Chapter 1
Hazards, Disasters, and Risks

In this chapter, we will elaborate on three basic terms in the field of disaster risk science: hazards, disasters and risks. We will also discuss the classification, indexes, temporal and spatial patterns, and some other fundamental scientific problems that are related to these three terms.

1.1 Hazards

According to the United Nations International Strategy for Disaster Reduction (UNISDR), a hazard is a natural process or phenomenon that may pose negative impacts on the economy, society, and ecology, including both natural factors and human factors that are associated with the natural ones. Hazards are the origins of disasters. Hazards are detrimental to the development of human beings and hinder the sustainability of the world.

During the development of human beings, people have experienced and gradually understood all kinds of hazards. From different perspectives, disaster risk scientists studied on the classification, temporal and spatial patterns, and causes of hazards.

In this section, we will focus on the different classifications of hazards. Refer to research in natural disaster science and disaster geography for the temporal and spatial patterns of hazards. If you are interested in the causes of hazards, you may look up related research findings in geoscience, life science, and environmental science.

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1.1.1 Classification of Hazards by Causes

There are all kinds of hazards in human society. However, from the perspective of causes, hazards can be divided into two types, that is, hazards caused by natural factors and hazards caused by human factors that are associated with natural environments. In fact, the percentage of the former type of hazards is dwindling, while that of the latter type of hazards is increasing.

(1) **Classification of hazards by ICSU-IRDR research program**

The Integrated Research on Disaster Risk (IRDR) program of the International Council for Science (ICSU) classified hazards into 6 families, 20 main events, and 47 perils (UN-ICSU 2012).

There are six broad hazard categories within the family group:

Geophysical hazard: a hazard originating from solid earth. This term can be used interchangeably with the term geological hazard.

Hydrological hazard: a hazard caused by the occurrence, movement, and distribution of the surface and subsurface freshwater and saltwater.

Meteorological hazard: a hazard caused by short-lived, micro- to mesoscale extreme weather and atmospheric conditions that last from minutes to days.

Climatological hazard: a hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability.

Biological hazard: a hazard caused by the exposure to living organisms and/or the toxic substances or vector-borne diseases that they may carry.

Extraterrestrial hazard: a hazard caused by asteroids, meteoroids, and comets as they pass near earth, enter the earth's atmosphere, and/or strike the earth, or change in interplanetary conditions that affect the earth's magnetosphere, ionosphere, and thermosphere.

There are 20 main events. They are earthquake, mass movement, volcanic activity, flood, landslide, wave action, convective storm, extratropical storm, extreme temperature, fog, tropical cyclone, drought, glacial lake outburst, wildfire, animal incident, disease, insect infestation, extra impact, airburst, and space weather.

(2) **Classification of hazards by Joel C. Hill**

Gill and Malamud (2014) divided natural hazards into six groups. In the paper, he also estimated the temporal and spatial scales of different hazard groups and types.

The 6 hazard groups and 21 hazard types are:

Geophysical hazard: earthquake, tsunami, volcanic eruption, landslide, and snow avalanche.

Hydrological hazard: flood and drought.

Shallow earth processes hazard: regional subsidence and uplift, local subsidence and heave, and ground collapse.

Atmospheric hazard: tropical cyclone, tornado, hail, snow, lightning and thunderstorm, long-term climatic change, and short-term climatic change.

Biophysical hazard: wildfire.

Space hazard: geomagnetic storm and extra impact events.

The hazard groups proposed by Joel C. Gill et al. are almost equivalent to the hazard families of ICSU-IRDR classification except for two differences. One difference is that the meteorological and climatological families of ICSU-IRDR were combined into a single atmospheric group in Gill's classification. The other difference is that the hazard group of shallow earth processes was added in Gill's classification in order to emphasize the hazardous impacts of shallow earth changes (Table 1.1).

Table 1.1 Definitions of 21 hazards in the classification by Gill and Malamud (2014)

Hazard group	Hazard	Code	Definition	Component hazards (where applicable)
Geophysical	Earthquake	EQ	The sudden release of stored elastic energy in the earth's lithosphere, caused by its abrupt movement or fracturing along zones of preexisting geological weakness and resulting in the generation of seismic waves	Ground shaking, ground rupture, and liquefaction
	Tsunami	TS	The displacement of a significant volume of water, generating a series of waves with large wavelengths and low amplitudes. As the waves approach the shallow water, their amplitude increases through wave shoaling	
	Volcanic eruption	VO	The subterranean movement of magma and its eruption and ejection from volcanic systems together with associated tephra, ashes, and gases, under the influence of the confining pressure and superheated steam and gases	Gas and aerosol emission, ash and tephra ejection, pyroclastic and lava flows
	Landslide	LA	The downslope displacement of surface materials (predominantly rock and soil under gravitational forces)	Rockfall, rotational and translational slide, debris flow, lahar, and soil creep
	Snow avalanche	AV	The downslope displacement of surface materials (predominantly ice and snow under gravitational forces)	

(continued)

Table 1.1 (continued)

Hazard group	Hazard	Code	Definition	Component hazards (where applicable)
Hydrological	Flood	FL	The inundation of typically dryland with water.	Flash flood, fluvial flood, rural ponding, urban flood, coastal flooding, storm surge, jökulhlaups, glacial lake bursts
	Drought	DR	A prolonged period with lower than expected precipitation, resulting in a serious hydrological imbalance or the removal of once existent and persistent water through poor agricultural practice or water diversion	Meteorological drought, agricultural drought, hydrological drought
Shallow earth processes	Regional subsidence	RS	The sudden or gradual, downward vertical movement of the ground surface over a regional spatial extent	Tectonic subsidence
	Ground collapse	GC	The rapid, downward vertical movement of the ground surface into a void.	Karst and evaporate collapse, piping, metastable soils
	Soil (local) subsidence	SS	The gradual, downward vertical movement of the ground surface over a localized spatial extent	Soli shrinkage, natural consolidation and settlement
	Ground heave	GH	The sudden or gradual, upward vertical movement of the ground surface	Tectonic uplift, expansion (swelling) of soils and rocks
Atmospheric	Storm	ST	A significant perturbation of the atmospheric system, often involving heavy precipitation and violent winds	Tropical cyclone, hurricane, typhoon, mid-latitude storm
	Tornado	TO	A violently rotating column of air pendant (normally) from a cumulonimbus cloud and in contact with the surface of the earth	
	Hailstorm	HA	A significant perturbation of the atmospheric system, in which strong updrafts occur within convective storms where there is an ample	

(continued)

Table 1.1 (continued)

Hazard group	Hazard	Code	Definition	Component hazards (where applicable)
			supply of supercooled water droplets, resulting in heavy precipitation of hailstones when they have sufficient mass to leave the atmospheric system	
	Snowstorm	SN	A significant perturbation of the atmospheric system, with heavy precipitation of snow	
	Lightning	LN	The atmospheric discharge of static electricity, occurred when the resistance of the intervening air between areas of positive and negative charge is overcome	
	Extreme temperatures (heat)	ET (H)	A prolonged period of temperatures above the normal average for a designated period of time (either short or long term, local, regional, or global)	Heat waves, climatic change
	Extreme temperatures (cold)	ET (C)	A prolonged period of temperatures below the normal average for a designated period of time (either short or long term, local, regional, or global)	Cold waves, climatic change
Biophysical	Wildfires	WF	An uncontrolled fire fueled by natural vegetation.	
Space/ celestial	Geomagnetic storms	GS	A perturbation of the earth's magnetosphere because of changes in space weather, i.e., the intensity of solar wind.	
	Impact events	IM	The impact of a celestial body with the earth's surface	Asteroid, meteorite

This table outlines six hazard groups (geophysical, hydrological, shallow earth processes, atmospheric, biophysical, and space/celestial). These hazard groups contain 21 natural hazards, with the codes used in Gill et al.'s paper. Each natural hazard is defined, and the component hazards are outlined

(3) **Classification system of hazards by Kenneth Hewitt**

In the book *Regions of Risk* by Hewitt (1997), hazards were divided into the following categories:

Natural hazards include four types (meteorological, hydrological, geological and geomorphological, biological and disease hazards)

Technological hazards include hazardous materials, destructive processes, and hazardous designs.

Social violence hazards include weapons, crime, and organized violence.

Compound hazards include fog, dam failure, and gas explosion.

Complex disasters include famine, refugees, poisonous flood, nuclear wastes and explosion of nuclear power plants (Table 1.2).

Table 1.2 Classification system of hazards by regions of risk (Hewitt 1997)

Category	Single conditional process (medium)	Synthetic disaster factor (disaster type)
Natural	**Atmosphere**	
	Temperature, fog, rain	Thunder/hailstorm, tornado
	(Strong) wind, lightning, hail	Rain/storm, tropical cyclone
	Snowfall	Snowstorm
	Freezing rain (glaze)	
	Hydrology	
	Runoff (surface, river)	Flood: river-type, coastal-type (marine-type), natural dam span and barrier lake burst-type floods
	Ground snowfall	
	Freeze–thawing	Glacier forward and flows
	Sea ice, iceberg	Ice sea area
	Geology/geomorphology	
	Earthquakes, volcanic	Earthquakes, volcanic eruptions
	Tsunami (earthquake wave)	Rock collapse, debris flow
	Earth/rock material: flowing soil, flowing sand	Seabed landslip
	Block movement	Surface subsidence
	Radiation phenomenon	Radon hazard factor
	Geothermal	
	Biological and pest disaster factors	
	Viruses (e.g., measles, HIV, dengue, fever)	Disease outbreaks/epidemics, black death, plague, yellow fever, flu, sexually transmitted diseases
	Bacteria (e.g., pneumonia)	
	Protozoa (e.g., Giardia, malaria)	
	Fungi (e.g., Pneumocystis fusiformis)	Red tide (toxic algae)
	Algae	Plant infection, plant infestation
	Plant (weed)	Insect plague/invasion
	Insect (insect)	Rodent, shellfish poison
	Animal (harmful)	

(continued)

Table 1.2 (continued)

Category	Single conditional process (medium)	Synthetic disaster factor (disaster type)
Technology category	**Hazardous materials**	
	Radioactive material	Contamination: construction, soil, surface and groundwater
	Toxic substances (e.g., dioxin)	Industrial pollution
	Harmful gases (e.g., carbon monoxide)	Agricultural pollution
	Mutagen	
	Carcinogens	
	Harmful process	
	Radiation phenomena	Release of harmful Substances, gas media (radionuclides, SO_2), water media (sewage, coolant)
	Fire	Structure collapsed collision, explosion accident spread
	Harmful equipment	
	vehicle	
	Power	Plant
	Explosives	
	Contraceptive tools	Medical, Surgical
Social atrocities	**Social violence**	
	Weapons	Bombing (artillery, warships)
	Firearms, incendiary bombs, atomic energy, chemicals, toxins, poison gas, biological weapons	Air strikes Guerrilla warfare CBT war
	Crime	Environment war
	Armed forces	Siege, terrorist action
	Government	Releases excessive dangerous goods, oil spills/fires/chemicals
	Terrorist organization	
	Means	
	War, terror, subversion, deliberate destruction, genocide	
Recombination	**Haze** (fog + air pollution) (inversion + sun + pollution)	
	Dam break (accident + flood wave)	
	Air raid/storm fires (bombing + fires + storm)	
Complex	**Famine** (drought + poor harvest + food hoarding + poverty)	
	Refugee crisis (famine + war)	
	Toxic floods (tailings dams + toxic waste + flood)	
	Harmful nuclear tests and power plant explosions (nuclear explosion and pollution + atmospheric circulation + rain and atomic dust + migration)	

1.1.2 Classification of Hazards by Occurrences

Another way to categorize hazards is based on the environment where hazards occur (also called disaster-formative environment). The classification based on causes emphasizes the origin of hazards, that is, whether the hazards are caused by natural factors, human factors, or the interaction between natural and human factors. In contrast, the classification based on disaster-formative environment lays stress on the environmental basis of hazards, especially the distinctions among different spheres of the earth, and relatively ignores the causes. Actually, different kinds of hazards nowadays contain effects from both the natural and human factors to different degrees. And this is one of the important reasons why UN changed the goal of the global disaster reduction activities from natural disaster reduction to disaster risk reduction.

(1) **Classification of hazards by Peijun Shi**

In Shi's paper (1991) published on the *Journal of Nanjing University* (*Natural Sciences, Special Issue on Natural Hazards*), hazards were divided into four levels: systems, groups, types, and kinds. This classification highlights not only the occurrence environment but also the causes of hazards (Shi 1991).

The first level of this classification is focused on the causes, the second level the environments, the third level the types, and the fourth level the detailed hazards.

The hazard system is composed of three systems: nature, human, and environment.

The natural hazard system is then divided into four groups: atmosphere, lithosphere, hydrosphere, and biosphere. The hazards are mainly caused by natural environmental factors.

The human hazard system includes three groups: technology, conflicts, and wars. The hazards are mainly caused by human environmental factors.

The environmental hazard system is made up of five groups: global change, environmental pollution, desertification, vegetation degradation, and environmental diseases. The hazards are due to integrated natural and human factors.

(2) **Classification of hazards in Zhang Lansheng and Liu Enzhen**

The Atlas of Natural Hazards in China edited by Zhang and Liu, as a result of the cooperation between Beijing Normal University and the People's Insurance Company of China, was published by China Science Press (Beijing) in 1992. Based on the atlas, the paper *A Research on Regional Distribution of Major Natural Hazards in China* by Wang et al. (1994) was published, and the classification system of major natural hazards in China consisting of types and subtypes (Table 1.3) was built. The major natural hazards in China can be divided into 5 environments, 31 types, and 108 subtypes based on the differences in disaster-formative environments.

Table 1.3 Major natural hazards in China (Wang et al. 1994)

Environment	Major hazards (types)	Number of subtypes
Atmosphere	Drought (spring drought, summer drought, autumn drought, winter drought, summer half year drought, mid-summer drought, spring drought in pastoral area, annual drought) Typhoon (number of days of typhoon rainstorm, landing typhoon intensity) Rainstorm(average annual number of days of rainstorm, maximum rainfall in 72 h or 24 h) Hailstorm (average annual number of days of hailstorm, annual maximum number of days of hailstorm) Extreme low temperatures (maximum annual extreme low temperature, average annual extreme low temperature) Frost (freezing injury of winter wheat, freezing injury of subtropical economic orchard, chilling injury of tropical crops, chilling injury of Northeast China crops, cold dew wind) Ice and snow (average annual snow accumulation, snow-driving wind and freezing, maximum snow depth and snow reference pressure, sea ice) Sandstorm (annual days of maximum sandstorm, average annual days of sandstorm, average annual frequency of sand-driving wind) Dry-hot wind (dry-hot wind of wheat-producing area in North China)	30
Hydrosphere	Flood (maximum flow, maximum runoff) Urban waterlogging (severity of waterlogging) Storm surge (typhoon storm surge, extratropical cyclone storm surge) Sea wave (wind waves, tidal waves) Tsunami (seismic tsunami)	8
Lithosphere	Landslide (landslide, landslide-induced debris flow) Debris flow (debris flow) Subsidence (subsidence, cave-in, collapse) Wind-drift sand (drift sand, wind-drift sand, aeolian sand) Earthquake (magnitude, earthquake fault, earthquake-induced collapse and landslide of bedrock, collapse and landslide of loess, liquefaction of sand soil)	14
Biosphere	Crop disease (rice disease, rice virus, wheat stripe rust, wheat gibberellic disease, powdery mildew, virus disease) Crop pest (rice stem borer, migrating pests of rice, budworm, cotton pink bollworm, cotton aphid, big cotton aphid, red spider mite, verticillium wilt, blight, locust) Forest disease and pest (pine moth, trunk borer, variegate, bamboo locust, leaf cast and larch casebearer, pinewood nematode) Rodent (grassland rodent, forest rodent) Poisonous weed (*Astragalus variabills* Bunge, *Euphorbia fischeriana*, *Stellera chamaejasme*, hemlock, *Oxytropis glabra* DC, *Achnatherum inebrians*, *Oxytropis kansuensis*) Red tide (exogenous red tide, endogenous red tide)	33

(continued)

Table 1.3 (continued)

Environment	Major hazards (types)	Number of subtypes
Geosphere	Soil erosion (water erosion, wind erosion, freeze–thaw erosion, wind–water erosion, hydrochemical erosion, divot slide, gravitational erosion) Desertification (potential, developing, extant grassland desertification) Soil salinization (saline-alkali soil, secondary salinization) Frozen soil (permafrost, seasonal frozen soil, seasonal freezing injury) Endemic disease (Keshan disease, Kaschin–Beck disease, thyromegaly, crippling fluorosis) Environmental pollution (exhaust emission, wastewater emission, land occupation of solid waste, storage volume of solid waste)	23
Sum	31	108

Atmosphere including nine natural hazards—drought, typhoon, rainstorm, hailstorm, extreme low temperatures, frost, ice and snow, sandstorm, and dry-hot wind.

Hydrosphere including five natural hazards—flood, waterlogging, storm surge, sea wave, and tsunami.

Lithosphere including five natural hazards—earthquake, landslide, debris flow, subsidence, and wind-drift sand.

Biosphere including six natural hazards—crop diseases, crop pests, forest diseases and pests, rodents, poisonous weeds, and red tide.

Geosphere including six natural hazards—soil erosion, desertification, soil salinization, frozen soil, endemic disease, and environmental pollution.

1.1.3 Intensity Classification of Hazards

(1) **Intensity classification of single hazard**

The intensity classification of single hazard is based on the measurement specifications and standards of hazards. Hazards of different origins and in different environments are measured by different indicators. For example, earthquakes are measured in magnitude, rainstorms in rainfall intensity, typhoons in maximum sustained wind, and floods in flood stage. Those hazard measurement specifications and classification standards can be found on the Web sites of international or national departments of measurement standards.

Generally speaking, meteorological departments set up the measurement specifications and classification standards for atmospheric hazards; hydrological or water resources, and oceanic administrations for hydrosphere hazards; geological and earthquake administrations for lithospheric hazards; agricultural, forestry, and health administrations for biosphere hazards; and environmental and land resources administrations for geosphere hazards.

A large number of observations show that there is a negative correlation between hazard intensity and frequency. In other words, the higher the intensity is, the lower the occurring frequency is and the longer the repeating period is. There is a power function relationship between the hazard intensity and the occurring frequency (Chen and Shi 2013).

Refer to textbooks or monographs on geoscience, life science and resources and environmental science for the intensity classification of single hazard.

(2) **Intensity classification of multi-hazards**

The regional and integrated disaster risk research requires scientists to understand the diversity of hazards of different spatial and temporal scales and classify the intensities of multi-hazards. Because the measurement indicators vary among different hazards and there is no universal indicator, the intensity classification method for single hazard mentioned in the previous section will not be able to meet the needs of the regional and comprehensive studies of the diversity of hazards.

Based on current data, it is very difficult to synthesize various hazard intensities measured in different indicators. One way to get around this problem is to divide each kind of hazard intensity into relative levels and then calculate the average of levels weighted by the area that respective type of hazard covers during a certain period of time. This method can approximately reflect the regional overall hazard intensities in a certain space and a certain period of time. But there is one problem with this method; that is, different hazards with the same level of relative intensity might have different impacts on hazard-affected bodies. Therefore, in order to eliminate this effect, another term is added—the weighted average of the loss rate of each hazard in a certain space and time period.

Referring to the quadrat method in the vegetation investigation, we proposed to use multiple degree to describe the abundance of hazards in a region. Another way to do this is similar to the multiple cropping index calculation in land-use research. Based on Wang et al.'s paper (1994), in this book, we propose to use multiple degree and covering index of hazards to express the clustering degree and influence of multiple hazards in a region.

Multiple degree (H_D): the clustering degree of hazards in a certain region. As a relative value changing with the compared region, it can be expressed as

$$H_D = n/N \tag{1.1}$$

where H_D is the multiple degree of hazards in a region (%), n is the number of hazards in the region, and N is the number of hazards in a higher level of region (e.g., World, Asia, China). The value of N is set to be 108 (Table 1.3) for the calculation of county-level multiple degree of natural hazards in China.

Relative intensity (H_i): the relative destructive or damaging ability of hazards. Relative intensity is a relative value and only a quantity of the hazard per se. It is not an obvious positive correlation with the disaster loss or damage but is the basic reason (condition) for the regional loss. It can be calculated as follows:

$$H_{\mathrm{i}} = \sum_{i=1}^{n} P_i \cdot S_i \quad i = 1, 2, \ldots, n \tag{1.2}$$

where H_{i} is the relative intensity (level) of hazards in a region, P_i is the relative intensity of hazard i, and S_i is the area ratio of hazard i, ranging from 0.01 to 1.0, i.e., 1–100% and i is the number of hazard types.

Covering index of hazards (*H_c*): the percentage of covering area of hazards in a region. It can be expressed as

$$H_{\mathrm{C}} = \sum_{i=1}^{n} S_i \quad i = 1,\ 2,\ \ldots,\ n \tag{1.3}$$

where S_i is the percentage of covering area of a type of hazard in a region and i is the number of hazard types.

Composite index (*H*): the sum of the three indexes mentioned above divided by the respective maximum values. The formula is

$$H = H_{\mathrm{D}}/\max(H_{\mathrm{D}}) + H_{\mathrm{i}}/\max(H_i) + H_{\mathrm{C}}/\max(H_{\mathrm{C}}) \tag{1.4}$$

where H_{D} is the hazard multiple degree, H_{i} is the relative intensity, H_{C} is the covering index of a hazard in a region, and max () is the maximum value of the respective index.

1.1.4 Regional Difference in Multiple Natural Hazards of China

We will use the calculated results in Wang et al.'s paper (1994) to demonstrate the practical application of the four indexes–multiple degree, relative intensity, covering index, and composite index of hazards.

Multiple degree of natural hazards. In Fig. 1.1, the maximum value of the natural hazard multiple degree is about eight times as large as the minimum value in China. The value ranges from below 0.04 to above 0.30. This large variation shows that there is an obvious spatial clustering feature of natural hazards in China. Generally speaking, the high values are centered in North China and decrease toward northeast, northwest, and southeast. Ninety percent of the districts and counties with H_{D} value greater than 20% are located in the middle latitude belt (25°–45°N). In Southwest China where the H_{D} values are relatively low, the H_{D} value increases in some topography-transition areas. Thus, it can be seen that natural hazards relatively cluster in natural environment transition zones, such as

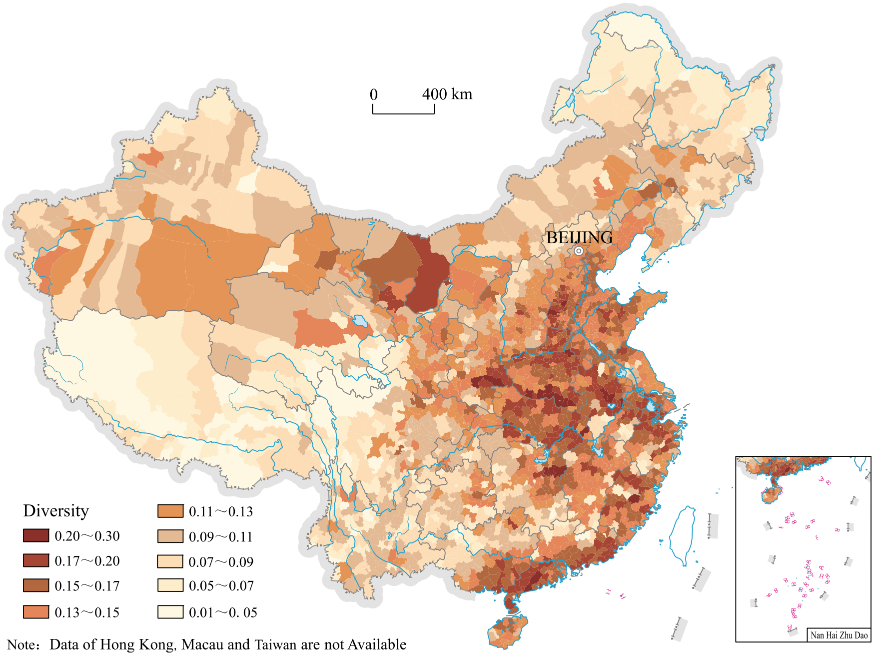

Fig. 1.1 Multiple degree of China's natural hazards (Shi 2011)

the middle latitude belt, sea–land transition zones, topography-transition areas, and semiarid farming–pastoral ecotone. In the transition regions of several natural environments, there exist continuous areas with high H_D values. North China is right in such location and thus becomes the most concentrated area of natural hazards in China, also an important part of the Pacific Rim and mid-latitude multiple hazard belt. Therefore, regional natural hazards' factors are of important value to the degree of regional natural environmental change.

Covering index of natural hazards. Figure 1.2 shows that there is a large variation in covering index of natural hazards in China, ranging from less than 0.02 to more than 11.0 and indicating obvious regional differences. On the whole, the trapezoid region with Qiqihar, Harbin, Tianshui, and Hangzhou as four vertexes has the highest H_C values (>8.0) in the country. In this high-value region, the Northeast China Plain and the North China Plain have values usually greater than 9.0. The regions with H_C values greater than 10 display a Lambda-shaped layout; that is, one line is Qiqihar–Tongliao–Beijing–Taiyuan–Baoji–Tianshui, and the other line stretches from southern Hebei Province to Hangzhou along the Grand Canal. The low-value regions are centered in the Northern Tibetan Plateau, from which H_C value increases outwards. In regions south of the Yangtze River, there are two high-value belts: southeast coastal belt and southwestern provinces including Yunnan, Guizhou, and Sichuan. There is a positive correlation between the H_C value and the H_D value. It can be seen from Figs. 1.1 and 1.2 that H_C values and H_D

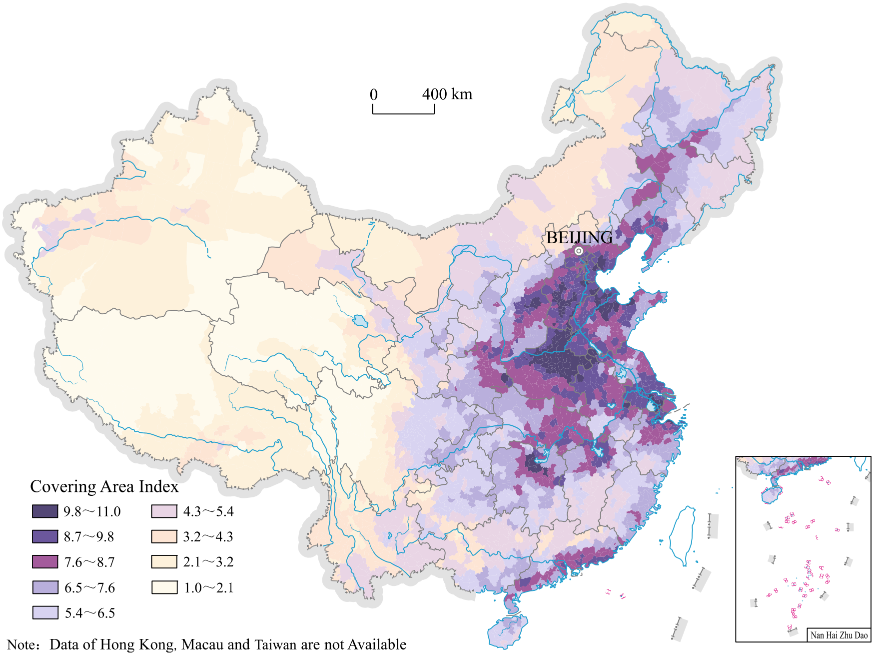

Fig. 1.2 Covering index of China's natural hazards (Shi 2011)

values share the same regional distribution, especially in North China, and the distributions of H_C values and H_D values are related to those of different kinds of natural hazards. Usually areas influenced by natural hazards of atmosphere, hydrosphere, and biosphere tend to have relatively high H_C values. Examples are the previously mentioned high-value regions including North China Plain, Northeast China Plain, and Loess Plateau, where meteorological, floods and biological hazards are concentrated and influence extensively.

Relative intensity of natural hazards. Figure 1.3 shows that H_i values are within the range of 0.8–24.0. Regions with a H_i value greater than 19.0 are sparsely distributed. One high-intensity area ($H_i > 16.0$) stretches from the northeast to the southwest, and another one is in the southeastern side of the first one—Hunan and Jiangxi Provinces. The relative intensities in the vast north-central Tibetan Plateau and Northwest China are relatively low. The regional differentiation of relative intensity is tightly associated with the regional distribution of several major hazards. First of all, the seismically active belts of China, i.e., the Pacific Rim belt and Himalayan seismic belt, have the correspondingly high intensities. Seismic regions, once having an earthquake with a magnitude greater than 8, usually become small high-intensity centers, such as West China, Tangshan. Secondly, the high-intensity regions are overlapped with the regions concentrated with cloudbursts. For example, the coastal typhoon belt, the northern Hebei Mountains–Taihang Mountains–Dabie Mountains cloudburst belt, and the cloudburst belts in western Sichuan and

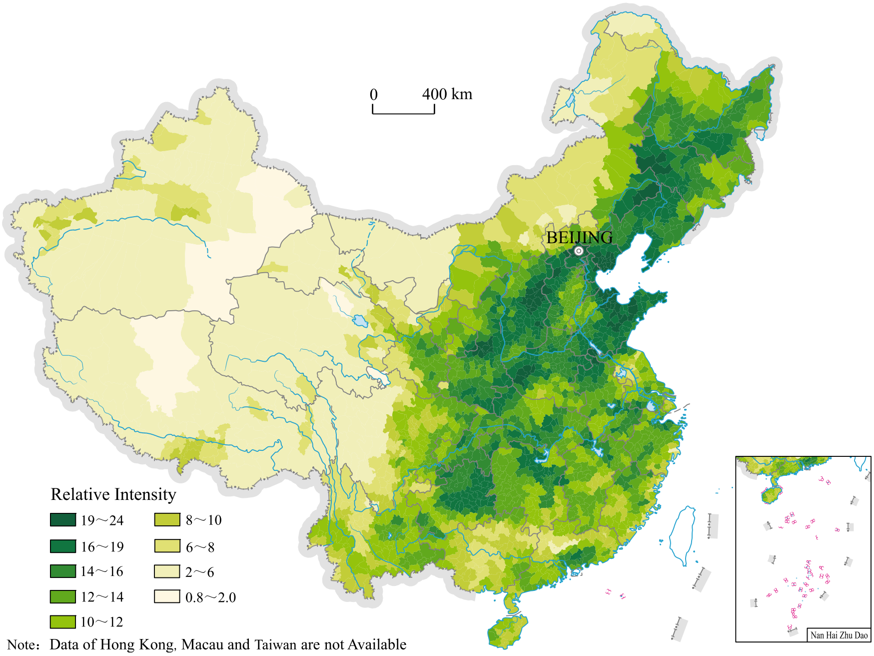

Fig. 1.3 Relative intensity of China's natural hazards (Shi 2011)

western Hunan. Thirdly, the frequently flooded areas also correspond to high relative intensity areas. These areas include Liaohe Plain, North China Plain, Northern Jiangsu Plain, and Hubei and Hunan Plains. Finally, areas with frequent debris flows and landslides, mainly in the "Second Step" east to Tibetan Plateau, have high values of relative intensity. Therefore, the overall relative intensity of natural hazards is controlled by several major natural hazards. However, these major natural hazards may also interact in the same region, which makes the regional differentiation of relative intensity of China's natural hazards more complicated and also expands the high-intensity regions. In every high relative intensity area, there is at least one dominant natural hazard.

Relationships among multiple degree, relative intensity, and covering index. The interaction of the three indexes varies among regions. Figure 1.4 shows the regional distribution of the composite index of natural hazards in China. North China has the highest values of all three indexes and thus is affected by frequent and catastrophic hazards. Coastal areas have the second highest values of three indexes and are subject to frequent and severe hazards. The third highest value regions include the farming–pastoral ecotone in northern and western Sichuan, Yunnan, western Guizhou, and southeastern Tibetan Plateau in the southwest. Whereas, the northern Tibet is a low-value region. The above outlines the basic regional differentiation of natural hazards in mainland China.

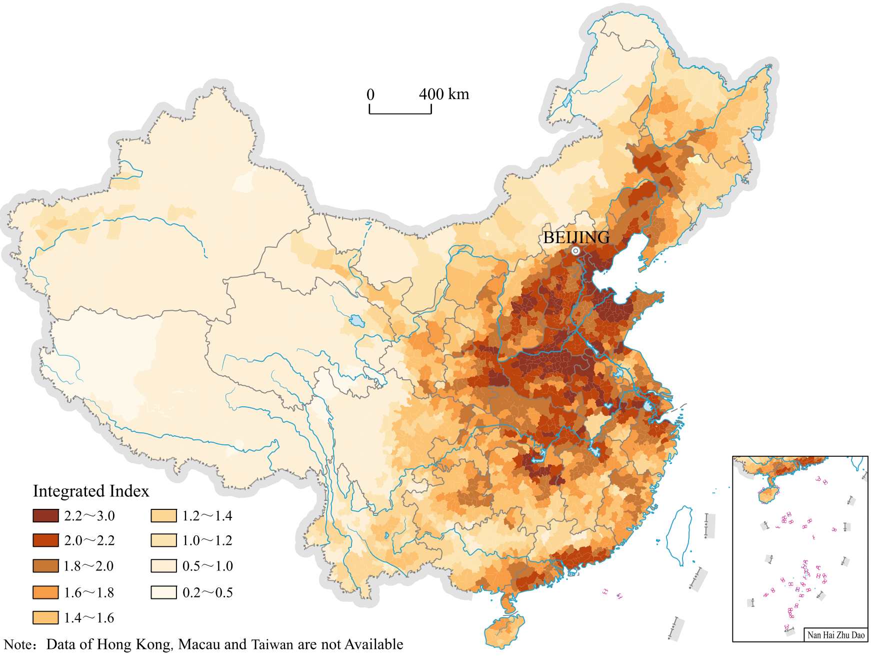

Fig. 1.4 Regional pattern of the composite index of China's natural hazards (Shi 2011)

There are differences in natural hazards between eastern and western China and between southern and northern China. As for east–west differentiation, the values of multiple degree, relative intensity, and covering index are higher in the east and lower in the west. The high values in the east are centered in North China while the low values in the west are centered in northern Tibet. As for north–south differentiation, the vast area within 25° to 45°N in the east has values of all three indexes higher than areas to its south and north. Among this vast area, the highest values exist in range of 30° to 40°N. However, the north–south differentiation in the west is not obvious, since there are incomplete data records, especially in the border area among Tibet, Qinghai, and Xinjiang, or the Hoh Xil region. Due to inadequate data, this region has the lowest values of all three indexes nationwide.

The regional differentiation of natural hazards is closely associated with the environments where hazards develop. The environmental evolution-sensitive zones usually have high multiple degree, high relative intensity, and high covering index, suffering frequent or severe hazards. However, a small number of ecologically vulnerable areas have low values of multiple degree and intensity. One outstanding example is eastern Guizhou. In areas with harsh environment, such as the vast West China, the multiple degree and relative intensity are not necessarily high. Therefore, there is no direct relationship between environmental conditions and the impacts of natural hazards.

1.2 Disasters

Disasters are direct or indirect results of hazards. Disaster impacts include human losses, property losses, resources and environmental destruction, ecological damages, disruption of social order, and threats to the normal functioning of lifelines and production lines.

The classification of disasters is closely associated with hazards and disaster-affected bodies. In Chinese literatures, "Zaihai" is used to refer to both hazards and disasters. However, in Western literatures, hazard and disaster are two terms used separately. Most researches in the West are focused on the classification of hazards, rarely on the classification of disasters. Whereas, in Chinese literatures, the classification of disasters takes the place of the classifications of both hazards and disasters. This confusion of hazards with disasters, or the confusion of hazard science with disaster science (e.g., seismology substitutes for earthquake catastrophology, and rainstorm meteorology for rainstorm catastrophology), negatively affects the development of disaster risk science.

With the development of human society, the types of disaster-affected bodies (exposure) have increased and the distribution of disaster-affected bodies has expanded. At the same time, human's ability of disaster prevention has also been improved. Therefore, even the same hazard could induce varying degrees of disasters. When analyzing the disasters, people stress on the disaster-affected bodies; namely, focus on human's disaster prevention level, which is referred as the vulnerability, resilience, and adaptation of human beings to hazards in the Western literatures.

1.2.1 Classification of Disasters

As mentioned above, in Western research there is more of an emphasis on the classification of hazards than that of disasters. In Chinese official documents or research literatures, the majority is the classification of disasters based on the causes and scales of disasters. The genetic classification of disasters according to the causes in Chinese literatures is basically the same as that of hazards in Western literatures.

(1) **Classification of disasters by Zongjin Ma**

In the book *Introduction to Catastrophology* by Ma (1998), according to the causes, disasters can be divided into natural disasters and man-made disasters. Natural disasters can be further categorized into natural disasters and man-made natural disasters, while man-made disasters are composed of man-made disasters and natural man-made disasters. When the management of disasters is taken into account at the same time, disasters can be divided into 5 classes and further 30 types. In the book, the author also clearly pointed out the administration departments in charge of each type of disaster (Table 1.4). This classification is different from others in the classification of the disaster-formative environments, with an inclusion of ocean

Table 1.4 China's disaster classification and professional management (Ma 1998)

Causal classification	Natural disaster classification	Professional management department
Atmosphere	Drought, waterlogging, floods	Ministry of Water Resources
	Tropical cyclone, extreme temperatures, hail, mildew, land wind	Meteorological Administration
Ocean sphere	Storm surge, sea ice, tide, wave, sea fog	Oceanic Administration
Lithosphere	Earthquakes, volcanos	Earthquake Administration
	Landslide, debris flow, subsidence, ground fracture	Ministry of Land and Resources
Biosphere	Agricultural diseases and pests, rodents	Ministry of Agriculture
	Forest diseases and pests, forest fire	Forestry Administration
Social sphere	Fire, traffic accidents	Ministry of Public Security
	Engineering and factory accidents	Ministry of Human Resources
	Pandemic diseases, poisoning	Ministry of Health

sphere instead of hydrosphere. Another difference is that sources of flood and drought are attributed to the atmosphere in Ma's classification (Ma 1994).

Besides, this classification is basically in accordance with the classifications in *PRC Disaster Reduction Report* (1993) and *Major Natural Disasters and Disaster Reduction in China* (1994) (Table 1.5).

Table 1.5 Classification of major natural hazards in China

Class of disasters	Type of disasters	Source
N/A	Drought, floods, typhoon, earthquakes, hail, freezing, snowstorm, forest fires, agricultural diseases and pests, landslide, debris flow, sandstorm, storm surge, sea waves, sea ice, red tide	*PRC Disaster Reduction Report* (1993)
Earthquake	Earthquakes	*Major Natural Disasters and Disaster Reduction in China* (1994)
Meteorological disasters	Drought, waterlogging, typhoons, hurricanes, tornadoes, cold damage	
Oceanic disasters	Tsunamis, storm surge, extreme waves, sea ice, red tide	
Floods	Floods	
Geological Disasters	Landslide, debris flow, ground cracking	
Agricultural disasters	Agricultural diseases and pests, weeds	
Forest disasters	Forest diseases and pests, rodents, forest fires	

Similar to the classification of *Introduction to Catastrophology*, in the book *Natural Disasters* by Chen (2013), based on the differences between the internal, external, and gravitational energy of the earth, natural disasters were divided into seven major categories: earthquakes, tsunamis, volcanos, meteorological disasters, floods, landslide and debris flow, and spatial disasters. This classification does not only reflect the holistic view of disasters but also emphasizes the timescales of disasters and environmental processes of the earth system.

(2) **Classification of disasters in Chinese state standards**

For the dual purposes of comprehensive prevention, reduction and relief of disasters and counting the losses and damages caused by natural disasters, experts organized by State Disaster Reduction Center of Ministry of Civil Affairs drew up the classification standards of natural disasters in China, in which the definition and code of each disaster are also given. In this classification, natural disasters in China are divided into 5 groups and 40 specific types, including 13 specific meteorological and hydrological disasters, 9 seismic and geological disasters, 6 ocean disasters, 7 biological disasters, and 5 eco-environmental disasters (Table 1.6).

Table 1.6 Classification, definitions, and codes of natural disasters in China (The State Standard of the People's Republic of China 2012)

Code	Name	Definition
010000	**Meteorological and hydrological disasters**	Natural disasters resulting from the abnormal or anomalous quantity, intensity, temporal and spatial distribution, and combination of meteorological and hydrological elements, causing adverse impacts on people's lives and properties, industrial and agricultural production, and ecological environment
010100	Drought	A deficiency in precipitation and/or a shortage in river runoff or other kinds of water resources, causing adverse impacts on people's life, industrial and agricultural production, and ecological environment
010200	Flood	An overflow of water from rivers or other water bodies onto land which is usually dry, caused by excessive rainfall, melting snow and ice, levee breach and storm surge, resulting in life losses, property losses, and disruption in social functioning
010300	Typhoon	A tropical cyclone that develops in a wide area over tropical or subtropical oceans, accompanied with heavy winds, rainstorm, storm surge and huge waves, bringing out damages to human lives and properties
010400	Rainstorm	Rainstorm happens when the precipitation rate is more than 16 mm per hour, or more than 30 mm for 12 h or 50 mm for 24 h, causing damages to human lives and properties

(continued)

Table 1.6 (continued)

Code	Name	Definition
010500	Wind Disaster	Wind disaster occurs when average or instantaneous wind speed reaches a certain level, causing damages to human lives and properties
010600	Hail	Hail is a type of solid precipitation formed in thunderstorm clouds and controlled by strong convective weather, causing damages to human lives and properties and to crops and animals
010700	Thunder disaster	Thunder disaster is an electric discharge, directly or indirectly striking human and animals, resulting in damages to human lives and properties
010800	Low-temperature disaster	Intrusion of strong cold front or constant low temperatures, causing freezing injury and damages to crops, animals, human beings, and infrastructures, disrupting normal life and production
010900	Snow and ice disaster	Due to snowfall, a wide area is covered with snow or affected by snowstorm, avalanche, frozen road, and other infrastructures. It severely disturbs the lives of human beings and animals and causes damages to traffic, power, and communication systems
011000	High-temperature disaster	High temperatures cause harms to the health of animals, plants and human beings and damages to production and environment
011100	Sandstorm	A strong wind blows loose sand and dirt that later mix with air from a dry surface, causing damages to human lives and properties. Horizontal visibility is usually less than 1 km
011200	Fog	A visible mass composed of cloud water droplets and ice crystals suspended in the air or near the earth’s surface, causing damages to human lives and properties and especially harms to the traffic safety. Horizontal visibility is usually less than 1 km
019900	Other M&H disasters	Meteorological and hydrological disasters that are not mentioned above
020000	**Seismic and geological disasters**	Natural disasters resulting from the sudden energy release or violent mass transport in the lithosphere of the earth or long-term accumulative geological changes, causing damages to human lives and properties and ecological environment
020100	Earthquake	The strong shaking of the earth’s surface and the accompanying ground rupture, resulting from the sudden release of energy in the earth’s crust. It causes damages to human lives, buildings and infrastructures, social functioning, and eco-environment

(continued)

Table 1.6 (continued)

Code	Name	Definition
020200	Volcano	The sudden occurrence of a violent discharge of the interior materials of the earth, causing direct damages to human lives and properties. The erupted material is referred to as lava. Other impacts include pyroclastic flow, lava flow, volcanic gases and ashes, and eruption-induced debris flow, landslide, earthquake, and tsunami
020300	Collapse	The sudden fall of unstable materials occurring at the edge of a steep cliff, causing damages to human lives and properties
020400	Landslide	A slide of a large mass of dirt and rock down a slope under the action of gravity, causing damages to human lives and properties
020500	Debris flow	A special water flow, entraining objects such as fragmented rocks, muds, branches in the path, rapidly rushes down mountain valleys or slopes. It results from heavy rains, reservoir or pond breach, or a sudden melting of snow and ice, causing damages to human lives and properties
020600	Surface collapse	A surface depression due to abandoned mines or karst processes, causing damages to human lives and properties
020700	Ground subsidence	A large-area land subsidence due to excessive extraction of groundwater or gas and oil, causing damages to human lives and properties. It occurs in unconsolidated or semi-consolidated soil areas
020800	Ground fracture	A linear fissure on the ground surface cracking through the rocks or soils, causing damages to human lives and properties
029900	Other geological disasters	Geological disasters that are not mentioned above
030000	**Ocean disasters**	Disasters resulting from the abnormal or drastic change of the ocean environment and occurring on the sea or coast
030100	Strom surge	A coastal flood caused by non-periodic abnormal rising of water over part of the sea that results from tropical cyclone, extratropical cyclone or cold front, causing damages to human lives and properties along the coast
030200	Sea wave	Sea waves with wave height of more than 4 meters, causing damages to ships, offshore oil drilling facilities, fishery, aquaculture, harbors and ports, seawalls, or other ocean and coastal engineering
030300	Sea ice	It blocks channels and causes damages to ships, offshore facilities and coastal engineering

(continued)

Table 1.6 (continued)

Code	Name	Definition
030400	Tsunami	Sea waves with wavelength up to hundreds of kilometers, induced by seafloor earthquakes, volcanic eruptions, underwater landslide, and subsidence, producing a sudden upward displacement of seawater and forming a "water wall" on the coast, devouring farmlands and villages, causing damages to human lives and properties
030500	Red tide	A sudden increase or high concentration of aquatic planktons and microorganisms changing the water body color to red or brown. It disrupts the normal aquatic ecology and causes damages to human lives and properties and eco-environment. See also the red tide disaster in the biological disasters
039900	Other ocean disasters	Ocean disasters that are not mentioned above
040000	**Biological disasters**	Natural disasters in the forest or grassland resulting from activities of living being, lightning, or spontaneous combustion, causing damages to crops, woods, cultivated animals and related facilities
040100	Plant diseases and pests	An outbreak of pathogenic microorganisms and pests, harming the farming and forestry
040200	Pandemic disease	An epidemic of infectious disease caused by microorganisms or parasites that rapidly spreads through human or animal populations, usually resulting in a high morbidity or mortality. It causes great damages to animal husbandry and harms to human health and life safety
040300	Rodents	An outbreak of rodent-related disasters, causing damages to plantation, animal husbandry, forestry and properties
040400	Weeds	Weeds cause severe damages to plantation, animal husbandry, forestry, and human health
040500	Red tide	A sudden increase or high concentration of aquatic planktons and microorganisms changing the water body color to red or brown. It disrupts the normal aquatic ecology and causes damages to human lives and properties and eco-environment
040600	Forest/grassland fire	A fire in a forest or grassland caused by lightning, spontaneous combustion or human beings under combustible conditions. It causes damages to human lives and properties and eco-environment
049900	Other biological disasters	Biological disasters that are not mentioned above
050000	**Eco-environmental disasters**	Natural disasters induced by the damage to ecosystem or ecological imbalance, bringing out negative impacts on the harmony between human beings and nature and on the living environment of human beings

(continued)

Table 1.6 (continued)

Code	Name	Definition
050100	Soil erosion	The loss of surface soil and soil parent materials that are eroded by water, wind, or other external forces, causing damages to soil resources and land productivity
050200	Desertification	Expansion of natural deserts and loss of vegetation caused by wind erosion, resulting in the decrease of soil productivity and the deterioration of eco-environment
050300	Soil salinization	The phenomenon or process of increasing the content of easily soluble salts in the upper soil layers, causing damages to soils and vegetation
050400	Stony desertification	A land degradation in the form of a large area of exposure of bedrock or gravel buildup in tropical, subtropical, semi-humid climate, and karst areas as a result of vegetation destruction and soil erosion, causing the decrease of soil productivity
059900	Other eco-environmental disasters	Eco-environmental disasters that are not mentioned above

From the comparison between the classification of the *Twelfth Five-Year Special Plan* and that of the *State Standards*, it can be seen that they share the same five big groups of natural disasters, but the latter one has 15 more specific types than the former one.

Besides, an emergency incident is defined as "a natural disaster, accidental disaster, public health incident or social safety incident, which takes place by accident, has caused or might cause serious social damage and needs the adoption of emergency response measures" in Emergency Response Law of the People's Republic of China (2007).

1.2.2 Classification of Disaster Scale

There is no universal standard for the classification of disaster scale. Although there are different standards in different fields, the major factor considered is the scale of the hazardous event-induced disasters. Generally, the classification indicators include the number of casualties, the amount of property loss, disaster-affected area, and hazard intensity.

(1) **Indicator system of UNISDR**

In the *Sendai Framework for Disaster Risk Reduction 2015–2030*, there are seven disaster reduction indicators, four of which are related to the measuring of disasters, namely disaster mortality, disaster-affected people, direct disaster economic loss in relation to global gross domestic product (GDP), damage to critical infrastructure and disruption of basic services (especially health and educational facilities) (UNISDR 2015). The disaster events include the natural or man-made disasters in specific spatial and temporal conditions (Table 1.7).

Table 1.7 Disability types in UNISDR disaster indicators (UNISDR 2015)

Disaster class	Subdisaster class	Hazard factor
Natural hazard factors	Geophysics	Earthquake
		Plot movement
		Volcanic activity
	Hydrological	Flood
		Landslide
		Wave movement
	Meteorology	Convective storm
		Outside the tropical storm
		Extreme temperature
		Fog
	Climate	Tropical wind
		Drought
		Ice lake floods
		Wildfire
	Alien planet class	Collision
		Space weather
Environmental hazard factors	Environmental degradation	Erosion
		Deforestation
		Salinization
		desertification
		Asian dust cloud
		Wetland reduction/ degradation
		Glacier subsided/ melted
Biological hazard factors	Biology	Infectious disease
		Epidemic
		Animal epidemic
		Injurious insect
		Pest
		Animal events
		Pollution

(continued)

Table 1.7 (continued)

Disaster class	Subdisaster class	Hazard factor
Man-made hazard factor (humanistic hazard factor)	Technical hazard factor	Industrial disaster
		Structure collapse
		Power failure
		Fire
		Explosion
		Mine disaster
	Chemical radiation hazard factors	Chemical leakage
		Oil spill
		Radiation pollution
	Major traffic accident	Aviation accident
		Railway accident
		Road accident
		Sailing accident
		Space accident

Mortality. Number of people killed or missing from a hazardous event. The death toll refers to the number of death population during or after the event, while the missing toll only refers to the total number of missing people during the event.

Besides counting the total number of dead and missing people, it is also important to calculate the percentage of killed and missing people per 100,000 people. Thus, the effect of population base can be eliminated in temporal and spatial comparison of mortality.

Affected people. It refers to the total population that are affected directly or indirectly by disasters. Directly affected people are those whose health was affected, such as injured and sick people, and those evacuated, displaced or relocated, and those who suffered from the disaster-induced direct damages to livelihoods, infrastructure, social culture, environment, and properties. At the same time, disaster statistics also need to include people whose houses were destroyed or collapsed and people who receive food aid.

Indirectly affected population are those suffered from the additive effects of disasters, namely people affected by disaster-induced disruption or modification of economy, critical facilities, basic services, business, work, society, and health.

In practice, due to the difficulty in counting indirectly affected population, only directly affected population are included in the disaster statistics. Likewise, it is also worth calculating the percentage of affected people per 100,000 people.

In addition to counting the killed and missing people and affected people, it is also common to specify their ages, genders, residence addresses, and disabilities.

Direct economic loss. Direct economic loss refers to disaster-induced loss of materials or properties, such as houses, factories, and infrastructures. Usually after the occurrence of a disaster, it is advised to assess the property loss as soon as possible to facilitate the cost estimation for disaster recovery and insurance claims processing.

It is also recommended to calculate the percentage of direct economic loss accounting for the global or national gross domestic product (GDP).

Direct economic loss can be further divided into agriculture loss, loss of industrial and commercial facilities, houses, critical infrastructure damaged or destroyed by disasters.

Direct agriculture loss: It refers to crop and livestock losses and also includes the losses of poultry, fishery, and forestry.

Industrial facilities damaged or destroyed: It refers to the loss of manufacturing and industrial facilities damaged or destroyed by hazardous events.

Commercial facilities damaged or destroyed: It refers to the loss of commercial facilities (including storage, warehouse, cargo terminal, etc.) that are damaged or destroyed by hazardous events.

Houses damaged: It refers to the loss of houses slightly affected by hazardous events and subject to no structural or architectural damages. After repair or cleanup, these damaged houses can still be habitable.

Houses destroyed: It refers to the loss of houses that collapsed or were burnt, washed away, and severely damaged and are no longer suitable for long-term habitation.

Critical infrastructure damaged or destroyed: It refers to the loss of educational and health facilities, and roads damaged or destroyed by hazardous events.

Educational facilities damaged or destroyed: It refers to the number of educational facilities damaged or destroyed by hazardous events. Educational facilities include children's playroom, kindergarten, elementary school, high school (junior and senior), vocational school, college, university, training center, adult education school, military school, and prison school.

Health facilities damaged or destroyed: It refers to the number of health facilities damaged or destroyed by hazardous events. Health facilities include health centers, clinics, local or regional hospitals, outpatient centers, and facilities that provide basic health services.

Roads damaged or destroyed: It refers to the length of road networks in kilometers that are damaged or destroyed by hazardous events.

Infrastructure damaged or destroyed: It refers to the loss of infrastructures other than the critical infrastructures, such as railways, ports, airports.

Railways damaged or destroyed: It refers to the length of railway networks in kilometers that are damaged or destroyed by hazardous events.

Ports damaged or destroyed: It refers to the number of ports that are damaged or destroyed by hazardous events.

Airports damaged or destroyed: It refers to the number of airports that are damaged or destroyed by hazardous events.

Basic services. Basic services refers to the disruption of public services or time loss due to low-quality services, which are caused by hazardous events. Basic services include health facilities, educational facilities, transportation system (including train and bus terminals), ICT system, water supply, solid waste management, power supply system, emergency responses, etc.

The health facilities, educational facilities, transportation system are mentioned above in the critical infrastructure loss and infrastructure loss sections.

ICT system refers to communications and the associated equipment network, including radio and TV stations, post offices, public information offices, Internet, landline and mobile telephones.

Water supply includes drinking water supply and sewerage systems.

Drinking water supply system includes drainage system, water processing facilities, water transporting channels (channels and aqueducts) and canals, water tank, or tower.

Sewerage system includes public sanitary facilities, sewerage treatment system, collection and treatment of solid wastes from public sanitation.

Solid waste management refers to collection and treatment of solid wastes that are not from public sanitation.

Power/energy system includes power facilities, electrical substations, power control centers, and other power services.

Emergency response includes disaster management offices, fire departments, police stations, military, and emergency control centers.

(2) **Indicator system of statistical system of damages and losses of large-scale natural disasters in China**

The Ministry of Civil Affairs and National Bureau of Statistics of China jointly introduced the regulation *Statistical System of Damages and Losses of Large-scale Natural Disasters* in 2013, which brought the comprehensive assessment of natural disaster loss into the regulation system (Shi and Yuan 2014). This Statistical System explains the purpose and meaning of statistics of large-scale disasters and defines the statistical scope and major indicators. Other contents described in this regulation include the submission procedure, forms of organization and data collection, 26 loss statistical report forms (1 of which is the loss summary table), 1 basic report, and 738 indicators. Some examples of these indicators are affected people, houses damaged and destroyed, household property loss, agriculture loss, industry loss, service loss, infrastructure loss, loss of public service system, resources and environmental loss, and so on (Table 1.8).

Figure 1.5 shows the changes in the percentage of direct economic loss accounting for GDP and human mortality caused by disasters in China (1990–2012, among which Wenchuan earthquake data are not included). The overall decreasing trends of the two items demonstrate a good result of comprehensive disaster reduction.

Compared to the disaster indicators in Sendai Framework for Disaster Risk Reduction 2015–2030 that incorporates both the human-made and natural disasters, the Statistical System can only be applied to natural disasters. In contrast to the emphasis of the latter one on the comprehensiveness, the former one only highlights the key points. Another difference between these two is that the latter one includes

Table 1.8 Report system in China's statistical system of damages and losses of large-scale natural disasters (Shi and Yuan 2014)

Report #	Name of report	Type of loss
Z01	Summary report of economic loss	Economic loss
A01	Report of affected people	Number of people affected
B01	Report of rural residential houses damaged and destroyed	
B02	Report of urban residential houses damaged and destroyed	
B03	Report of non-residential houses damaged and destroyed	
C01	Report of household property loss	
D01	Report of agriculture loss	
E01	Report of industry loss	
F01	Report of service loss	
G01	Report of infrastructure (transportation) loss	
G02	Report of infrastructure (communications) loss	
G03	Report of infrastructure (energy) loss	
G04	Report of infrastructure (water conservancy) loss	Amount of materials damaged and destroyed
G05	Report of infrastructure (municipal service) loss	Economic loss
G06	Report of infrastructure (living facilities in rural area) loss	
G07	Report of infrastructure (geological hazard prevention) loss	
H01	Report of public service (educational system) loss	
H02	Report of public service (technology system) loss	
H03	Report of public service (health system) loss	
H04	Report of public service (culture system) loss	
H05	Report of public service (media system) loss	
H06	Report of public service (sports system) loss	
H07	Report of public service (social security and service system) loss	
H08	Report of public service (social management system) loss	
H09	Report of public service (cultural heritage system) loss	Amount of material damaged and destroyed
I01	Report of resources and environmental loss	Amount of materials damaged and destroyed
J01	Report of basic indicators	

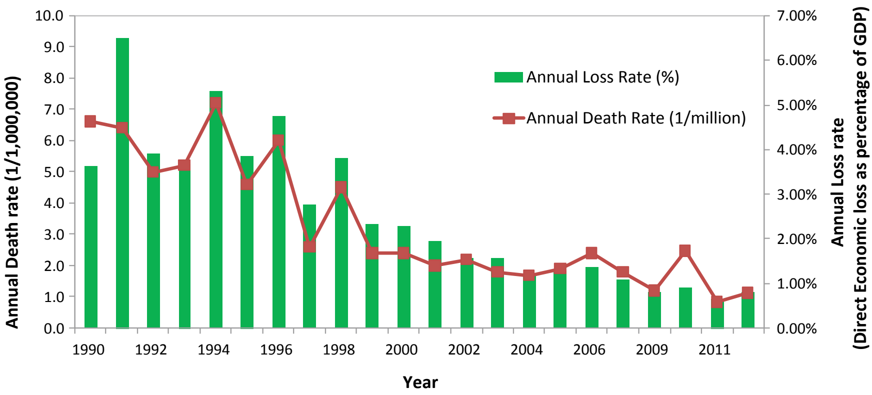

Fig. 1.5 Percentage of direct economic loss accounting for GDP and human mortality caused by disasters in China (1990–2012, Wenchuan earthquake data are not included) (Shi 2011, 2012)

the resources and environmental damages caused by natural disasters, while the former one stresses on the effectiveness and quality losses of infrastructure and services caused by disasters. Therefore, there are similarities in the disaster indicators of these two regulations, and there are also differences due to social and cultural differences. Even though some indicators share the same name in two systems, the actual meanings might be different. In practice, people need to be cautious in choosing the right indicator(s).

At present, the classification of disaster grade mainly adopts the standardized division method of disaster risk factors of each disaster, while there is no standard division for multi-hazard classification. The qualitative approach is usually used to classify disaster intensity levels, that is, the use of continuous quantitative or semiquantitative indicators, such as Applied Multi-Risk Mapping of Natural Hazards for Impact Assessment (ARMONIA) that categorizes a disaster into high, medium, or low level according to its intensity. Another example is hazard score proposed by Odeh Engineers Inc. (2001) that takes into account the level, frequency, and percentage of the affected area in the total research area. A higher score means the hazard has a higher intensity. The world natural disaster hotspots identified by the World Bank are based on 2.5° × 2.5° grid cells for risk assessment. In each grid cell, the hazard indexes of all types of hazards occurred are summed to give a score for the determination of hotspots. The hazard index of each type of hazard is established according to the corresponding data.

(3) **Very large-scale disaster indicator system**

The term very large-scale disaster emerged in the beginning of the twenty-first century.

At the end of the twentieth century, a series of disasters happened worldwide and caused great impacts on the human society and economy. For example, Hurricane Andrew occurred in USA in 1992 claimed 65 lives and caused 26-billion-dollar losses (1992 price). The Kobe earthquake with magnitude 7.3 that struck Japan in 1995 caused the death of 6434 people and losses of 130 billion dollars (1995 price). And 1562 people were killed in the 50- to 100-year floods in South China in 1998 that also caused the death of 1562 people and losses of 107 billion Chinese yuan (1998 price, equivalent to 16 billion US dollars of 1998). The subsequent 7.4- and 7.2-magnitude Marmara earthquakes happened to the middle west of Turkey in 1999 caused the death of 18,373 people and damages of 13–19 billion US dollars of 1999 (OECD 2004).

Since the beginning of the twenty-first century, no decreasing trend has been seen in the impacts of disasters on the human society and economy. The terrorist attacks upon USA on September 11, 2001, caused the death of 2996 people and economic losses of 120 billion US dollars of 2001 (OECD 2004). The outbreak of Severe Acute Respiratory Syndrome between the end of 2002 and the spring of 2003 in China resulted in 8437 cases (among which 5327 cases occurred in mainland China) and 813 deaths (of which 348 deaths occurred in mainland China). SARS is named by World Health Organization (WHO) to describe a viral respiratory disease caused by the SARS coronavirus (SARS-CoV) (Baidu Baike 2016). In the same year, the widespread heat waves in Europe killed 70,000 lives (Robine et al. 2008).

Because these large-scale or very large-scale disasters have great and wide impacts, people are becoming more and more interested in the studies of them. In 2004, OECD published a book named *Large-Scale Disasters—Lessons Learned*. In 2008, Cambridge University Press in UK published a book called *Large-scale Disaster—Prediction, Control, Reduction* compiled by Mohamed Gad-el-Hak. The international research project Integrated Risk Governance was launched in 2010 to cope with very large-scale disasters. Afterward, academia paid more attention to the study of very large-scale disasters.

Definition of Very Large-scale Disaster. The Chinese word "juzai" appeared in 1986 in China for the first time and was used to mistranslate the word "Catastrophic disaster" in the Western literatures. The appearance of "juzai" in Chinese media and academia is closely related to the founding and explanation of the catastrophic disaster insurance funds. According to the statistical data from cnki.com.cn, as of the end of December 2011, there were up to 1359 literatures that include "juzai" in the titles. And the number of papers increased annually with the peak of 504 publications in the year 2008. More than half of these 504 papers are related to the catastrophic disaster insurance. Due to the frequent occurrences of very large-scale disasters in recent years, the new words such as "juzai prevention," "juzai relief," and "juzai assessment" are becoming more and more widely used in scientific publications.

In the Chinese academic literatures, it is the author of this book that first introduced the word "dazai" for "large-scale disaster" and "juzai" for "very large-scale disaster" in the Western literatures after attending the High Level Advisory Board Seminar of Financial Management of Large-scale Catastrophes held by OECD in Paris in the July 2006 (Shi et al. 2006, 2007).

Although a lot of work has been done in the definition and classification of very large-scale disasters, there are no well-recognized definition and classification standards of very large-scale disasters in the fields of academia or finance. Different scholars have their own angles.

In Western literatures, the following definitions have great influences.

In the book *Large-Scale Disasters–Lessons Learned* published by OECD in 2004, the terms large-scale disasters (or Megadisasters) and very large-scale disasters were used, but the specific quantitative criterion was not provided. In OECD's opinion, very large-scale disasters can cause a great number of casualties, property losses, and widespread infrastructure damage. The impacts are so great that governments of the affected area and neighboring regions become unable to cope with; even public panic occurs. OECD also emphasizes the importance of cooperation and assistance among the member countries in response to the very large-scale disasters (OECD 2004).

In the book *Large-scale Disaster—Prediction, Control, Reduction* by Mohamed Gad-el-Hak (2008), disasters are divided into large-scale and very large-scale disasters based upon the disaster scope and death toll (Fig. 1.6). A very large-scale disaster is defined as a disaster with the death toll more than 10,000 or the affected area over 1000 km^2.

The definition of catastrophic disaster is usually based on the scale of the insured property losses by experts on insurance and financial management and development. The Insurance Services Office (ISO) of USA defines a catastrophic disaster as an event that causes insured property losses of 25 million dollars or more and affects a significant number of property/casualty policyholders and insurers. Swiss Re uses losses more than 38.7 million US dollars as a standard. From the amount of property losses, it can be seen that the scale of a catastrophic disaster cannot reach that of a large-scale disaster or megadisaster, let alone a very large-scale disaster. This also shows that the term "juzai" mentioned in the Chinese literatures in the late 1980s has a scale of the catastrophic disaster and was only paid attention to by experts on insurance and financial management and development.

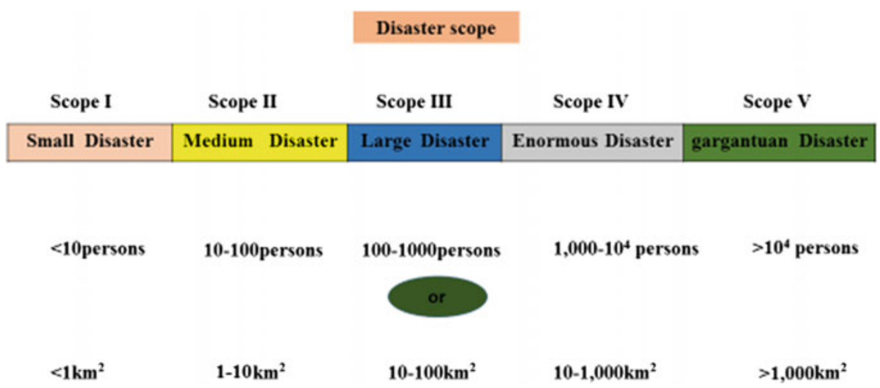

Fig. 1.6 Criteria of very large-scale disasters in the book *Large-scale Disaster—Prediction, Control, Reduction* (Gad-el-Hak 2008)

Therefore, before the use of large-scale disasters or megadisasters and very large-scale disasters in the Western literatures in the early twenty-first century, the term “juzai” in the Chinese literatures only refers to a catastrophic disaster.

From the angle of geoscientists, very large-scale disasters are usually defined according to the hazard intensity, casualties, property losses, and affected scope. A very large-scale disaster in Ma’s opinion must reach two of the following criteria: over 10,000 deaths, direct economic losses of more than 10 billion Chinese yuan of 1990, economic losses of more than the average annual fiscal revenue of the previous three years of a Chinese province, drought disaster rate more than 70%, or flood disaster rate more than 70%, crop losses of more than 36% of the average annual crop production of the previous three years of a Chinese province, more than 300,000 houses collapsed, and livestock death toll of more than 1 million (Ma et al. 1994). Shi et al. defines a very large-scale disaster as a great disaster caused by a 100-year hazard (e.g., a 7.0-magnitude or stronger earthquake) and resulting in a great number of casualties and large and widespread property losses (Shi et al. 2010). Also in Shi’s definition, the impacts of a very large-scale disaster are so great that the affected area is unable to respond by itself and has to resort to outside help (Table 1.9). According to the classification standard in Table 1.9, the very large-scale disasters caused by natural hazards worldwide between 1990 and 2015 are listed in Table 1.10.

From Table 1.10, we can see that one of the characteristics of the very large-scale disasters is the big hazard intensity. A very large-scale disaster can be a disaster chain composed of a very large hazard and its induced secondary disasters. It can also be a superposition of multiple types of disasters that are triggered by multiple hazards in a specific region and during a specific period of time. Besides, very large-scale disasters usually cause a great number of deaths and injuries, a huge amount of property losses, severe impacts on economy, society and natural

Table 1.9 Classification standards of disasters (Shi et al. 2010)

Level	Indicator			
	Hazard intensity (recurrence interval)	Death toll (people)	Direct economic loss (billion CNY)	Affected area (km^2)
Very Large-Scale	7.0 (earthquake) or over 1/100a	$\geq$ 10,000	$\geq$ 100	$\geq$ 100,000
Large-scale	6.5–7.0 (earthquake) or 1/50a–1/100a	1000–9999	10.0–99.9	10,000–99,999
Medium-scale	6.0–6.5 (earthquake) or 1/10a–1/50a	100–999	1.0–9.9	1000–9999
Small-scale	Below 6.0 (earthquake) or below 1/10a	$\leq$ 99	$\leq$ 1.0	$\leq$ 1000

Note (1) For each disaster level, at least two of the four criteria must be met. (2) Death toll includes both the people dead and people missing over 1 month. (3) Direct economic loss is the value of actual disaster-caused property loss of the year. (4) The affected area is the area where there are casualties, property losses, or damages to ecosystems

Table 1.10 List of worldwide very large-scale disasters between 1990 and 2015

Year	Event	Intensity (recurrence interval)	Death toll (people)	Affected area (10^4 km^2)	Economic loss (billion CNY)
1992	Hurricane Andrew, USA	1/100a	65	Not applicable	**26 billion USD (approx. 182 billion CNY)**
1995	Kobe earthquakes, Japan	**7.3**	6434	**approx. 12.0**	717.5
1999	Marmara earthquake, Turkey	**7.4, 7.2**	**18373**	Not applicable	13–**19 billion USD** (approx. 91–133 billion CNY)
1998	Yangtze River Floods, China	1/50a–**1/100a**	1562	**22.3**	**107**
2003	SARS, China	1/50a–**1/100a**	336	**Approx. 500.0**	**210**
2003	Heat waves, Europe	1/50a–**1/100a**	**37,451**	**Approx. 100.0**	**130**
2004	Indian Ocean Tsunami	**8.9**	**230,210 dead 45,752 missing**	800 km of coastline 5 km inland	Approx. 7
2005	Hurricane Katrina, USA	**1/100a**	1300	**Approx. 40**	**Approx. 875**
2005	Kashmir earthquake	**7.6**	**80,000**	**Approx. 20**	Approx. 35
2008	Cyclone Nargis, Myanmar	1/50a–**1/100a**	**78,000 dead 56,000 missing**	**Approx. 20**	Approx. 28
2008	Chinese winter storms	1/50a–**1/100a**	129 dead 4 missing	**Approx. 100**	**151.7**
2008	Wenchuan earthquake, China	**8.0**	**69,227 dead 17,923 missing**	**Approx. 50**	**845.1**
2010	Chile earthquake	**8.1**	802	**Approx. 60**	**105–210**
2010	Pakistan floods	1/80a–**1/100a**	3000	**Approx. 16**	Approx. 70
2010	Haiti earthquake	7.3	**222,500**	**Approx. 1.5**	Approx. 55
2011	Tohonku earthquake, Japan	**9.0**	**28,000**	Approx. 0.1	**1300–2200**
2015	Nepal earthquake	**8.8**	802	**Approx. 14**	349

Note USD:CNY = 1:7. The indicators highlighted in bold mean they reach the standards of very large-scale disasters environment, and a large disaster area. The emergency aids and reconstruction when or after the occurrence of the very large-scale disasters usually need help from a larger region or the whole country. In some cases, even international aids are indispensable.

All the very large-scale disasters mentioned so far are caused by sudden hazards. The indicators and classification standards for disasters caused by the accumulation of gradual hazards should be different (Zhang et al. 2013).

However, there are few discussions about the classification standards of gradually generated very large-scale disasters. Drought is one of the major natural disasters in both China and the world. Since 1949, a number of severe droughts causing great number of casualties and huge property losses have happened in China. For example, more than tens of thousands of people were killed due to the three-year great drought from 1959 to 1961. Based on the case of drought, we will discuss the classification standard of gradual very large-scale disasters below.

We cannot use hazard intensity to measure or to classify very large-scale droughts. This is because the forming process of a drought is very complicated. A drought hazard could be meteorological, or hydrological. It can also be soil drought or socioeconomic drought. The indicators and measurement criteria vary among different types of droughts. The data and studying methods are also different. What's more, there is no linear relationship between the drought intensity and drought losses. And there is no definite relationship between the drought hazards and the formation of drought disasters neither.

The impacts of a very large-scale drought disaster can be represented in crop losses and population in need of aids. Drought could result in a bad harvest or total crop failure and water shortage for both human beings and livestock. Industrial production, urban water supply, and ecological environment could also be affected to varying degrees if a drought lasts for a long time. In the Statistical System of Damages and Losses of Natural Disasters by PRC Ministry of Civil Affairs (2013), the following items are included in the statistics of droughts: affected population, population affected by water shortage, number of livestock affected by water shortage, affected crop area, crop disaster area, total crop failure area, affected grassland area, and population in need of food and water aids. The inclusion of population affected by water shortage and population in need of aids in this Statistical System demonstrates the "people-oriented" disaster relief philosophy. In the State-level Contingency Plan for Natural Disaster Relief by General Office of the State Council of PRC, it is mentioned that when the number of people in need of food and water aids from governments accounts for a certain percentage of the agricultural population or reaches a designated magnitude, the state will initiate emergency response of the corresponding level (Table 1.11).

Based on the severe droughts in China in Table 1.11, five criteria are used to define very large-scale drought disaster, crop disaster ratio, crop disaster area, disaster population, population in need of aids ratio, and direct economic loss (Table 1.12).

Table 1.11 List of severe drought losses in China since 1949 (Zhang et al. 2013)

Number	Event	Hard-hit region	Affected crop area (10^4 hm^2)	Crop disaster area (10^4 hm^2)	Population in need of aids (10^4)	Affected population (10^4)	Crop disaster area (10^4 km^2)	Crop disaster ratio (%)	Disaster population (10^4)	Population in need of aids ratio (%)	Direct economic loss (10^8 CNY)
1	1959–1961 Three-year drought	Henan, Shandong, Anhui, Hubei, Hebei, Inner Mongolia, Hunan, Shaanxi, Shanxi, Sichuan	10,980	4600	58,643	161,122	**46**	42	**38,141**	**36**	–
2	1972 North China drought	Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia	2149	1061	1034	8483	**10.6**	49	**4189** —	12	–
3	1978 Yangtze river basin drought	Jiangsu, Anhui, Jiangxi, Hubei, Hunan, Sichuan	1527	673	1547	15,903	**6.7**	44	**7014** —	10	–
4	1982 Northeast China drought	Liaoning, Jilin, Heilongjiang	665	323	154	1306	3.2	49	634	12	–
5	1986 National great drought	Shandong, Shaanxi, Shanxi, Inner Mongolia, Hunan, Hubei, Jiangsu, Anhui	3104	1476	1881	16,630	**14.8**	48	**7910**	11	–
6	1988	Shandong, Henan, Hubei,	1800	843	2580	17,647	**8.4**	47	**9542**	15	–

(continued)

Table 1.11 (continued)

Number	Event	Hard-hit region	Affected crop area (10^4 hm^2)	Crop disaster area (10^4 hm^2)	Population in need of aids (10^4)	Affected population (10^4)	Crop disaster area (10^4 km^2)	Crop disaster ratio (%)	Disaster population (10^4)	Population in need of aids ratio (%)	Direct economic loss (10^8 CNY)
	Middle-eastern China summer drought	HunanAnhui, Jiangsu									
7	1989 Northeast and Shandong drought	Shandong, Liaoning, Jilin, Heilongjiang	2349	1021	778	5756	**10.2**	43	2993	14	–
8	1990 South China autumn drought	Hunan, Hubei, Guangxi, Sichuan	752	403	1180	8231	4.0	54	4408	14	–
9	1990 National drought	–	3298	1705	2139	16,010	**17.1**	52	**8276**	13	–
10	1992 National drought	–	3028	1784	2550	14,700	**17.8**	59	**8658**	17	–
11	1999–2001 Three-year drought	–	10,910	6709	10,014	52,961	**67.1**	**61**	**32,568**	19	**Approx. 2 600**
12	2006 Sichuan–Chongqing drought	Sichuan, Chongqing	378	203	1537	6647	2.0	54	2289	23	223

(continued)

Table 1.11 (continued)

Number	Event	Hard-hit region	Affected crop area (10^4 hm^2)	Crop disaster area (10^4 hm^2)	Population in need of aids (10^4)	Affected population (10^4)	Crop disaster area (10^4 km^2)	Crop disaster ratio (%)	Disaster population (10^4)	Population in need of aids ratio (%)	Direct economic loss (10^8 CNY)
13	2009 Inner Mongolia–Liaoning summer drought	Liaoning, Inner Mongolia	429	317	179	1096	3.2	**74**	723	16	179
14	2010 Southwest China drought	Yunnan, Guizhou, Sichuan, Chongqing, Guangxi	648	425	1817	7405	4.3	**66**	4800	25	447
15	2011 Spring–summer droughts in middle and lower Yangtze river basin	Hunan, Hubei, Jiangxi, Anhui, Jiangsu	428	240	619	4269	2.4	56	2384	14	191

Notes (1) Disaster data from literatures (Leroy 2006). (2) Indicator explanation. Affected crop area is the crop area that has a reduction of more than 10% of production. Crop disaster area is the crop area that has a reduction of more than 30% of production. Crop disaster ratio is the ratio of crop disaster area over affected crop area. Population affected is the number of people who suffer from losses caused by natural disasters (including non-permanent residents). Disaster population is the population that are affected by the crop disaster. In this table, it is estimated from the crop disaster area and the cultivated area per capita in the disaster province. Population in need of aids is the number of people who are directly affected by natural disasters and are in need of food and water supply or medical treatment from the government (including non-permanent residents). Population in need of aids ratio is the ratio of population in need of aids to the population affected. Direct economic loss is the value of depreciated of the disaster-bearing bodies or the value of the disaster-bearing bodies forfeited. In this table, it is the value of actual property damages of the year when the disaster happened. (3) The disaster population in events 1–11 was estimated from the crop disaster area and the cultivated area per capita in the disaster province. (4) The cell highlighted in bold means the number in the cell reaches one of the criteria of very large-scale drought disasters (Table 1.11)

Table 1.12 Classification standards of very large-scale disasters (Zhang et al. 2013)

Type	Indicator	Criteria	Notes
Sudden very large-scale disaster	(a) Hazard intensity (recurrence interval) (b) Death toll (c) Direct economic loss (d) Disaster area	(a) ≥ 7.0 (earthquake) or 100-year (b) $\geq 10{,}000$ people (c) ≥ 100 billion CNY (d) $\geq 100{,}000$ km^2	• Must meet any two criteria • Death toll includes both the people dead and people missing over 1 month • Direct economic loss is the value of actual disaster-caused property loss of the year • Disaster area is the area where there are casualties, or property losses, or damages to the ecosystem
Gradual very large-scale disaster (drought)	(a) Crop disaster ratio (b) Crop disaster area (c) Disaster population (d) Population in need of aids ratio (e) Direct economic loss	(e) $\geq 60\%$ (f) $\geq 50{,}000$ km^2 (g) ≥ 500 million people (h) $\geq 30\%$ (i) ≥ 100 billion CNY	• Must meet any 3 criteria • Crop disaster ratio is the ratio of crop disaster area over affected crop area • Disaster population is the population that are affected by the crop disaster • Population in need of aids ratio is the ratio of population in need of aids over the population affected • Direct economic loss is the value of actual property damages of the year when the disaster happened

1.3 Risks

Risk is the probability of disaster loss in a future period of time in a region, or the future disaster. Essentially, risk is the probability of occurrence of a future hazardous event and its impacts (loss and/or damage). UNISDR (2004) defines risk as the probability of harmful consequences resulting from interactions between natural or human-induced hazards and vulnerable conditions. Two aspects that need special attention are the influence of social factors on risk and the estimation of hazard intensity and distribution.

Disaster risk usually refers to natural disaster or environmental risk that is associated with natural factors. The wide attention which disaster risk receives is related to the disaster (especially catastrophic disaster) insurance and the risk governance of emerging risks and very large-scale disasters.

The International Risk Governance Council, founded in 2003 in Geneva, Switzerland, paid high attention to the governance of emerging risk and slow-developing catastrophic risks and also established the transition from risk management to risk governance.

In 2006, Chinese National Committee for the International Human Dimensions Program on Global Environmental Change (CNC-IHDP) proposed to IHDP to undertake the Integrated Risk Governance (IRG) research under the background of global environmental change. This international scientific program proposal was approved by the scientific committee of IHDP and launched in 2010 (Shi et al.

2012). This program especially emphasizes the risk governance of very large-scale disasters. In 2015, this program was listed as a core program in the ICSU Future Earth Scientific Plan and focuses more on the risk governance of very large-scale disasters and green development.

In 2006, the Davos World Economic Forum issued the Global Risk Report for the first time (WEF 2006). And then it issued one report every year afterward. Until 2016, there have been 11 global risk reports being published. The series of reports deal with both traditional and non-traditional risks.

1.3.1 Risk Classification System of Davos World Economic Forum

In early 2014, the Davos World Economic Forum published the Global Risk Report 2014, where 31 global risks are grouped into five categories (Table 1.13). The top ten global risks of highest concern in 2014 picked out by the World Economic

Table 1.13 Global risk classification system of Davos World Economic Forum (WEF 2014)

Category	Risks
Economic	1. Fiscal crises in key economies 2. Failure of a major financial mechanism or institution 3. Liquidity crises 4. Structurally high unemployment/underemployment 5. Oil price shock to the global economy 6. Failure/shortfall of critical infrastructure 7. Decline of importance of US dollar as a major currency
Environmental	1. Greater incidence of extreme weather events (e.g., floods, storms, fires) 2. Greater incidence of natural catastrophes (e.g., earthquakes, tsunamis, volcanic eruptions, geomagnetic storms) 3. Greater incidence of man-made environmental catastrophes (e.g., oil spills, nuclear accidents) 4. Major biodiversity loss and ecosystem collapse (land and sea) 5. Water crises 6. Failure of climate change mitigation and adaptation
Geopolitical	1. Global governance failure 2. Political collapse of a nation of geopolitical importance 3. Increasing corruption 4. Major escalation in organized crime and illicit trade 5. Large-scale terrorist attacks 6. Deployment of weapons of mass destruction 7. Violent interstate conflict with regional consequences 8. Escalation of economic and resource nationalization

(continued)

Table 1.13 (continued)

Category	Risks
Societal	1. Food crises 2. Pandemic outbreak 3. Unmanageable burden of chronic disease 4. Severe income disparity 5. Antibiotic-resistant bacteria 6. Mismanaged urbanization (e.g., planning failures, inadequate infrastructure, and supply chains) 7. Profound political and social instability
Technological	1. Breakdown of critical information infrastructure and networks 2. Escalation in large-scale cyber attacks 3. Massive incident of data fraud/theft

Source Global Risk (2014, pp. 1–3)

Forum are fiscal crises in key economies, structurally high unemployment/underemployment, water crises, severe income disparity, failure of climate change mitigation and adaptation, greater incidence of extreme weather events (e.g., floods, storms, fires), global governance failure, food crises, failure of a major financial mechanism/institution, and profound political and social instability. It can be seen from the above that, besides the continuing focus on the traditional risks, we need to accelerate the study of response to a series of non-traditional risks.

The five categories of risks were not changed in the Global Risk Report 2016, but the number of specific risks was decreased from 31 to 29 (Global Risk 2016). In this report, a global risk is an uncertain event or condition, if occurring, which can cause significant negative impact for several countries or industries within the next 10 years. A global trend is a long-term pattern that is currently taking place and that could contribute to amplifying global risks and/or altering the relationship between them (Table 1.14).

The Global Risks Landscape 2016 was proposed in the Global Risk Report 2016. From the landscape, it can be seen that the risks with the highest impact and likelihood are failure of climate change mitigation and adaptation, water crises, large-scale involuntary migration, fiscal crises, interstate conflict, profound social instability, cyber attacks, and unemployment or underemployment (Global Risk 2016). In the Global Risks Interconnections Map 2016, the most strongly connected risks are failure of climate change mitigation and adaptation, profound social instability, large-scale involuntary migration, and unemployment or underemployment (Global Risk 2016).

Table 1.14 Global risk classification system of Davos (WEF 2016)

Asset bubbles in major economies	Extreme weather events (e.g., floods, storms)	Inadequate urban planning
Deflation of major economies	Slow down and respond to climate change	Food crisis
Major financial mechanism or institutional collapse	Major biodiversity and ecosystem collapse (land or sea)	Large-scale involuntary resettlement
Critical infrastructure failure/deficiency	Major natural disasters (e.g., earthquakes, tsunamis, volcanic eruptions, geomagnetic storms)	Far-reaching social instability
Financial crisis in major economies	Human environmental hazards (e.g., oil spills, radioactive contamination)	Water crisis
Structural unemployment is high or inadequate employment	Failure of state governance (e.g., failure of legal system, corruption, political impasse)	The adverse consequences of technological progress
Illegal trade (e.g., illegal money flows, tax evasion, trafficking, organized crime)	Conflict between countries with regional influence Key	information infrastructure and network crashes
Severe energy price shocks (increase or decrease)	Massive terrorist attacks	Large-scale network attacks
Uncontrollable inflation	National disintegration or crisis (e.g., internal conflict, military coup, national governance failure)	Significant data fraud/theft
	Weapons of mass destruction	

1.3.2 *Risk Classification of International Risk Governance Council*

For the purpose of improving the governance of emerging risks and slow-developing catastrophic risks, the International Risk Governance Council (IRGC) provided the risk taxonomy in 2005. This classification system includes six categories: physical factors, chemical factors, biological factors, natural forces, social-communicative hazards, and complex hazards. Based on these general categories, there are 33 specific risks (Table 1.15).

Table 1.15 Risk taxonomy of International Risk Governance Council (IRGC 2005)

Physical factors
• Ionizing radiation
• Non-ionizing radiation
• Noise (industry, entertainment)
• Kinetic energy (explosion, collapses)
• Temperature (fire, overheat, hypothermy)

(continued)

Table 1.15 (continued)

Chemical factors
• Toxic substances
• Genotoxic/carcinogenic substances
• Environmental pollutants
• Compound mixtures
Biological factors
• Fungi and algae
• Bacteria
• Viruses
• GMOs—genetically modified organisms
• Pathogens
Natural forces
• Winds
• Earthquakes
• Volcanic activities
• Droughts
• Floods
• Tsunamis
Social-communicative hazards
• Terrorism and sabotage
• Human violence (criminal activities)
• Humiliation, mobbing, stigmatizing
• Experimentation with humans (e.g., innovative medical application)
• Mass hysteria
• Psychosomatic syndromes
Complex hazards
• Food (chemical and biological)
• Consumer products (chemical, physical, etc.)
• Technologies (physical, chemical, etc.)
• Large constructions, like buildings, dams, highways, and bridges
• Critical infrastructures, in terms of physical, economic, social-organizational and communicative

The Davos World Economic Forum Reports involve a wide range of global risks covering the fields of economy, politics, culture, society, and ecology and could be corresponding to the economic development, political development, cultural development, social development, and ecological development proposed by the Chinese government, respectively. Thus, it can be seen that the risk classification of the World Economic Forum emphasizes the combination with practice.

The risk taxonomy of IRGC is from the perspective of hazards, similar to the disaster classification in Sect. 1.2. This classification stresses on the causes of risks and thus lacks in combination with practice. However, it pays attention to emerging risks and slow-developing catastrophic risks, including the governance of very large-scale disaster risks. At the same time, it provides the framework for systematic risk assessment and governance.

In China, the classification of risks is tightly associated with the security and disaster classifications. For example, the overall national security concept proposed by the Chinese government is in a one-to-one correspondence with the global risks in the World Economic Forum Report. In detail, the political security, homeland security, and military security correspond to geopolitical risks; economic and resource security to economic risks; cultural and societal security to societal risks; technology, information, and nuclear security to technological risks; ecological security to environmental risks (Xi 2016). Another example is the four public securities proposed by the Chinese government corresponding to five of the six risk categories of IRGC, that is, natural disaster of the former corresponds to the natural forces of the latter, accidental disasters to physical risks, public health accidents to chemical and biological risks, and social security incidents to social-communicative hazards. The complex hazards are usually related to the four public securities proposed by the Chinese government, and also to the integrated disasters.

The classification system of risks is built upon the hazard and disaster classifications in China. For example, if hazards are divided into natural, man-made, and environmental ones, risks can be classified into the corresponding three types. In the same way, risks can also be divided into four categories of natural, accidental, public health, and social security ones based on the four-type classification of hazards.

1.3.3 Classification Criteria for Risk Levels

The natural disaster risk level is usually expressed in exceedance probability or return period, the same way as the intensity level of natural hazards. For example, the meteorological, hydrological, and ocean disaster risks can be divided into 10-year level (small-scale disaster), 20-year level (medium-scale disaster), 50-year level (large-scale disaster), and 100-year level (very large-scale disaster). The earthquake disaster risk level is usually expressed in earthquake magnitude. For example, a magnitude 7.0 or above earthquake poses a very large-scale disaster risk, 6.5–7.0 large-scale, 6.0–6.5 medium-scale, and 6.0 or below small-scale disaster risks. The natural disaster risk level does not only depend on the natural hazard intensity but also count on the vulnerability and exposure of the hazard-bearing bodies. In practice, the classification of natural disaster risk levels is even more complicated and thus usually resorts to the relative levels such as the first-level risk, the second-level risk, the third-level risk, the fourth-level risk, and the fifth-level risk. The larger the number is, the higher the risk level is. In the Atlas of Natural Disaster Risk of China by Peijun Shi (Chinese–English bilingual version, Shi 2011) and the World Atlas of Natural Disaster Risk by Peijun Shi and Roger Kasperson

(Shi et al. 2015), the temporal and spatial patterns of natural disaster risks of China and the world are displayed by using indicators including risks, risk grades, and risk levels (Qin et al. 2015; Shi 2011, 2015).

It is more difficult to classify man-made and environmental risk levels by using quantitative criteria. A common way is to use relative level, or using the trends and changes of man-made and environmental risks to describe their levels. The Global Risk Trends 2015 in the Davos World Economic Forum Risk Report is an example of this kind of way of reflecting global risk levels. In detail, increasing global risk levels at 2015 are aging population, changing landscape of international governance, climate change, environmental degradation, growing middle class in emerging economies, increasing national sentiment, increasing polarization of societies, rise of chronic diseases, rise of cyber dependency, rising geographic mobility, rising incoming and wealth disparity, shifts in power, and urbanization (WEF 2015).

The top three most likely global risks in 2016 in each region are reported in the Global Risk Report 2016 of WEF (WEF 2015). In North America, the top three are cyber attacks, extreme weather events, and data fraud or theft. In Latin America and the Caribbean, the top three are failure of national governance, profound social instability, and unemployment/underemployment. In Europe, the three are large-scale involuntary migration, unemployment/underemployment, and fiscal crisis. In the Middle East and North Africa, they are water crises, unemployment/underemployment, failure of national governance, and profound social instability. In sub-Saharan Africa, they are failure of national governance, unemployment/underemployment, and failure of critical infrastructure. In Central Asia (including Russia), they are energy price shock, interstate conflict, and failure of national governance. In East Asia and the Pacific, they are natural catastrophes, extreme weather events, and failure of national governance. In South Asia, the top three are water crises, unemployment/underemployment, and extreme weather events.

The exceedance probability mentioned previously, a concept usually used in the study of natural disaster risks, refers to the likelihood of the intensity or motion parameters of an earthquake, or the flood level, or the maximum wind speed at the center of a typhoon exceeding a designated value or values in a specific location and during a certain period of time. In other words, it is the probability of the required value exceeding the given value and can be mathematically expressed as

$$P_{\text{exceed}} = P(u > u_{\text{limit}}) \tag{1.5}$$

where P_{exceed} is the likelihood of the required value (u) of a data series exceeding the limit value (u_{limit}).

For example, a set of data X ($x_1, x_2, \ldots x_n$) have n raw data points that are arranged from the lowest to the highest. The exceedance probability of data point x_i is

$$P = \left[\frac{n - i + 1}{n}\right] \times 100\% \tag{1.6}$$

The following takes the earthquake as an example for the calculation of exceedance probability.

Within t years, the probability of earthquake occurrence for n times $P(n)$ in a region is

$$P(n) = F(n) \tag{1.7}$$

In the same way, within t years, the likelihood of no earthquake happening in this region is

$$P(0) = F(0) \tag{1.8}$$

Then, the likelihood of at least one earthquake within t years, or the exceedance probability, is

$$F(t) = 1 - P(0) = 1 - F(0) \tag{1.9}$$

The probability density is

$$f(t) = F'(t) \tag{1.10}$$

Poisson distribution is widely used in earthquake studies. Within t years, the probability $P(n)$ of n earthquakes occurring in a region can be expressed in the Poisson distribution form as below:

$$P(n) = \frac{e^{-u} \times vt^n}{n!} \tag{1.11}$$

Then, within t years, the likelihood of no earthquake happening in this region is

$$P(0) = \frac{e^{-vt} \times vt^0}{0!} = e^{-vt} \tag{1.12}$$

So the likelihood of at least one earthquake happening or the exceedance probability within t years is

$$F(t) = 1 - P(0) = 1 - e^{-vt} \tag{1.13}$$

The corresponding probability density is

$$f(t) = F'(t) = v \times e^{-vt} \tag{1.14}$$

The variable v mentioned above is the annually averaged occurrence probability of earthquake in a region, which has an inverse relationship with the return period T_0:

$$T_0 = \frac{1}{v} \tag{1.15}$$

From here, we can see that the relationship between the return period T_0 and the exceedance probability $F(t)$ can be expressed as

$$T_0 = \frac{1}{v} = \frac{-t}{\ln(1 - F(t))} \tag{1.16}$$

Based on the equation above, we can calculate the return periods of different exceedance probabilities for a period of time.

For example, the exceedance probability of 63% for 50 years is equivalent to a 50-year disaster, 10% means a 474-year disaster, and 2–3% means a 1600–2500-year disaster.

In summary, hazards are negative factors to human beings, and the temporal and spatial patterns of hazards can be studied by comparing with historical observed data. Disasters are the impacts of hazards on human beings and can be measured in terms of losses and damages. Risks are future hazard-induced disasters in a specific location. In short, disaster risk science is a discipline studying the mechanics, processes, and dynamics of the interactions among hazards, disasters, and risks, as well as disaster risk prevention and reduction. The relationships among hazards, disasters, and risks are shown in Fig. 1.7.

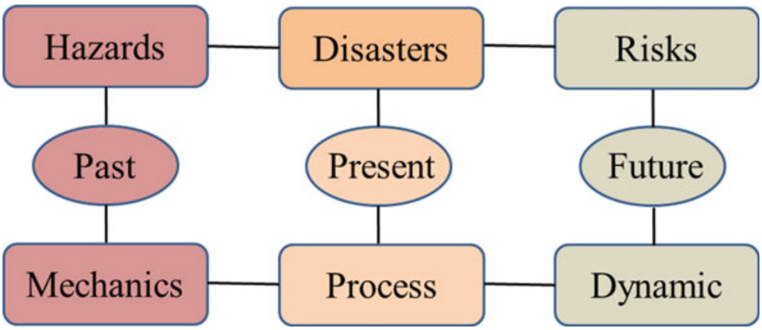

Fig. 1.7 Relationships among hazards, disasters, and risks

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