Chapter 2

Losses, Risks, and Vulnerability Induced by Natural Disasters to Agricultural Production Networks and Food Value Chains – Examples from the European Alps

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January 2020

This chapter should be cited as

Keiler, M. and and S. Fuchs (2020), ‘Losses, Risks, and Vulnerability Induced by Natural Disasters to Agricultural Production Networks and Food Value Chains – Examples from the European Alps’, in Breiling, M. and V. Anbumozhi (eds.), *Vulnerability of Agricultural Production Networks and Global Food Value Chains Due to Natural Disasters.* Jakarta, Indonesia: Economic Research Institute for ASEAN and East Asia, pp. 20-41.

CHAPTER

2

LOSSES, RISK, AND VULNERABILITY INDUCED BY NATURAL DISASTERS TO AGRICULTURAL PRODUCTION NETWORKS AND FOOD VALUE CHAINS – EXAMPLES FROM THE EUROPEAN ALPS

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Introduction

Taking into account that the international community as a whole is affected by considerable damage to infrastructure and property as well as loss of lives, the United Nations General Assembly designated the 1990s as the International Decade for Natural Disaster Reduction (IDNDR) (United Nations General Assembly, 1989). Within the associated international framework of action, the objective was to promote concerted action to reduce loss of life, property damage, and economic disruption caused by natural hazards not only with a particular focus on developing countries but also with respect to most developed countries. Initially, IDNDR was largely influenced by scientific and technical interest groups. However, a broader global awareness of the social and economic consequences of natural disasters developed as the decade progressed (White, 1994). Based on this framework, which was continued by the International Strategy for Disaster Reduction (UN General Assembly, 2000), the primary focus on hazards and their physical consequences was shifted to emphasise the processes involved in physical and socio-economic dimensions of vulnerability and risk into the wider understanding, assessment, and management of natural hazards. This highlighted the integration of approaches for loss and risk reduction into the broader context of sustainable development and related environmental considerations. The main challenge of risk reduction is rooted in the inherent connected systems dynamics driven by both geophysical and social forces, calling for an integrative risk management approach based on a multi-disciplinary concept, taking into account different theories, methods, and conceptualisations. As a result of the outcomes of the IDNDR, the need to deal with the adverse effects of natural hazards was continuously emphasised by multiple institutions at various national and international levels. This was addressed in the 'Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities', a global document that addresses disaster risk reduction issues in all types of environments and settings. Mountains remain a marginal element in this document as well as in the succeeding document of Sendai 2015. Environmental issues were, in general, given more space (Zimmermann and Keiler, 2015).

Multiple definitions of the term 'disaster' exist, which is rooted in different conceptualisations by authorities, scientists, and journalists and the context in which these definitions are used (Keiler, 2013). The UN defines disaster within the IDNDR as 'a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources' (UN General Assembly, 1989). This definition provides the base for different worldwide databases on natural disasters. The Centre for Research on the Epidemiology of Disasters, for instance, declares more precisely when the local capacity is exceeded by 'necessitating a request to a national or international level for external assistance' (CRED, 2010).

Following Varnes (1984) and Fell et al. (2008a), a hazard is, in general, a condition with the potential for causing an undesirable consequence. A natural hazard is defined as a phenomenon rooted in the natural environment and endangering any elements at risk. Therefore, a natural hazard represents the potential interaction between humans and their environment (Tobin and Montz, 1997). With respect to natural processes, the description of hazard should include the location, volume (or area), classification, and velocity (or pressure), hence, information on its probability of occurrence within a given period of time for a specific location, referred to as frequency, and on a given magnitude. Frequency is the number of occurrences within a given period, and magnitude refers to scientifically based measures of the strength of physical processes. If measures of magnitude concern impacts of an event on the human-use system (such as elements at risk to natural hazards), intensity is used instead. With respect to mountain hazards, assessments are repeatedly based on intensity estimates that incorporate human variables as indices of destruction since direct measurements of process magnitude are not regularly available.

Elements at risk refers to the population, buildings and engineering works, economic activities, public services utilities, other infrastructures, and environmental values in the area potentially affected by natural hazards. If elements at risk are monetised, the term 'values at risk' is used (Fuchs et al., 2013). Vulnerability is considered by taking an engineering approach (Fuchs, 2009; Papathoma-Köhle et al., 2015), and refers to the susceptibility of elements at risk. Vulnerability is the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural hazard of a given frequency and magnitude. It is expressed on a scale from 0 (no damage) to 1 (total loss). Risk is a measure of the probability and severity of an adverse effect to health, property, or the environment (Fell et al., 2008b). This is often estimated by a function of probability of a phenomenon of a given magnitude times the consequences. In general, risk results from an interaction between hazards and vulnerable conditions (United Nations, 2004), and is conceptualised in this paper by using the engineering definition of an expected degree of loss due to a particular natural phenomenon. Consequently, risk is expressed by the product of hazard times vulnerability times values at risk (Varnes, 1984), initially neglecting any responsibility related to the structure of society or any other human dimension (Wisner et al., 2004).

In recent years, increasing numbers of natural hazards and associated losses have shown to the European Commission and the member states of the European Union the paramount importance of the natural hazards issue for the protection of the environment and the citizens (Barredo, 2007), and therefore also of food value chains. There is a strong scientific evidence of an increase in mean precipitation and extreme precipitation events, which implies that temperature extremes and associated weather phenomena might become more frequent across Europe (Keiler et al., 2010; Kundzewicz et al., 2010). The major increase in both number of disaster events and associated losses was related to meteorological hazards (tropical storms, winter storms, severe weather, hail, tornados, and local storms) and hydrological hazards (storm surges, river floods, flash floods, mass movements, and landslides). The reasons for this, apart from the increase in major weather-related hazards due to climate change processes, were assumed to be a result of socio-economic developments in hazard-prone areas, such as increasing concentrations of values, rising population figures, and the settlement and industrialisation of exposed areas (Jongman et al., 2014; Fuchs et al., 2015). Combined with business activities such as those associated with the agricultural sector, vulnerability and risk become focal points in managing natural hazards throughout Europe.

However, according to the International Panel on Climate Change (Field et al., 2012), loss estimates of the available national or global database are lower bound estimates for two main reasons: (a) some impacts are less reflected because it is difficult to value and monetise the losses (e.g. loss of human lives, cultural heritage, and ecosystem services), and (b) impacts on the informal or undocumented economy as well as indirect economic effects are generally not counted in reported estimates of losses. This is especially true for the agricultural sector, which is additionally highly dependent on the climate and weather-related events, but the damage and losses on global and regional scale provide no information on the impacts disaggregated to the different economic sectors (FAO, 2015). Thus, a clear understanding on how the hydro-climate hazards and the increase of extreme events (Field et al., 2012) impact the agricultural sector, the food production, and food value chains is essential to protect the investments for food security and to strengthen the community resilience to disasters. Yet, focusing on mountainous (alpine) regions in this context adds further challenges since risk from natural hazards and mountain development are inherently linked (Zimmermann and Keiler, 2015).

Mountains – Characteristics and Challenges for Agricultural Production and Food Value Chains

Many mountain settlements and agricultural land are located on alluvial fans, which were created over a long period of time by debris flows, mud flows, or floods. Especially, meadows and special crops are located on floodplains in the valley bottom. Hazard processes, although occurring only episodically, constitute a major threat for people's lives, livelihoods, and assets. In addition, snow avalanches, landslides, or rock avalanches are menacing life in mountains. Beside these hazards types, hail, storms, and late frost have main effects on the agricultural sectors as well as, depending on the region, droughts, and heatwaves.

Mountain areas are characterised by high geodiversity, steep gradients, and high variability in the hydroclimate systems, topography, and ecosystems. The main drivers for natural hazards are the high relief, the hydroclimate, and human activity. Socio-economic factors, particularly demographic changes, influence vulnerability and exposure of mountain communities. There are a number of other particularities of hazards, risks, and risk reduction that challenges sustainable mountain development (Zimmermann and Keiler, 2015):

- A multi-hazard environment prevails in many places in mountain areas and exhibits its specific footprint. Communities can be affected in the same location by floods, debris flows, and snow avalanches, and may influence each other (Kappes et al., 2010).
- The proximity of safe and hazard-prone areas is very typical for mountainous settlements. In the European Alps, for example, the old village centre with the church is often located in a relatively safe place whereas new housing estates and agricultural land can be often found around this centre in locations where hazards occur.
- Climate change may intensify hazard conditions in mountainous areas (Haeberli and Whiteman, 2015) as it causes glaciers to melt or permafrost to degrade, thus altering the sources for rock avalanches, landslides, or debris flows. It may even create hazard conditions without historic parallels, like the formation and potential outbreak of

glacial lakes or the development of debris flows of unparalleled size originating in a periglacial environment as already observed in the European Alps since the 1987 flood disasters.

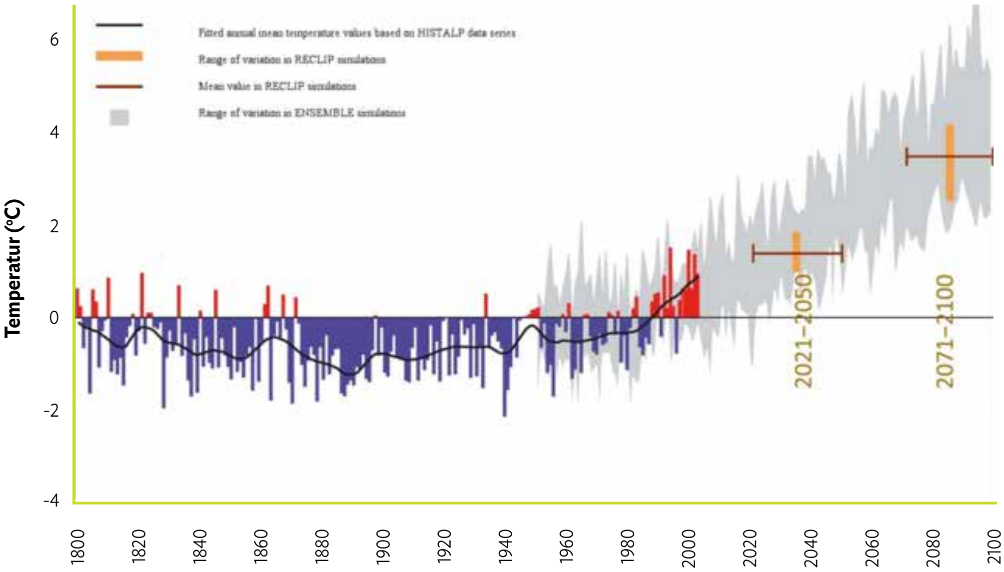
- Space for living is extremely limited in mountainous areas. According to Tappeiner et al. (2008), only about 17% of the total area of the European Alps are suitable for permanent settlement. Overall, the mountain population has more than tripled in the last 3 decades (Slaymaker, 2010) and urbanisation trend is as well visible in mountains. In Switzerland, 60% of mountain populations concentrate on bigger settlements. Therefore, inevitably many settlements, infrastructure, and agricultural land are exposed to natural hazards. Notably on a global perspective, from 1950 to 2010, the majority of urban population growth occurred in hilly or mountainous areas between 500 m and 1,500 m (Kohler et al., 2014).
- Highland–lowland system: In mountainous areas, the interfaces between highland and lowland have a high relevance. Very often, the highland is seen as the main source for intensified hazardous conditions in the lowland. On the other side, highlands provide important ecosystem services as drinking water, special food products, and recreation. However, such interdependences are not always obvious and sometimes also misinterpreted.
- Remoteness of mountain communities: Mountains are often physically remote spaces with difficult access due to the natural relief, which is an additional challenge to build up food value chains. Furthermore, these communities are more often cut-off from the outside during disasters for a longer period of time than lowland areas.

A sustainable use of mountain areas must include the analysis, assessment, and management of natural hazard risk due to the relative scarceness of utilisable areas. Taking countries in the European Alps as an example, only 38.7% of the territory is suitable for settlement and arable production purposes in Austria, while in the western part of the country (Federal State of Tyrol), it is only 11.9% (Statistik Austria, 2008). In Switzerland, 26% of the territory is classified as non-productive and approximately 37% of the territory is classified as area for agriculture and 31% for forestry purpose. As a result, only around 7% is suitable for settlement and infrastructure purposes (Hotz and Weibel, 2005).

In the following, an overview on agricultural production and food value chains in the European Alps (Austria and Switzerland) will be given. Mountain areas cover around 40% of the total land area of Europe, where almost 20% of the total population live (Nordregio, 2004). European mountain regions, therefore, provide a significant proportion of human settlements and areas used for economic purpose and recreation. However, mountain regions are exceedingly prone to changing environmental conditions. Thereby, mountain geosystems are not exceptionally fragile but they show a greater range of susceptibility to disturbance than many landscapes (Slaymaker and Embleton-Hamann, 2009).

Probably the most important cause of attention towards hazards, vulnerability, and risk is the recognition that global changes of important magnitude, in particular climate and land-use change, are already taking place (Stocker et al., 2013). According to modelling exercises, the nature and magnitude of potential impacts could be dramatic (Schröter et al., 2005). The assumed global rise in temperature (Stocker et al., 2013), which is already verified at the regional scale of mountain regions in Europe by measured data and analysed proxies (Auer et al., 2007), will have impacts on both the hydrosphere and the cryosphere (Huggel et al., 2015). The rise in temperature is accompanied by an increased content of moisture in the lower atmosphere, which results in intensified dynamics with respect to precipitation events (Foelsche, 2005).

Figure 1: Mean Surface Temperature in Austria from 1800 to 2100 in Terms of Deviation from the Mean of the Period 1971–2000



Note: A global average surface temperature rise of 3-5 °C is expected by 2100 compared to the first decade of the 20th century.

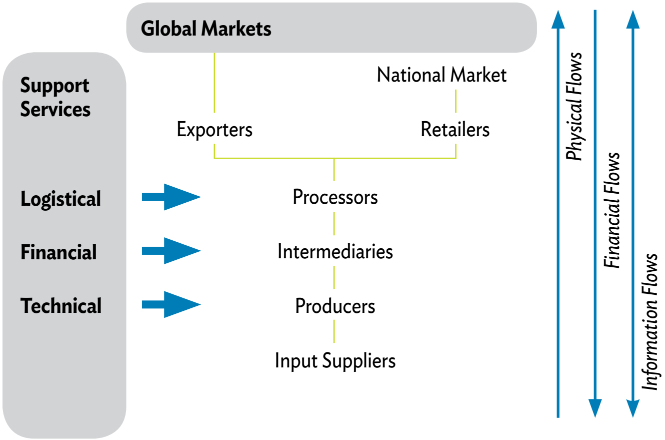
Source: APCC, 2014.

In the 21st century, an increase of precipitation in the winter months and a decrease in the summer months is to be expected for the European Alps (CH2011, 2011; APCC, 2014). Due to the expected accentuated precipitation regime, the frequency and magnitude of geomorphologic processes such as landslides or torrent processes may increase. Additionally, drought phenomena and temperature extremes are most likely to increase (Olesen et al., 2011) (see also Figure 1). In addition to extreme events, gradual temperature and precipitation changes also have economic ramifications such as the shifting potential yields in agriculture, in the energy sector, or on snow-reliability in ski areas with corresponding impacts on winter tourism. The impacts of climate change on agriculture vary by region. In cooler, wetter areas, e.g. in the northern foothills of the Alps, a warmer climate mainly increases the average potential yield of crops. In areas with poorer precipitation, such as north of the Danube in eastern and south-eastern Austria or in southern Switzerland, increasing drought and heat-stress reduce the long-term average yield potential, especially of non-irrigated crops, and increase the risk of failure. The production potential of warm-tolerant crops such as corn or grape will expand significantly (CH2011, 2011; APCC, 2014).

Agricultural Production Networks and Food Value Chains

Agricultural value chains are vulnerable and exposed to hazards due to the disaster risk of each of its components. Value chains operate as economic systems, and risks at certain nodes or of certain components have implications for other nodes and components. Resilience is a property of the value chain as a whole and is related to the vulnerability of each value chain component (United Nations, 2013). Reducing the vulnerability of agricultural production networks and food value chains is an emerging field of science, and is essential to ensuring the resilience of the regional, national, and sometimes also global food systems. Food is produced, distributed, and consumed in an increasingly complex system, where threats and hazards in one part of the system can have significant implications in others. Taking a systemic risk approach, we will present the challenges associated with the exposure of food value chains to mountain hazards based on evidence from the European Alps.

Figure 2: Agricultural Production Chain



Source: Jaffee et al., 2010.

Agricultural production networks are integral components of the food value chains. As such, the vulnerability and exposure of agricultural systems to hazards can have far-reaching and cascading effects for food security (United Nations, 2013). These value chains have different components, as shown in Figure 2. They can be conceptualised as having the following entities (Jaffee et al., 2010): input suppliers (i.e. groups or businesses that supply producers with fertilisers, chemicals, seeds, and other inputs), producers (i.e. individuals or businesses involved with primary agricultural production), intermediaries (i.e. commodity buyers or brokers who act as middle people), processors (i.e. businesses that are involved with the secondary production of food goods from commodities), marketers (i.e. businesses that aim to sell the food goods), and consumers (i.e. those that eat the food). At every step of the chain, transport and associated infrastructure can be at risk of direct damage from hazard events, meaning that interruptions at critical points or nodes can ripple through the supply chain. It is therefore important to focus on key supply chain participants, flows, and transaction points and to identify appropriate levels of analysis. Supply chain analyses can be carried out at different levels of analysis (Croom et al., 2000), including the dyadic level (the two-party relationship, such as between input supplier producer, producer and buyer, producer and financial institution), the sub-chain level (a set of dyadic relationships, such as input supplier and producer, and buyer), and the chain or network level (the entire supply chain and network of operations, i.e. backward and forward linkages, horizontal linkages, and enabling environment).

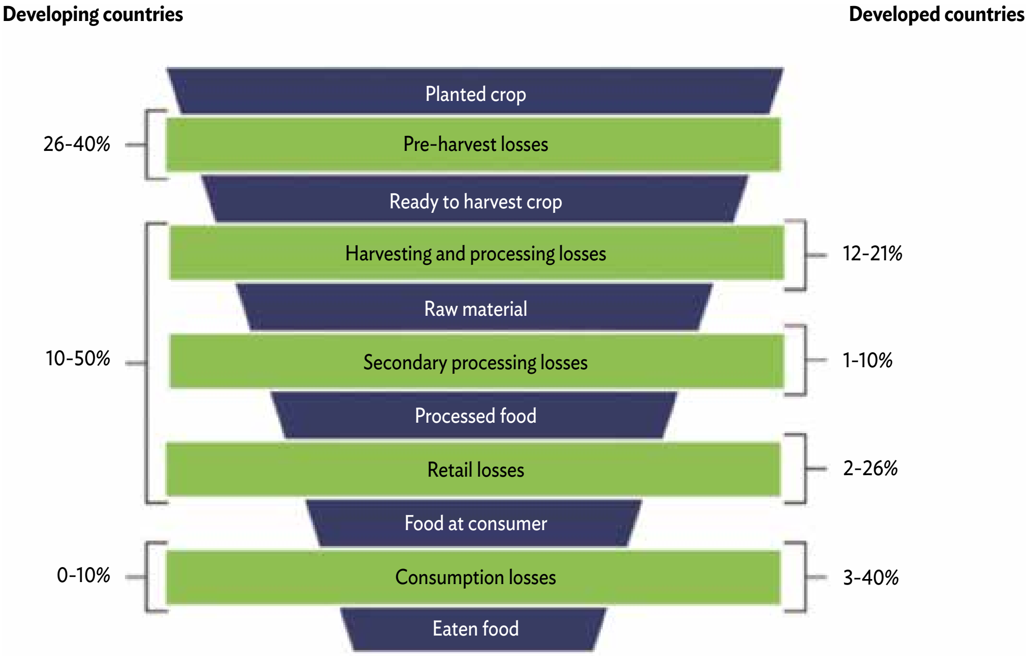
Subdividing the supply chain into dyadic and sub-chain components can make it easier to identify joint interests and potential synergies for risk management, as well as for finance. Those investing in agricultural production, processing, and trade, therefore, have a vested interest in the uninterrupted functioning of this infrastructure and in reducing damage owing to disasters (Jaffee et al., 2010).

Following this definition, agricultural disasters are one type of risk that limits the ability of the food system to provide complete food and nutritional security. Others include effects on transportation and supply infrastructure, to production facilities other than building of the primary sector, and to suppliers. In recent years, numerous assessments have been made of individual supply or value chains in developing country agriculture (United Nations, 2013) as well as for agriculture sector in Europe (e.g. Olesen et al., 2011), frequently as antecedents to investments by governments, donor agencies, or private enterprises.

Losses and Vulnerability of Individual Components of the Food Value Chain

Estimation of loss in food value chains is concentrated on waste loss (e.g. Figure 3). A study for Switzerland indicates that considering the energy balance, 48% of the total calories produced (edible crop, yields at harvest time, and animal products, including slaughter waste) is lost across the whole food value chain (Beretta et al., 2013). In this estimation, losses due to disasters are not included.

Figure 3: Total Loss in Food Value Chain



Source: Deloitte, 2013.

For the agriculture sector, typical losses due to disasters include the decline in production of agriculture, livestock, fisheries/aquaculture, and forestry, and possible higher costs of production, lower revenues, and higher operational costs in the provision of services (FAO, 2015). These losses include changes in economic flows arising from the disaster which continue until full economic recovery and reconstruction have been achieved. However, most available loss data due to disasters and regarding agriculture sector are estimations of direct costs deduced from reconstruction efforts without applying a standard approach. This includes mainly the economic impact on the physical damage to crops and livestock, agriculture, or transport infrastructure or supplier (FAO, 2015). Furthermore, indirect costs of agricultural production and food value chains imply further challenges because the evaluation of all effects has to be estimated. The end result is that the full consequences of disasters on the agriculture sector are not well understood at the global, regional, national, or subnational levels (FAO, 2015). Thus, approaches to estimate the losses are also missing for the European Alps.

One first step in the assessment of vulnerability is to investigate. With respect to agricultural production and food value chains, the concept of vulnerability is central and is supported by multiple disciplinary theories underpinning either a technical or a social origin of the concept and resulting in a range of paradigms for either a qualitative or quantitative assessment of vulnerability (Fuchs, 2009). However, efforts to reduce susceptibility to hazards and to create disaster-resilient communities require intersections amongst these theories, since human activity cannot be seen independently from the environmental setting. Acknowledging different roots of disciplinary paradigms, issues determining structural, economic, institutional, and social vulnerability should be combined to be able to prepare for climate change and necessary adaptation. Boruff and Cutter (2007) remarked on the lack of agreement and understanding concerning the methods or techniques for comparing hazard vulnerability within or between places, and stated that a refinement of vulnerability assessment methods and the delineation of highly vulnerable hotspots (e.g. strategic infrastructure) may support stakeholders interested in reducing vulnerability and using their resources more efficiently.

By applying the concept of risk, the definition of vulnerability plays an important role in agricultural production and food value chain within mountain environments. Hence, considerable areas in European regions are vulnerable to natural hazards. This is repeatedly stated in studies related to losses due to natural hazards (e.g. Rougier, 2013; Fekete and Sakdapolrak, 2014), and is therefore also valid for European mountain regions. Hence, this topic is addressed in the following section in more detail.

Producers are usually in the supply chain’s most vulnerable position (United Nations, 2013). Agricultural production itself is vulnerable to natural hazards, whereas efforts to quantify this vulnerability in terms of a risk approach are relatively scarce. Dutta et al. (2003) produced relative stage-damage curves for residential and non-residential property and non-residential stocks exposed to flooding. Additionally, they developed relative damage curves for crops, relating flood duration to relative damage for three inundation depth classes. Merz et al. (2010) reported a review of damage functions for floods in a wider application of assessment methods for economic flood damage. They distinguished various relative (used in the US HAZUS-MH model) and absolute (used in the UK and Australia) vulnerability functions, and summarised the respective challenges in the assessment procedure. For static inundation, the depth of water may indeed be the dominating factor and is sufficient for a vulnerability and risk analysis. Merz et al. (2004), however, criticised this hazard indicator as too simplistic since a considerable variety of further parameters may still influence the quantity of losses, above all of which are contamination (due to oil spill from the heating system in case of European studies) and flood duration (e.g. Büchele et al., 2006).

Adaptation measures in the agricultural sector can be implemented at varying rates. Within a few years, measures such as improved evapotranspiration control on crop land (efficient mulch cover, reduced tillage, wind protection), more efficient irrigation methods, cultivation of drought or heat-resistant species or varieties, heat protection in animal husbandry, a change in cultivation and processing periods as well as crop rotation, protection from frost and hail, and risk insurance are seen as being feasible (OcCC and ProClim, 2007; APCC, 2014). In the medium term, possible adaptation measures include erosion protection; soil conservation practices; water retention strategies; improvement of irrigation infrastructure and equipment; warning, monitoring, and forecasting systems for weather-related risks; breeding stress-resistant varieties; risk distribution through diversification; increase in storage capacity; animal breeding; and adjustments to stable equipment and to farming technology. The shifts are caused by a future climate and the suitability for the cultivation of warmth-loving crops (such as grain corn, sunflower, soybean).

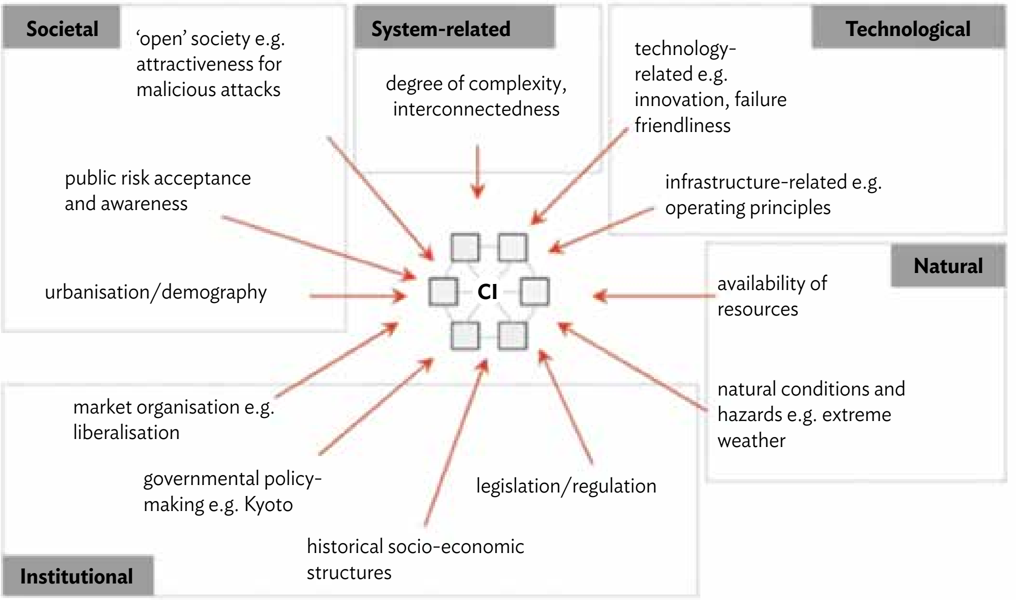
A very important component of the food value chain is infrastructure. Types of strategic or critical infrastructure may include, but are not limited to, energy, transportation, and telecommunications (Michel-Kerjan, 2003). Often, these infrastructures are interconnected and damage to one network of critical infrastructure can have cascading effects upon other critical infrastructure networks, possibly causing major damage to a country's national security and identity. The interconnectedness of these infrastructures not only extends to other types of critical infrastructure but can also be extended across political boundaries. In many cases, strategic infrastructures are dependent on international agreements and cross international borders, such as, for example, power networks and railway lines in the European Alps. Therefore, the vulnerabilities of a specific strategic infrastructure are dependent on condition and decay, capacity and use, obsolescence, interdependencies, location and topology, disruptive threats, policy and political environment, and safeguards (Grubesic and Matisziw, 2013). Strategic infrastructure networks include the highly complex and interconnected systems that are so vital to a city or state that any sudden disruption can result in debilitating impacts on human life, the economy, and the society as a whole (Cavalieri et al., 2012). The vulnerability of a system is multidimensional (Yates and Sanjeevi, 2012), a vector in mathematical terms. There are two major considerations for the efficacy of risk management in the context of infrastructure resilience and protection (Haimes, 2006). One is the ability to control the states of the system by improving its resilience. Primarily, this is the ability to recover the desired values of the states of a system that has been attacked within an acceptable period and at an acceptable cost. Resilience may be accomplished, for example, through hardening the system by adding redundancy and robustness or by simply constructing them hazard-proof if the exposure is obvious and can be assessed quantitatively. The second consideration is to reduce the effectiveness of the threat by other actions that may or may not necessarily change the vulnerability of the system (i.e. not necessarily changing its state variables). Such actions may include detection, prevention, protection, interdiction, containment, and attribution. Note that these actions (risk management options), while not necessarily changing the inherent states of the system, do change the level of the effectiveness of a potential threat.

With respect to European mountain regions, much less data are available regarding the vulnerability of infrastructure to natural hazards other than those for buildings (Fuchs et al., 2007; Papathoma-Köhle et al., 2011). In many parts of the world, however, the failure, disruption, or reduced functionality of infrastructure is likely to have a larger impact on livelihoods, production networks, and the local economy than damage to buildings (Jenkins et al., 2014). In some cases, it can act as a catalyst to existing economic, social, or agronomic decline (e.g. Wilson et al., 2012) because of high systemic vulnerability (interdependencies between physical, economic, and social systems).

The impacts of mountain hazards for infrastructure vary depending upon the hazard intensity but could include disruption of electricity supplies, contamination of agricultural processing areas, and sedimentation of surface water networks, requiring extensive and repeated clean-up (Bundesministerium für Land- und Forstwirtschaft, 2006). Even if usually manifest at local level, threats may result in cascading effects such as delays in transport times which then are likely to compound any disruption and associated impacts. Loss of transport functions due to locally deposited materials on roads can potentially be mitigated through the use of engineered channels, dams, and barriers or repeated clean-up in case of low-intensity/high-frequency events. However, the diverse range of infrastructure system designs, types, and configurations make it very difficult, perhaps impossible, to reliably create generic infrastructure vulnerability curves. Therefore, analysing interdependencies between infrastructural systems and carrying out comprehensive local inventory surveys to produce site-specific vulnerability functions are the most valid approach (Jenkins et al., 2014).

Recently, numerous studies have applied complex network-based models to study the performance and vulnerability of infrastructure systems under various types of attacks and hazards. A major part of them is, particularly after the 9/11 incident, related to terrorism attacks (Maliszewski and Horner, 2010; Briggs, 2012). Here, vulnerability is generally defined as the performance drop of an infrastructure system under a given disruptive event (Ouyang et al., 2014). The performance can be measured by different metrics, which correspond to various vulnerability values.

Figure 4: Factors Shaping the Risks Faced by Critical Infrastructure



Source: Kröger, 2008.

Focusing on the Austrian Alps, Möderl and Rauch (2011) presented a region-scale spatial risk assessment method allowing for managing critical network infrastructure in urban areas under irregular and future conditions caused by, for example, terrorist attacks, natural hazards, or climate change. For the spatial risk assessment, vulnerability maps for critical network infrastructure were merged with hazard maps for an interfering process. The result were Raster-based vulnerability maps that use a spatial sensitivity analysis of network transport models to evaluate performance decrease under the studied scenarios. Kröger (2008) identified several factors that can shape vulnerability to critical infrastructure and fall under societal, system-related, technological, natural, and institutional categories. Societal factors include attractiveness for attack, public risk awareness, and demographics. System-related factors include the complexity and interconnectedness of the network. Technological factors include failure friendliness and infrastructure-related operating principles. Natural factors include availability of resources and natural hazards. Finally, institutional factors include historic structures, legislation, and market organisation (see Figure 4).

Gaps and Challenges with Respect to Alpine Production Networks and Food Value Chains

Regarding the particular characteristics of mountains, several challenges exist for food production and development of food value chains in the Alps. To achieve sustainable development in mountain regions, natural hazards and disasters are one challenge to deal with beside socio-economic changes. However, climate change will have regional different effects on food production and food value chains. A clear gap exists on the documentation of losses due to direct and indirect impact or due to business interruptions for the agriculture sector and food value chains. Consequently, standardised and systematic approaches to estimate losses or analysis risks for this context are missing. However, such methods would help to better understand the underlying risk factors and to develop appropriated risk management.

First attempts were presented considering vulnerability assessments. Yet, most vulnerability studies are focusing on (a) physical vulnerability affecting buildings exposed to hazards and not on agricultural production itself, and (b) hydrological processes, neglecting any effects of temperature extremes, which are less-well studied. Most of the reviewed methods consider vulnerability to be the degree of loss of a specific element at risk to a hazard of a given magnitude, following an engineering approach. As discussed in Douglas (2007), there are more vulnerability curves for other geohazards, such as earthquakes, rather than for mountain hazards affecting the food value chain. These hazards usually affect larger regions than mountain hazards and have higher frequency, leading to considerable economic loss. In general, for river flooding (static inundation), there is a variety of vulnerability curves available in the literature. The majority of the studies use vulnerability curves that demonstrate the relationship between expected damage and inundation depth. The large number of vulnerability curves in flood studies can be explained by the fact that floods (just like storms which are also hazards with very well-developed vulnerability curves) damage more buildings in a single event than other hazard types (Douglas, 2007). Additionally, most of the methodologies have been applied in Europe or in countries with similar level of development, such as North America and Australia. As pointed out by Papathoma-Köhle et al. (2011), the focus of the methodologies varies significantly. While the majority of the approaches are targeted at an assessment of buildings at risk, others also include potential victims, infrastructure, and lifelines such as the road network. Very few studies focus on the vulnerability of the environment or agricultural land, or the economic vulnerability of the affected community that can include the vulnerability of businesses, employment, etc.

A very limited number of the reviewed studies address the multi-dimensional nature of vulnerability (Leone et al., 1996; Liu and Lei, 2003; Sterlacchini et al., 2007; Fuchs, 2009). As far as the scale of the study is concerned, the majority of the studies, especially the ones involving landslides, concern methodologies designed to be applied only at local level (e.g. individual torrent fans), whereas only a few (Liu and Lei, 2003; Galli and Guzzetti, 2007) are applied on a regional scale which has more predictive power in terms of food value chains affected. In the case of studies concerning river floods, the majority of them are carried out on a regional scale (Grünthal et al., 2006; Meyer et al., 2008, etc.). The regional vulnerability assessment is important for the central or the regional government to make decisions regarding funding allocations. However, as far as on-site emergency management and disaster planning are concerned in particular, local vulnerability assessment can provide decision makers with useful information. Implementing the methodologies face many difficulties, the most common of which are the non-availability of data and the fact that some methods are time-consuming due to extensive field work and detailed data required.

Many risk assessment methodologies for critical infrastructures play a major role in food production chains. In general, the approach used is rather common and linear, consisting of some main elements: identification and classification of threats, identification of vulnerabilities, and evaluation of direct impact. This is a well-known and established approach for evaluating risk and is the backbone of almost all risk assessment methodologies (Giannopoulos et al., 2012). However, there is a huge differentiation of risk assessment methodologies based on the scope of the methodology, the audience to which it is addressed to (policymakers, decision makers, research institutes) and their domain of applicability (asset level, infrastructure/system level, system of systems level). In general, the methodologies reviewed fail to incorporate the social and organisational components into the analysis of physical infrastructures. This is arguably the most significant deficiency found in the current methodological and empirical practices to measure vulnerability and resilience. The interdependencies amongst physical and human components in infrastructure seem to be very strong and complex.

The notion of vulnerability emphasises the exposure of a system to a hazard from the point of view of the nature of that system itself. Ideally, such an account should include some of the systemic properties, particularly from the perspective of the resilience of the human-environment interfaces of the system under consideration. Because vulnerability has often been regarded as a property and not as an outcome of social relations and technological systems (Hilhorst and Bankoff, 2004), the concept is easier to deal with than that of risk, as it does not exclusively emphasise a future event or system state, but also, and perhaps most obviously, certain actually present qualities of a system. Vulnerability assessments cannot take place without attention to the hazard and, thereby, also to risk. However, the concept puts the emphasis on what an actor can directly affect rather than a threat from the outside, or a possible development in the future.

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