicator determines the capacity per district of government health-care facilities. This is assumed to have great impact on the coping capacity of an area in terms of emergency response and mitigation activities during disaster events. Research and experience have shown that forests also play an important role in reducing the vulnerability of communities to natural disasters, in terms of both reducing their physical exposure to natural hazards and providing them with the livelihood resources to withstand and recover from crises. The damage potential for less forested areas will therefore increase, which ultimately means that the coping capacity of the community will decrease (Ortwin 2006). A greater amount of agricultural land may generally indicate increased agricultural productivity, generating rural jobs and raising the income levels of the rural inhabitants, but the damage potential of agricultural land from severe floods is high. By using an 'improved water facility' indicator, it is assumed that sufficient access to such a facility may increase resilience and thereby reduce vulnerability to natural disasters (Cicone *et al.* 2003).

3.2 Total vulnerability calculation

Although the indicators selected for the total vulnerability assessment are likely to be interrelated, it has been assumed for the purpose of this study that each indicator can contribute independently to the vulnerability of an individual or community; they are therefore considered separately. Since these indicators were derived from different sources, values for each indicator were first aggregated and a weighting assigned (based on the Delphi method) before it could be used for total vulnerability classification. Figures were derived for the nine major indicators listed below, and in each case were then ranked from 1 to 4 (1 = very low, 4 = high), using the Jenks' Natural Breaks Classification method provided as one of the classification choices in ArcGIS:

- (1) *Population density*: Since the population density for 2009 is not available, it has therefore been estimated on the basis of extrapolation of 1981 and 1998 Census Reports of Pakistan.
- (2) *House structure*: Total number of mud houses in each district was obtained from 'Food Insecurity in Pakistan – 2009' by WFP.
- (3) *Income level*: Average household income levels for each district were obtained for 2009 from 'Food Insecurity in Pakistan – 2009' by WFP.
- (4) *Literacy rate*: Since the literacy rate for 2009 is not available, it has therefore been estimated on the basis of extrapolation of 1981 and 1998 Census Reports of Pakistan.
- (5) *Clean water facility*: The total number of houses in each district with access to clean water was obtained from 'Food Insecurity in Pakistan – 2009' by WFP.
- (6) *Degree of dependency*: The average ratio between the number of dependant children in a household and the number of economically active adults was obtained for each district from 'Food Insecurity in Pakistan – 2009' by WFP.

- (7) *Health facilities*: The total hospital facilities at district level has been measured on the basis of the total number of doctors per 1000 population, total number of nurses per 1000 population and hospital beds per 1000 population (obtained for each of the districts from the Pakistan Socio-economic Survey (1999)). Since there are no relevant data available for 2009, available data have been assumed to be the same for 2009.
- (8) *Total agricultural land*: Vector layers extracted from the National Landuse Plan for Pakistan (2003), prepared by SUPARCO (based on Landsat TM data) were utilized to measure the total area of agricultural land for each district.
- (9) *Total forest land*: Vector layers extracted from the National Landuse Plan (2003) were also utilized to calculate the total area of forest in each district.

Figure 4 shows the weighting for the population density indicator to be 20%, and for the two next most important indicators (literacy rate and total agricultural land) to be 15%. Four indicators (house structure, income level, total forest land and hospital facilities) each have 10% and two indicators (clean water facility and degree of dependency) have 5% weightings. All of these weightings are based on expert opinions. Finally, the weighted vulnerability indicators are added together and then classified into one of four classes ranging from the lowest to the highest total vulnerabilities, thus facilitating the integration of the socio-economic, physical and environmental vulnerability into a single total vulnerability.

3.3 Risk assessment methodology

An integrated total risk map was then produced by combining the total hazard map with the total vulnerability map, and assigning equal weights to both components (see figure 5) making it possible to distinguish between those areas that are high risk because of their total hazard classification, their vulnerability, or both.

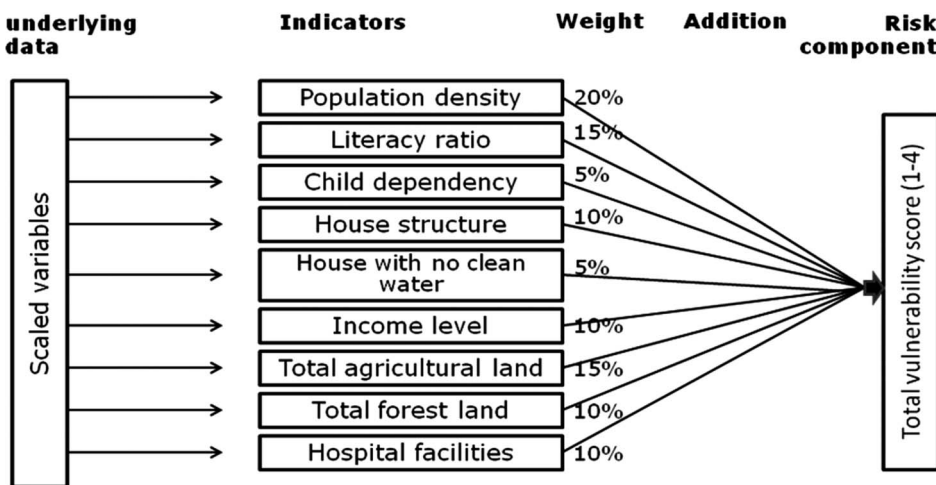


Figure 4. Calculation of total vulnerability scores (modified from Greiving 2006).

4. Discussion of results

4.1 Total hazard analysis

The total hazard assessment methodology, shown in figure 3, places an emphasis on floods, earthquakes and droughts with cyclones receiving a relatively low weighting. The resultant total-hazard map is displayed in figure 6. It reveals that districts with high and medium hazard rankings are mostly situated in the southern part of Pakistan, with a few districts also in the north. The 20 districts with the highest total hazard rankings are shown in figure 8: these districts are located in the northern (Chitral, Mardan, Sawat, Peshawar, Dir, Hafizabad), south-central (Jakobabad, Naushki), south-western (Chagai, Pashin, Awaran, Khuzdar, Bolan, Turbat, Gawadar, Panjgoor) and south-eastern (Thatta, Badin) parts of Pakistan.

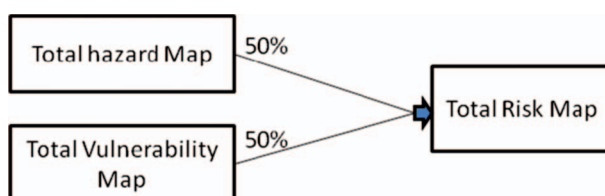


Figure 5. Total risk evaluation score procedure (adapted from SCEMD 2002).

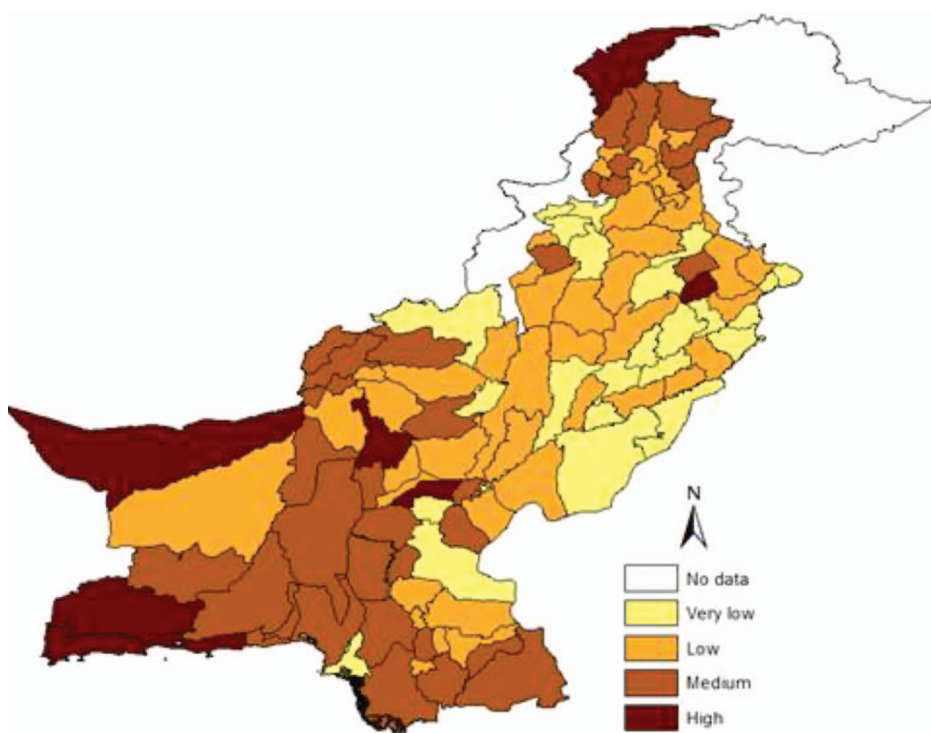


Figure 6. Total hazard assessment for Pakistan by district. Available in colour online.

4.2 Total vulnerability analysis

The total vulnerability assessment results depicted in figure 7 reveal that districts with high and medium vulnerability rankings correspond to areas with low levels of economic activity, and in particular with those that have the lowest income and education levels. They also reveal that the districts that have very few health facilities and very limited access to clean water are mostly situated in the southern part of the country, with only a few in the central and northern parts of Pakistan. Figure 8 also shows the 20 districts with the highest total vulnerability. These districts are located in the northern (Chitral, Dir, Charsada, Peshawar, Shangla and Buner), south-western (Pashin, Khuzdar Awaran and Turbat), south-eastern (Badin), eastern (Rahimyarkhan, Kasur and Rajanpur), and south-central (Dera Bugti and Dera Ghazi Khan) parts.

4.3 Total risk analysis

Figure 9 shows the overall pattern of total risk assessment for the districts of Pakistan. Higher risk areas occur where both the hazard threat and vulnerability are high and lower risk areas occur where both are low. A transition can be observed from low levels of risk in the central eastern areas to the extremely high or medium levels of risk that are predominant in the south-west and the far north of the country.

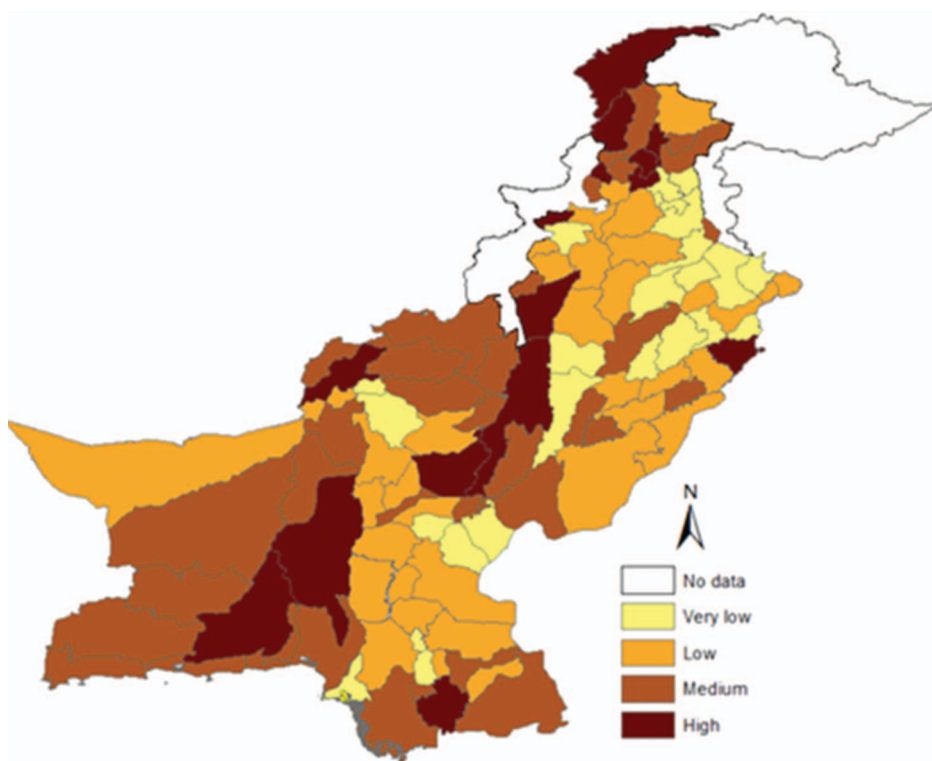


Figure 7. Total vulnerability assessment for Pakistan by district. Available in colour online.

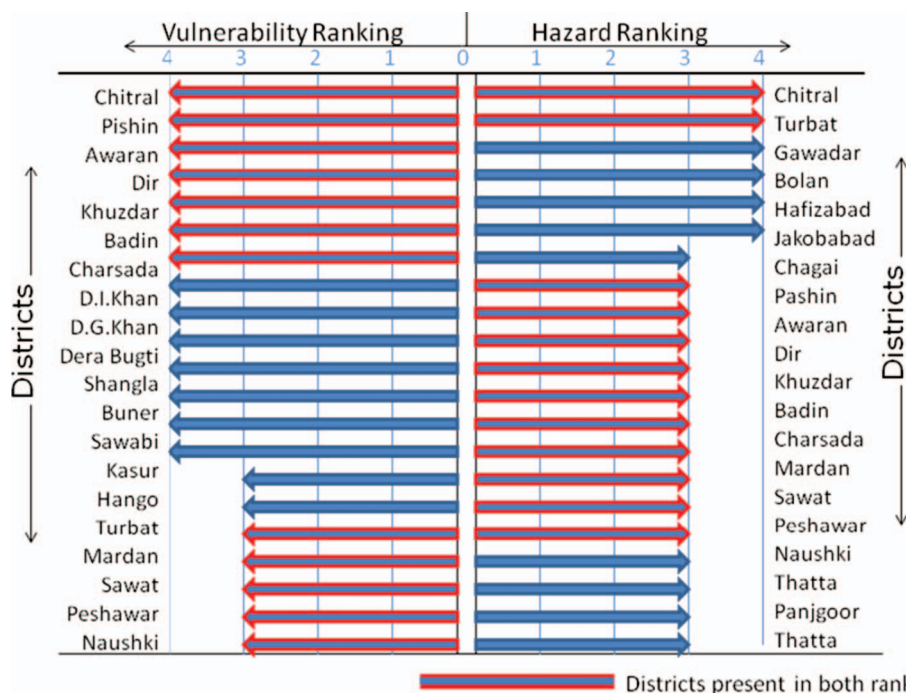


Figure 8. Top 20 districts by hazard and vulnerability rankings. Available in colour online.

Making an overall simplification and ignoring some anomalies, the total risk assessment map naturally divides Pakistan into four broad multi risk zones: very low risk in the eastern districts, low risk in the central areas, and moderate to high risk in the southern and northern areas. The districts with high risk rankings are mostly located in the south-west and include Gawadar, Turbat, Khuzdar, Awaran, Bolan and Pashin, with a few high risk areas in the north including Chitral, Charsada and Dir. The total risk assessment map clearly demonstrates the compound problem of high frequency of incidence involving multiple natural hazards and extremely high vulnerability in the high risk areas. Districts with a very low risk ranking are well developed and include the major hubs of Pakistan's economic activities, such as Karachi in the south and the four cities of Lahore, Faisalabad, Sargodha and Jhelum in the east. Intermediate risk areas are the Peshawar and Rawalpindi districts, which are ranked very low in the total vulnerability assessment but, due to high hazard frequencies (earthquakes and floods) both fall into a medium risk category.

4.4 Analysis of areas and populations prone to hazard, vulnerability and risk

On the basis of the methodology used in this study, approximately 9% of the total area covered by the selected districts, (or 6% of the total of Pakistan) is in high risk zones, while 43% (30% of Pakistan) is in medium risk zones. Only 38% (27% of Pakistan) is considered low risk and 10% (7% of Pakistan) very low risk. Similar calculations of area with respect to hazard and vulnerability assessments are shown in table 2.

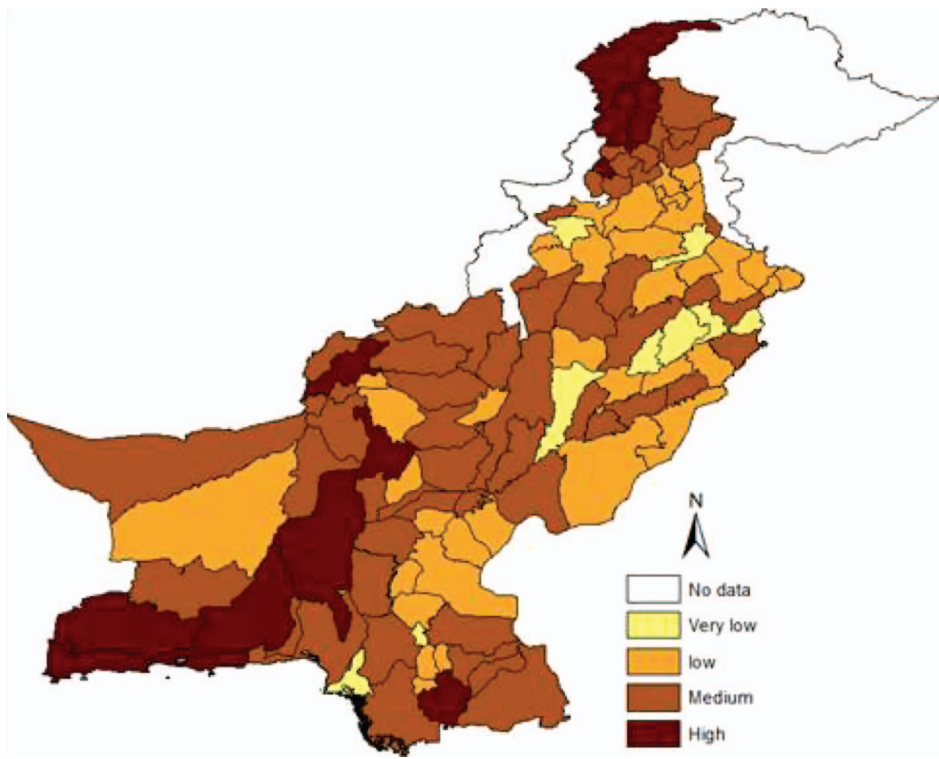


Figure 9. Patterns of total risk from natural hazards for Pakistan by district. Available in colour online.

Table 2. Affected areas (%) for hazard, vulnerability and risk.

	Hazard	Vulnerability	Risk
Area (%)	21	11	09
(with respect to total area of selected districts)	36	47	43
	31	36	38
	12	6	10
Total (%)	100	100	100
Area (%)	15	07	06
(with respect to total area of Pakistan)	26	33	30
	21	26	27
	08	04	07
Total (%)	70	70	70

Table 3 reveals that approximately 25% of the population within the selected districts live in moderated to high risk zones, whereas 47% of the population of the selected districts is in low risk zones. Only 28% of the population live in very low risk areas. Similar calculations of population proportions with respect to hazard and vulnerability assessments are shown in table 3.

Table 3. Population (%) under hazard, vulnerability and risk.

	Hazard	Vulnerability	Risk
Population (%)	8	8	3
(with respect to total population of selected districts)	28	36	22
	30	36	47
	34	20	28
Total (%)	100	100	100
Population (%)	6	6	2
(with respect to total population of Pakistan)	23	29	18
	24	29	38
	27	16	22
Total (%)	80	80	80

5. Conclusions

Due to the incomplete availability of data several simplifying assumptions had to be made during this study, placing some limitations on results, and we conclude as follows.

- The datasets relating to hazards were insufficient to allow an evaluation of absolute risk levels posed by any specific hazard or combination of hazards; they were, however, adequate for identifying the relative differences in single or multi-hazard risks between different areas.
- The weighting criteria need to be regarded as purely relative since assigning weights to different factors is a subjective process, and the observations and judgments involved may vary from expert to expert. The Delphi method employed in this study and the criteria used can be useful for creating a general understanding of the risks faced by a district or community.
- The kind of ranking produced has been shown to be easily understood even by experts and non-experts alike. The multi-hazard risk ranking was carried out on a district scale, and the results therefore only identify the most vulnerable districts without providing sufficient spatial resolution to identify more or less vulnerable areas within the districts.

In the introductory part of this article we suggested that the multi-faceted nature of spatial planning requires a multi-risk approach that will analyse both the relevant hazards and the vulnerability of the particular area under consideration. The resultant total risk assessment map allows determination of whether the level of risk is related to an area's hazard potential, its vulnerability, or to both, and enables the simple graphical portrayal of disaster risk rankings for Pakistan's district. The Delphi method adopted for determining the appropriate weightings for total hazard and total vulnerability assessments is based on common understanding of the relevance of particular hazards and vulnerabilities to particular districts. This common understanding can provide an essential foundation for consensus of policy makers and local authorities to (a) decide what is an acceptable level of risk, (b) determine what level of protection needs to be put in place, and (c) decide which is the best predefined mitigation measure to apply.

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